User aspects in synchronous visualisation of multiple photo streams

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Abstract

Photo sharing is becoming a common way of maintaining closeness and relationships with friends and family, and it can evoke pleasurable, enjoyable and exciting experiences. People have fun when sharing photos containing pleasant scenes or friends being caught doing something interesting. There has been a recent increase in studies that focus on the visualisation and sharing of photos using online services or sharing in the home environment using different digital technologies. Although previous studies have focussed on the important issues of photo sharing and visualisation, there is a dearth of research aimed at designing applications that enable people to share and visualise multiple photo streams that originate from multiple sources such as different people or capture devices. In addition, there is a lack of research that links new applications for photo sharing with user experience and the applications' value to the user.

This thesis, firstly, offers a new design for synchronous sharing and visualisation of multiple photo streams using temporal and social metadata. Moreover, different features, called transition modes, were added to the system to give a better experience within the system. The experience of photo sharing, however, does not exist without any connection to people or events; it is a social experience depending on people, places and time. Hence, an experimental study was conducted with twenty users, and the results demonstrate high user demand for concurrent presentation of multiple media streams as well as recommended transitions for extending its potential. In the second phase of this thesis, the temporal aspects of multiple photo streams such as manual transition, continuity detection and user desired time were designed and implemented. Following that, the results of the user study demonstrate good comprehension of the users' own and shared photo streams, and their temporal structure, even when presented at relatively high speeds. Users were easily able to contextualise events, recall specific photos and find them using the proposed interface. The final interface is built from the lessons that were learned from the first two phases of this study. In this version, the user was able to share their photos in real time and see them in an ambient display. Our final system for real-time photo sharing as an ambient display was tested in three different trials with three different user groups consisting of extended family, close friends and workplace colleagues. The results showed high user interest for extended family members and in the workplace environment.

Acknowledgements

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I would like specially to thank Diana and Iraj who have supported me throughout my life. I also would like to thank Mojdeh and all my friends for their loving support and patience all these years.

This thesis is dedicated to Maman, Baba and Hatooyi from the bottom of my heart.

Finally, I would like to add my favourite lines from Sohrab Sepehri, a Persian poet: "One must wash eyes, look differently to things words must be washed. The word must be wind itself, the word must be the rain itself. Life is nothing that might from my mind and your mind in the tip of habit's shelf. Life is a strange sense experienced by a migrating bird. Life is finding a penny in the street gutter. Life is the earth multiplied in our heartbeats."

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Chapter 1

Introduction

1.1 Introduction

Due to the recent proliferation of multimedia technology, the interest in designing systems that offer new experiences to the end user is growing. In recent years, there has been a plethora of applications and services that aim to improve various aspects of user's performance and/or experience. In order to achieve these improvements, it is essential to gain deeper understanding of both human activities and the technologies that support them. This understanding has become especially relevant due to the pervasive nature of the technology that surrounds us; for example, highly complex mobile communication devices, interconnected sensors all around our homes and the omnipresent displays in our pockets, hands and streets. We need to learn how to live with emerging technologies and not just how to use them. Furthermore, in order to design useful systems, we have to understand people's activities and the role of technology in those activities [23].

Photography is a long established technology that falls into the broad portfolio of the ubiquitous technologies that surround us. Nowadays, it is difficult to find people who do not capture memorable events from their lives in their personal photos. Photos are found commonly in bookshelves and in photo frames in different areas of a house, as well as shared over the Internet and displayed on mobile phones and computer screens. Photos and photography have become an integral part of our everyday life and social activities.

Photography has changed dramatically over the last two decades, making a transition from the 'Kodak' era of film-based capture and printed photos to mobile cameras and online photo sharing. In line with the evolution of photographic technology, the way people interact with photos has also changed significantly. Personal computers, notebooks, tablets, mobile phones and server repositories have become the new media hubs of digital photography.

Digital technologies have facilitated the expansion of traditional snap-and-print photo practices to wider range photo-related activities, such as sharing, editing, storing, displaying, commenting, managing and printing. Additionally, digital photography has changed some cultural aspects of traditional print photography. Motivated by seminal approaches to studying practice in digital photography, a structure is proposed which is derived from [24] and includes key aspects of user practices in digital photography such as capturing, organising, sharing and visualisation. With this in mind, there have been a lot of studies that focus on digital photography and related fields such as capture [25–27], sharing [2, 28, 29], organisation [30, 31] and visualisation [32–34] of digital photos.

Digital photos play an important role in our lives; digital photos are often used as means of social interaction [35, 36]. People use photos to share their important as well as their mundane moments, or to tell stories about their lives. Snapshots are currently the most commonly used medium to tell the stories of our lives [37].

With this in mind, this thesis focuses on studying existing practices and explores new ways of personal photo sharing and visualisation in different contexts, from collocated to remote. In addition, this thesis identifies photo sharing needs, and offers new means of photo sharing and visualisation platforms targeting small groups of people, such as friends and family members. Furthermore, this thesis offers recommendations for the design of future photo sharing systems.

1.2 Motivation and research gaps

The research focus on photo sharing and visualisation developed from the challenges of designing new user experiences of emerging multimedia technologies. In many existing studies, research on user experience has been directed towards exploring the requirements related to negative experiences and the problems that people had with the multimedia systems. The work presented in this thesis aims at learning about both negative and positive user experiences of emerging multimedia technologies focussing on social interaction, reminiscence, enjoyment and fun.

Being one of the most prevalent multimedia technologies in people's everyday lives, digital photography has been at the centre of this research. People enjoy taking photos, sharing them with others and also viewing their own or somebody else's photos. Thus, photography is one of the most popular contemporary multimedia experiences, especially in terms of social interactions. Therefore, there is an obvious need to explore people's experiences of photography and to offer them new applications and services to improve their private and social lives.

Historically, people used to store their photos in archives and view them occasionally at some later date. After the digital photography revolution, the photographic medium became so popular that there is virtually nobody who does not view or take photos on a daily basis; nowadays, photography is ubiquitous [38]. This growth has been driven by the uptake of point-and-shoot digital cameras and, more recently, by pervasive camera phones. Due to the proliferation of social media platforms, digital photo sharing has emerged as a new way of establishing the chronology of events and of reminiscing forgotten experiences. However, people still find it difficult to share and visualise the large number of photos obtained from a variety of sources.

The current literature in the area of digital photography shows that there is a need for applications offering photo sharing with small groups of people [39], such as family members and close friends. Moreover, we found that, although several applications have been designed for collocated photo capture and sharing [15] or photo sharing at the same place and time [16], there is a clear lack of designs that enable users to view and share multiple photo streams in a single interface, from different sources at either the same or different times and places.

In addition to sharing, visualisation of photo streams presents another challenge in existing photographic practices. There have been different methods proposed in the literature that address visualisation of photo collections [8, 40]; however, there is virtually no reported research on sharing photos from multiple sources with a small group of friends.

Having all these aspects of modern photography in mind, the topic of photo sharing from multiple sources in small user groups has prompted us to explore further new practices in personal photography, design new applications that support effective photo sharing and visualisation and, finally, find the dominant factors to user experience in this domain.

1.3 Research questions

Taking into consideration the aforementioned research context, this thesis addresses challenges in design and implementation of intuitive and effective user interfaces for sharing and visualisation of multiple photo streams. These multiple streams can be sourced from multiple users and/or multiple capturing devices. This focus stems from an identified research gap in the design of dedicated interactive or ambient photo sharing applications aiming to improve user experience of digital photography.

Due to the user-centric nature of the addressed challenge, aspects of photo capture, sharing, organisation and visualisation will be investigated to validate the design and development of photo sharing and visualisation applications, with users at the centre of attention. Having in mind these issues, the following research questions guide the research:

- What are the values and requirements of sharing and visualising multiple photo streams?
- What are the optimal temporal parameters for visualisation of multiple photo streams?
- How can the user experience of ambient multiple photo stream visualisation within small groups of people be optimised?
- What are the design recommendations for future photo sharing applications?

1.4 Research objectives

The main aim of this research is to study the current practices of sharing and visualisation of personal photos in the social context; this study will encompass multiple sources and multiple users. In order to achieve optimal capture of these practices, the research will adopt the user-centric methods of Human-Computer Interaction (HCI), coupled with image processing algorithms. This approach enables effective analysis and design innovation targeting user friendly presentation of multiple photo streams, obtained from different individuals and cameras. In this research, a wide range of aspects need to be considered in terms of user interface design and the user experience. Having in mind the research questions outlined in the previous section, in order to respond to these challenges, the main objectives of the research presented in this thesis are as follows:

- Use of a phase-based approach to design and implement applications for sharing and visualising historical photos and live photo updates.
- Design and conduct a user requirements study into visualisation of multiple photo streams.
- Design and conduct an experimental study into temporal aspects of multiple photo stream visualisation.

- Design and conduct a field study to study the values of ambient photo sharing display.

1.5 Contribution of the research

Having implemented the research objectives outlined above, this research made contributions to the HCI community in two ways. Three different designs of a photo sharing interface were implemented, following the requirements of the tasks addressed in the three phases of the project. In addition, the designed and implemented system was evaluated through a series of user experience studies.

This focus has been derived from an identified gap in understanding multiple photo stream visualisation and sharing for small groups of people such as friends and family members.

The research makes four major contributions:

1. Design and implementation of three systems for visualisation and sharing of multiple photo streams. The first system embodies the core design concept of the thesis to visualise synchronously photos sourced from multiple users in a small group. The second and third systems were redesigned, based on lessons learned in user studies. All three versions of the applications were implemented on different platforms.

2. A qualitative study to elicit the user requirements in multiple photo stream sharing and visualisation.

3. A task-based user experience study to identify the values and usability parameters of the designed system for multiple photo stream visualisation.

4. A mixed-method study that evaluates user experience of an ambient display for real-time photo sharing with small groups of people.

1.6 Structure of the thesis

As outlined above, the research reported here draws upon three different research areas: (i) photo sharing and visualisation, (ii) user interface design and implementation and (iii) user experience studies. Due to the breadth of the methodologies involved, two review chapters are presented.

Chapter 2 presents a critical review of the relevant literature regarding different aspects of digital photography and the relevant influencing factors. In addition, it provides an overview of relevant models and frameworks of digital photography in HCI and other disciplines in order to highlight existing deficiencies in our understanding of digital photography.

Chapter 3 presents a review of the research methods that were used during this study. Specific characteristics of the research design, data acquisition and data analysis procedures are discussed.

Chapter 4 provides a description of the first system for sharing and visualisation of multiple photo streams, focussing on the design, implementation and structure of a web-based photo sharing application. This application was shaped and built from the lessons that were learned from the literature review presented in Chapter 2.

Chapter 5 describes the experimental design and results of the first user study, which focussed on current user practices in personal photography. In addition, this chapter summarises the derived design requirements for multiple photo stream applications.

Chapter 6 introduces the challenges of temporal and synchronous visualisation of multiple photo streams. The focus on temporal aspects was derived from the user requirements study described in Chapter 5. Thus, this chapter presents the architecture, design and implementation of a task-based photo sharing application with different transition modes.

Chapter 7 brings the results of the second user study into temporal aspects of photo stream visualisation. The first part of this chapter comprises an evaluation of the user interface alongside the manual transitions by designing a multi-stage task-based user experience study. The second section describes an experimental study into visual continuity of photo visualisation and its implications for future designs. Finally, the desired photo transitions are evaluated and compared.

Chapter 8 provides a description of the '4Streams' system, an ambient photo sharing and visualisation display. Based on the design suggestions and requirements from Chapters 5 and 7, this chapter outlines the design, implementation and structure of the '4Streams' system.

Chapter 9 presents a comprehensive field study on the use of '4Streams' with small groups of people. The field study is divided into three main sections. The first section discusses use of '4Streams' by an extended family group, the second section focuses its use by a small group of close friends, while the last section reports on its use by five colleagues in a workplace environment.

Chapter 10 provides the summary of the thesis in terms of the research questions, contributions and limitations of this thesis, as well as future work.

1.7 Published work

Sam Zargham, Janko Calic, and David Frohlich. "User experience study of multiple photo streams visualisation." Proceedings of the 26th Annual BCS Interaction Specialist Group Conference on People and Computers. British Computer Society, 2012.

Sam Zargham and Janko Ćalić. "Dynamic Presentation of Synchronised Photo Streams." Proceedings of the 28th International BCS Human Computer Interaction Conference on HCI 2014-Sand, Sea and Sky-Holiday HCI. BCS, 2014.

Sam Zargham, Janko Calic and David Frohlich. "4Streams: An ambient display for sharing photos between extended families". Proceedings of the 29th International BCS Human Computer Interaction Conference on HCI 2015.

Sam Zargham, Janko Calic and David Frohlich. "Synchronous visualisation of multiple photo streams". Submitted to Human–Computer Interaction, Taylor and Francis.

Chapter 2

Literature Review

2.1 Introduction

This chapter presents a literature review of the relevant state-of-the-art research. Having in mind that the research theme of this thesis is synchronous visualisation and sharing of multiple photo streams, a multidisciplinary approach to HCI has been adopted. As stated in the research objectives, the work presented addresses several aspects, such as the design of novel interfaces for visualisation and sharing of photo streams and a number of user studies evaluating the designed interfaces. Therefore, in this chapter we cover the current research that aims at better user experience in digital photography alongside relevant existing enabling technologies.

2.2 Digital path of photography

Digital cameras were introduced into the marketplace in the early 1990s. This new technology took over from the film based 'Kodak' era very quickly due to the lower price of photo printing, no requirement to buy a film and the short lifecycle from photo capture to print. It also made it easier to take many photos without being concerned about the results and the process of editing became faster and more flexible. Moreover, the quality of photos improved rapidly.

In comparison to the 'Kodak' practices, new business models have been introduced in domestic photography, predominantly exploiting information and communication technology [41]. Although there are people who still print their own photos, the majority of captured photos are stored on home or cloud-based computer hard drives. Therefore, organising, sharing and visualisation of large numbers of photos as well as the need for user-friendly applications in digital photography have been key issues. Currently, there are software and device manufacturers that offer photo printing, management and editing software. Camera manufacturers, alongside mobile phone manufactures, introduce new photo-related features to their devices. In addition, internet connectivity with integration of photos into social networks has made the digital path prevalent yet full of challenges. Hence, unlike the old 'Kodak' practice, there is now no single dominant business model for making a profit from domestic photography and, as a result, business stakeholders have diversified. To better understand the challenges and innovate potential solutions, the next section presents a model for studying digital photography.

2.3 Approach to study digital photography

As photography has entered the digital era, the nature of domestic photography has changed; it has shifted from paper prints to digital photos and, as a result, the user interaction with their photo collections has changed. The most remarkable change is the number of photo collections as they no longer need films for printing; as a result, people take more photos of the same thing such as a scene, an object or a view [42].

During the 'Kodak' era, people were not able to edit their photos at home. However, the digital path offers consumers the ability to edit their photos (using actions such as cropping, adding filter colors, removing red eyes and making many similar copies). The term "photowork" was introduced by [24] to describe the activities that people perform with their digital photos after capture until they share them. In this work, twelve households were interviewed about their everyday photographic practices. The findings highlighted the processes of reviewing, downloading, organising, editing and storing, and they have been divided into three stages of pre-download, at-download and pre-share, which can be seen in Figure 2.1. In the first stage, the captured photo can be edited on the camera or left as it is. In the second stage, the captured photo is downloaded to the physical memory, edited and kept in the personal photo collection. In the third stage, the downloaded photo can be accessed and printed or shared with other people. The captured photos are reviewed and shared later.

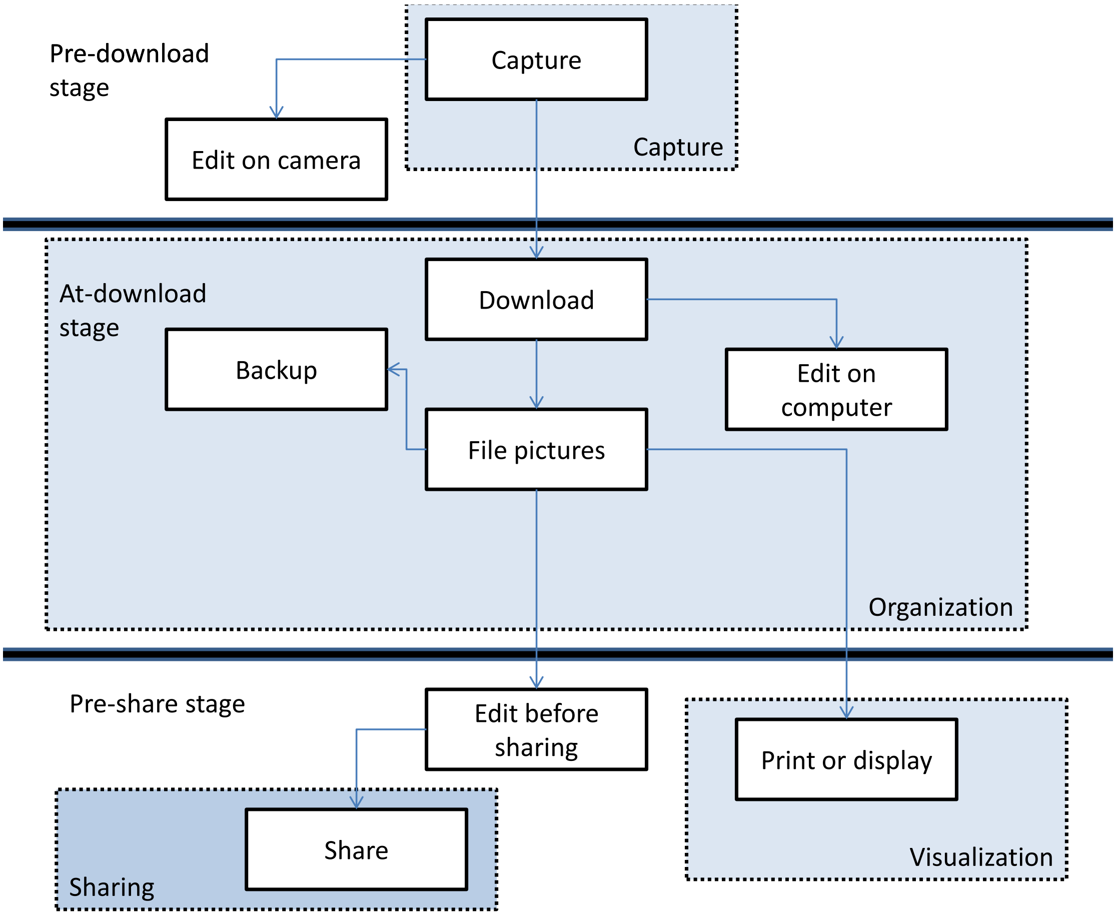

FIGURE 2.1: The stages of photowork from [?]

In another study [43], ten participants were interviewed in a semi-structured fashion, deriving the key themes of domestic photography as: photo taking, organising, search, browsing, reviewing and sharing. Moreover, Frohlich [28] found that sharing is the key novelty of digital photography once the users capture the photos into the digital realm. Thus, Frohlich proposed the requirements, which leverage the future of photo sharing, and called it "photoware".

Motivated by these seminal approaches to studying practice in digital photography, this research introduces a structure, which can be seen as dotted frames in Figure 2.1 and that includes the aspect of displaying photos. The proposed key aspects of user practices in digital photography are as follows: capturing, organising, sharing and visualisation. The literature review is, therefore, classified into these four aspects of digital photography.

2.4 Capture

As explained in the previous section, the first stage of digital photography is capture. The capture stage generates the digital photo that will be organised, visualised or shared in the next steps. Currently, there are different types of capture devices with various capabilities. Nowadays, most people have at least one capture device at home such as point-and-shoot camera or a camera phone, and digital photo capturing has become their dominant means of photo taking. In this section, different types of capture devices such as a camera phone [44], a passive camera [45–47] and an audio camera [48] are introduced and described.

In recent times, most camera phones have enabled users to take snapshots and this feature has made camera phones a supplementary device to the point-and-shoot camera. Mobile phones are easily portable and are more often at hand than any other device. A study by Kindberg et al. [25] indicated that the majority of photos on camera phones are taken for sentimental or emotional reasons. Moreover, the photos are mostly mutual experiences and, thus, often intended for communication with absent friends or family, either in real-time or offline. They concluded that camera phones, due to their ability of direct sending and sharing, let people use photos as a means of bringing physically remote people into a shared experience.

To support the sharing experiences and usage of camera phones, Van House et al. claimed [26] that the camera phone for the *networked generation* is seen as a memory tool as well as a communicative and expressive device, which can be used for creating and maintaining relationships alongside constructing personal and collective memories in various cases such as self representation and self expression.

An emerging type of capture device is the passive capture device. In passive capture, the user does not make any intervention in the capture processes; instead, the device, by the aid of sensors or timers, takes photos automatically. There have been various passive capture devices [45–47] introduced to the market. SenseCam [45], which can be seen in Figure 2.2, is a small wearable passive camera that is designed to take photos automatically and is marketed by Microsoft. SenseCam is equipped with a fisheye lens to cover a wide field of view, but it has a limited resolution and low quality of produced photos. In addition, SenseCam includes a number of additional electronic sensors (for light, temperature and time) so that any change on those sensors triggers capture of a photo.

There have been various studies focussing on the value of passive cameras. A research of user experience in passive capture [27] found that photos taken by passive cameras have often been appreciated more than photos that were taken manually. For example, passive photos gave a sense of a piece of time and sense of atmosphere during an activity. Moreover, although shooting only a small part of a target object could be considered a failure with a point-and-shoot camera, a photo of part of a hand holding dandelions, for example, introduces an unexpected aesthetic value to the passive capture. Unusual visual effects often add more value to the photos captured by a passive camera compared to a classic camera. For example, in one case, several people faced the camera without unnatural posing and the lens also resulted in a different feeling about the space in the photos.

Another study [1] indicated that the concepts of passive and active photography can be very different. Passive photography has the potential to serve as a novel form of photography with new experiences. The wearers of passive cameras saw the devices neither as a way of capturing specific information, nor as a means for heightening unfolding experience; instead, they were seen as a way of recording clear aspects of everyday life.

FIGURE 2.2: Passive camera: SenseCam [1].

Another kind of photography in current research is audio photography, which is the practice of capturing and merging audio with photos. Frohlich et al. [2] studied the values of sounds in different photo-related activities. In addition, the video medium was found to be too literal a record to leave room for thinking and talking about the past, such that Chalfen [49] stated that fewer details bring better experience when reminiscing about past events. Findings in previous research [2] showed that sound may have a positive role to play in domestic photography. Therefore, an audio photo can be a more realistic record of the past than a non-audio photo, but it also leaves more room for reflection and conversation than a video. The Blink audio digital camera, which implements these functionalities, can be seen in Figure 2.3

It can be concluded that there are different methods of photo capture and that they are not limited to the methods that we mention here. In addition, each method of capture has its own values. Regardless of the varied methods of capture in digital photography, a very large number of photos are generated in personal photo collections. Some of those photos need to be visualised and, in order to have

FIGURE 2.3: Audio camera [2].

an appealing visualisation, they need to be managed well. Therefore, in the next section, we describe the visualisation techniques of digital photo collections.

2.5 Visualisation

In this section, we review the previous studies that have been conducted focussing on the challenges in visualisation of photos. In order to visualise photo collections, a system should provide a good layout with the maximum information conveyed about the photo and a suitable display that enables appropriate user interaction. The next sections cover the topics of the layouts for visualisation of photo collections, levels of interaction and display size.

2.5.1 Layouts for visualisation of photo collections

An effective photo layout should give enough information to the user about the photos in a user-friendly and intuitive way. Many programs and researchers create a very simple grid-view to visualise photo collections. For example Microsoft Windows [50] enables users to view photos in a folder in grid-view or thumbnails of photos. Previously Boreczky et al. and Uchihashi et al. [51, 52] took advantage of video and extracted keyframes in order to summarise them by choosing the most important frames in comic book style for storytelling.

One layout technique that has been applied previously in order to visualise photos is tiling, which is laying out thumbnails of different sizes. Photomesa [32] is a user interface for displaying photo thumbnails by enabling the user to zoom into the photo thumbnails. All thumbnails of photos in the application interface can be seen in a page; this means that increasing the number of photos leads to smaller thumbnail size. However, to tackle the problem of the growth of the number of photos in a collection, users can click on a photo and then the sub-clusters related to that photo appear on the screen in an action which they called 'zoom in'. Although the 'zoom in' action decreases the visual information from the photo collection, it provides visually clearer photo collection representation.

A photo browser application by Graham et al. [30] was built to display a summary of photos in a chronological-based hierarchical manner by taking advantage of clustering in the same way as Photomesa [32]. Photomesa is a 2-D grid-based interface which enables the user to navigate the hierarchy of clusters using a tree view. In the same manner as these two applications, other photo browsing tools [53–56] use tile view characteristics and different hierarchical clustering techniques to generate a layout for visualisation of photo collections.

Other zoomable applications are Time Quilt [3] and Tree Browser [5]. Tree Browser is a zoomable interface but it does not show the results in a grid. Instead, it consists of three components: a timeline, a zoomable presentation canvas and a tag panel. All the photos are displayed chronologically on the timeline section and events are visualised as peaks in a temporal histogram. However, in Time Quilt, as in previous zoomable interfaces, the results are shown on a grid. The key in all these presentation interfaces is chronological ordering. Moreover, FreeEye [4] is an application to let the user browse photos by similarity and time measures, and it has been built based on different size tiles. In this system, when a user selects a photo from the display by clicking, the photo relocates to the centre and photos that are related to the selected photo will surround the new main photo; this feature differentiates FreeEye from other interfaces. In FreeEye, users do not have the freedom to select the specified clusters by intention and the system provides the most relevant photos for the user; this makes browsing more playful and brings more room for users to discover unexpected photos in their collections. Time Quilt, Tree Browse and FreeEyes interfaces can be seen in Figure 2.4.

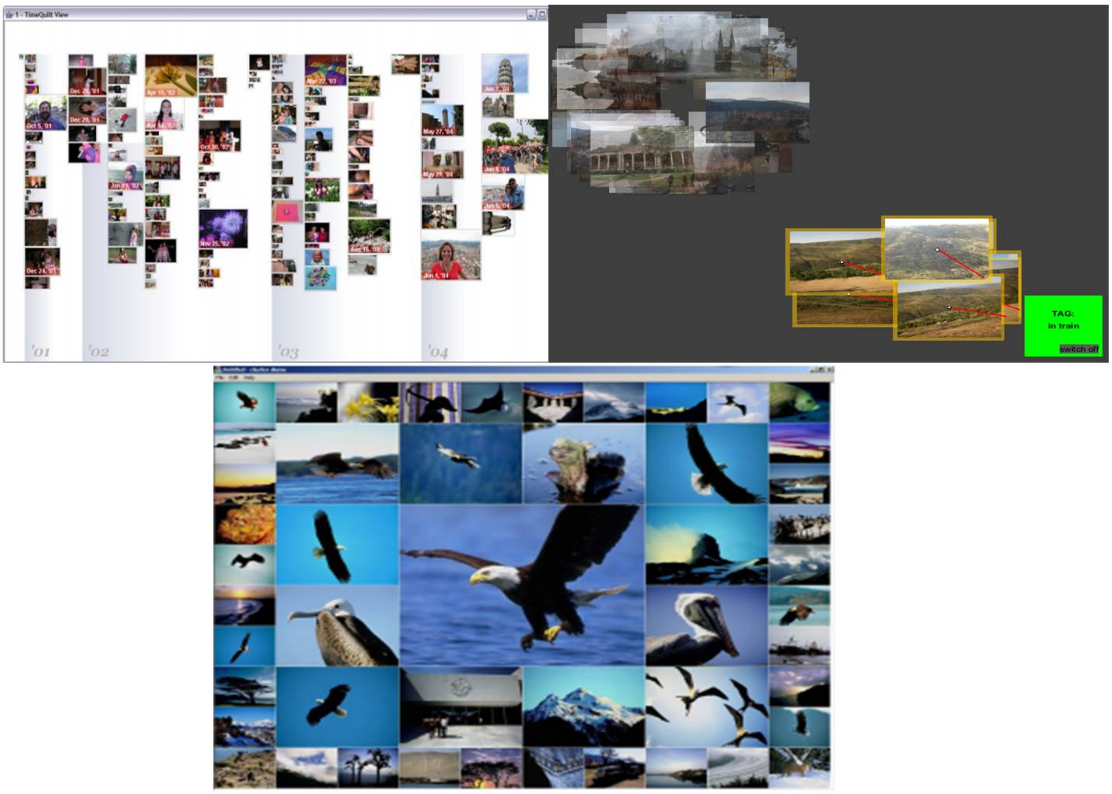

FIGURE 2.4: Tile layout examples for visualisation of photo collections. Left: Time Quilt [3], Bottom: FreeEye [4] and Right: Tree Browser [5].

Another technique for laying out photo collections is collage. The system by Fogarty [33] offers an aesthetically pleasing interface to provide the maximum information from photo collections in collage format. The aim of the system is to create an artistic result and to do it automatically, unlike Diakopoulos and Essa [57], who built a system to let the user choose the photos and template and then generate the collage. Another automatic collage generator was applied by Wang et al. [7] that arranges the position of the photos by choosing the salient regions of each photo automatically; this leads to having all the important information in each photo alongside generating photo collages by maintaining the original aspect ratio.

Another collage-like interface is Digital Tapestry [6] which, the same as [7], takes advantage of saliency to identify the important features in an image by using a graph cut algorithm. This system generates a collage which can be seen as a tool to create a new single photo from multiple photos. Therefore, the result does not have coherency and might give completely new meaning to the photo collection. Digital Tapestry [6] and Wang et al. [7] layouts can be seen in Figure 2.5.

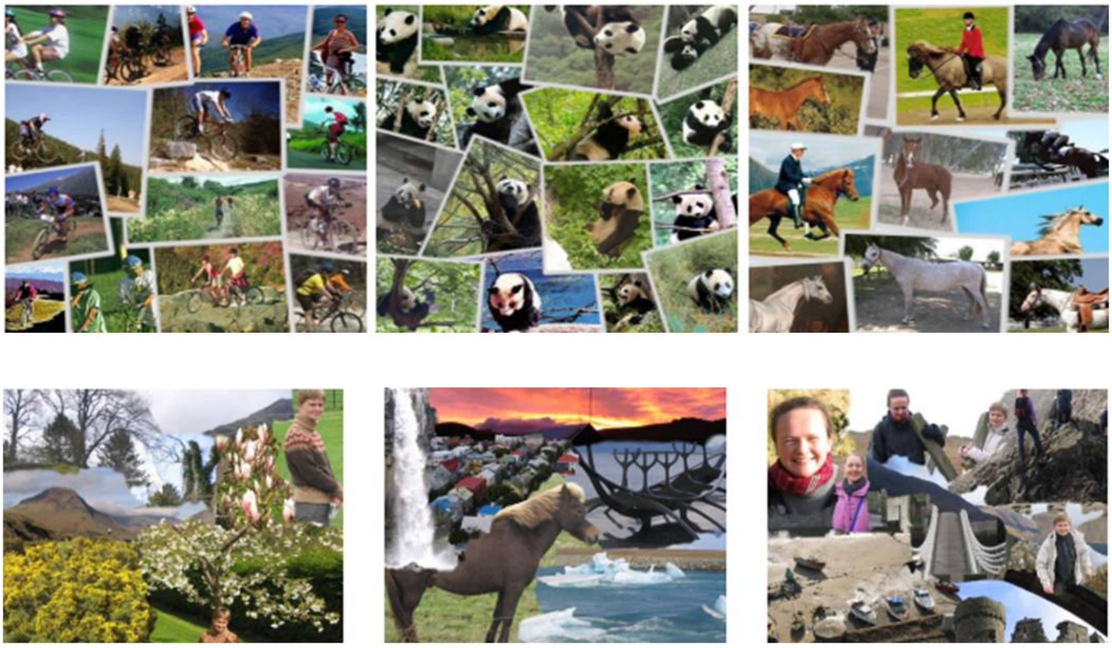

Figure 2.5: Collage presentation layouts. Bottom is from Digital Tapestry [6] and top is from Wang et al. [7].

In addition to the purely spatial visualisation methods presented so far, the temporal aspect of presentation is vital in representing photos. The most common method to exploit the sequential nature of photos is the slideshow. Nowadays, all commercial photo viewer applications support slideshows and researchers have applied different elements into simple slideshows in order to create better interfaces. Photos can be seen in slideshows with a fixed two-second interval slideshow in Microsoft Windows [50]. Apple in MAC OS [58] provide a better experience by setting the transition layouts. DAD [34], which is an ambient display system, extracts the keyframes of a video and detects the user eye gaze with their camera-equipped system. By following the eye gaze, they can determine the attention of the user on the display and display a diverse summary of still images from the original video in slideshow mode.

Cunxun et al. [59] presented another slideshow system for presentation of photo streams in mobile phones. In their approach, because of the limited size of the mobile phone screen and the demand on viewing photos in smaller screen size devices, mobile users have the freedom to control the region of interest for each photo and, then, the slideshow re-targets the image to a smaller size photo while keeping the proper aspect ratio.

One difficulty with slideshows is that they are very time consuming for the user when there are many photos in the presented collection. To solve this problem, Liu et al. [60] proposed an approach to measure the attraction of each photo using photo features and adjusting the duration of photo transition to be related to that measure. Chu et al. [8] presented an advanced combination of photo tiling, sound and slideshow techniques by adjusting clusters into different layout tiles, and smart re-targeting to solve the problem of long time presentation in slideshow mode by showing more photos in each slide; this can be seen in Figure 2.6.

Sound also played a role in previous slideshow techniques, whereas in [61], the system automatically combined the slideshow with appropriate music for a better experience of photo collection visualisation. The same option is available in the Mac OS [58] built-in photo viewer application, except that the music is chosen by the user and is not automatic.

Previous work that takes advantage of the slideshow format has been focussed mostly on ambient displays and has aimed to present photos in a more relaxing way. Moreover, applications that visualise photos through slideshows decrease the level of user interaction with the display.

FIGURE 2.6: Tiling slideshow [8].

So far in this review, different layouts for visualisation of photo collections have been described. However, nowadays, high quality mobile cameras with a reasonable amount of data storage are widely available and the number of mobile photos is growing rapidly so that visualisation and management of mobile photos has become an important topic. Mobile phones have small screens and it is difficult for users to view their photos through albums or to find photos. Even grid-view is not the most user-friendly option to go through entire photo collections on a mobile phone. Large photo visualisation has been mentioned before but for smaller devices a solution has been proposed in [9] where the implemented mobile application using a multiscale timeline concept resulted in a more efficient browsing experience by showing the photo summary as well as the most representative photo in different segments of the photo collection. Another problem in mobile photo visualisation is the speed of processing; processors in mobile phones are not as efficient as in current computer systems. Therefore, their new incremental clustering algorithm significantly accelerated the speed of album re-organisation when new photos were added to large photo albums. Figure 2.7 shows the interface of this application.

Figure 2.7: Mobile phone photo visualisation [9].

In addition to the layouts for photo visualisation that have been described above, there exist storytelling tools that enable users to see their photo collections and videos as a story. For example, in [10], video frames are summarised into shorter frames and puzzled together as a comic-like story [62], which can be seen in Figure 2.8. Unlike a video where the sequence of image frames is ordered chronologically by default, in a photo collection, the photo stream is sorted by the time of capture. There are other techniques, such as slideshow, to show the story of photo collections, which can be seen in Windows slideshow and iPhoto [63].

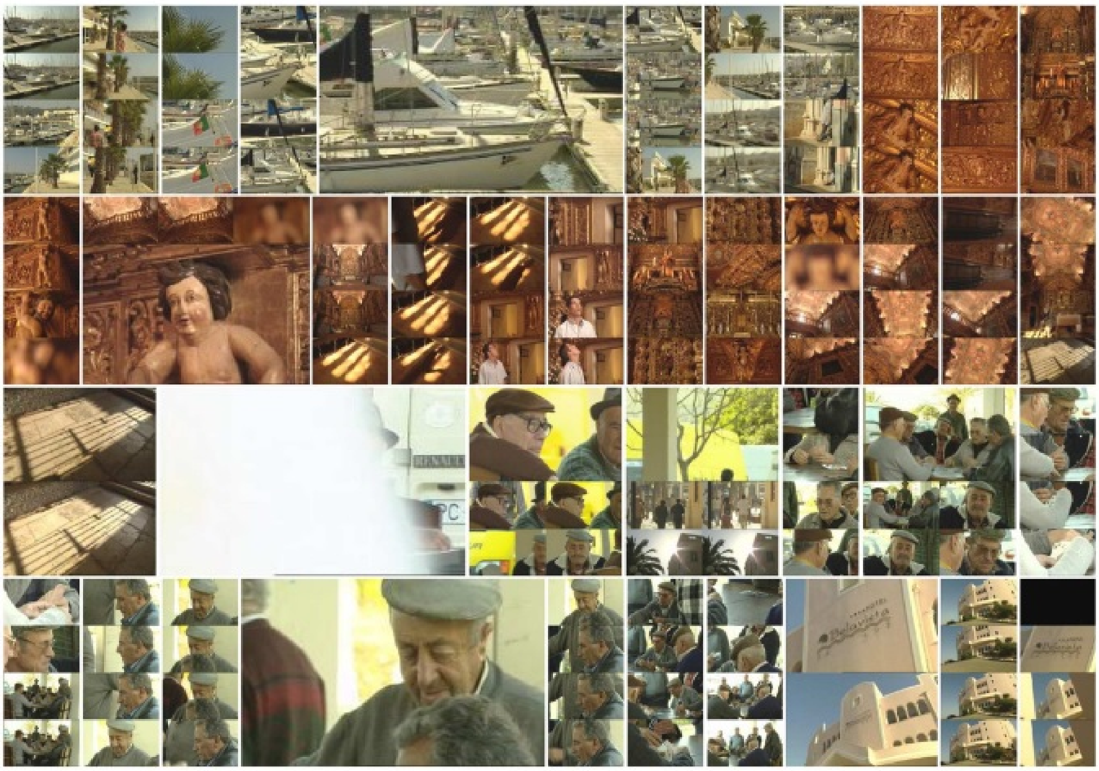

FIGURE 2.8: The comic-like photo story of a video. Obtained from [10].

In the film industry, the concept of multiple narratives in storytelling brings multiple stories into one unified form. Multiple narratives have been defined in [64] as a type of story that presents several characters rather than one. This technique has not been applied in photo story tools and layouts. Therefore, in the future, multiple narrative techniques for photographic storytelling will potentially support stories from multiple photo streams that have been obtained by different people to create meaningful stories in a single place by a newer design of layouts for visualisation.

In this section, different layouts for visualisation of photo collections were described. However, in order to be able to see the photos in different layouts, users need to interact within the applications. Therefore, in the next section, the levels of interaction within the display are explained.

2.5.2 Levels of interaction with the display

In order to visualise photo collections in different layouts, the user needs to interact with the photo application. The interaction aim might be for viewing, browsing, searching, storytelling etc. Sometimes the interaction level is high and the user has many options to select, while sometimes the interaction just involves the user's attention without any complicated interaction with the system. Building upon previous research [65–67], Vogel and Balakrishnan [11] developed an interaction framework that covered the range from distant implicit interaction to explicit personal interaction (see Figure 2.9), with the following four continuous phases:

1. Ambient display
2. Implicit interaction
3. Subtle interaction
4. Personal interaction

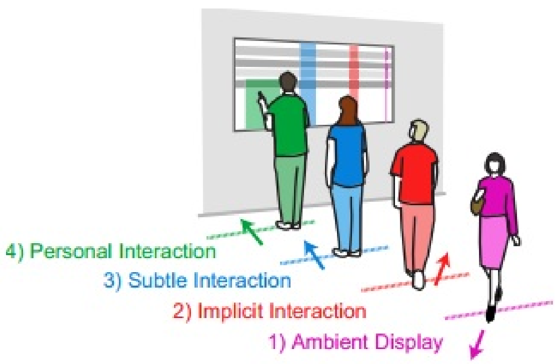

FIGURE 2.9: Four interaction phases facilitating transitions from implicit to explicit and public to personal interactions [11].

The ambient display phase is when the display shows a range of information with the capability of updating slowly and this state is neutral [68–70]. For photo visualisation, Biemans et al. [71] took advantage of the ambient phase for visualisation of digital photos. In this display, the digital photo frame was situated in a place and the family members of elderly relatives were sending their photos via MMS or Email so that the newest sent photos appeared on the screen.

The next phase is that of implicit interaction whereby a user passes by a display. The system should recognise the user's body position and orientation to provide information. Implicit interaction was used for photo visualisation in [72]. The display can identify the user and measure how far away they are; when the user is a long distance from the display, the display acts as an ambient display and when the user comes within an appropriate range for interaction, the display shows photos that are related to the user.

When the user approaches the display and is attracted towards it, the system should enter the subtle interaction phase. This phase is very short and hand gestures, alongside the body movements and eye gazing, can be applied for the interaction. An example of visualisation of photos using subtle interaction is presented in [34]. The display shows stylised photos with the aid of eye gazing. When the user looks at the screen, the system presents photos to promote user interest in the display, guided by the level of the user's attention. This means that persistent attention will guide the semantically similar content to that which attracted the user's gaze.

In the personal interaction phase, the user should be able to move close to the screen and interact with the system in more detail such as through direct touch. For example, in [73], an interactive display was built to visualise photos of different people from different sides and the user was able to switch the photo on any four screens that they designed for their system by the rotating head on top of the device. Moreover, in [4], the device was interactive and the user could select a photo on the screen and the most related photos based on time and photo contents would appear on the screen.

In this section, different kinds of interaction via the system were explained. However, the type of interaction also depends on the size of the display. In the next section, the size of the display used for photo visualisation will be discussed.

2.5.3 Size of the display

Another important aspect for photo visualisation is the size of the display. The layout and interaction levels of photo sharing applications depend on the size of the display. Nowadays, people review their archive and social network photos on their personal computer, tablets, mobile phones, digital photo frames and TVs. Display size is important in presenting personal photos. Small devices, such as mobile phones, have a smaller workspace to interact and show the photos. Currently, smart phones use multi-touch interaction technology due to their small screen size. For medium size screens such as iPads, digital photo frame size displays were created for visualisation of photos [34, 74]. Therefore, prior studies have focussed on interacting with small displays [75] and presenting photos in small displays [59, 76, 77]. Simakov et al. [76] applied bi-directional similarity to support the cropping of photos by showing the most important objects on the photo. They changed the image scale by re-targeting in a way such that the resulting photo was complete and coherent. However, the new photo contents and the distance of the features might be different from the original one. Seam curving [78] is another approach to re-target an image into a smaller size by maintaining the aspect ratio. There are also simpler techniques such as showing the centre of the photo or showing the region of interest of a photo [59].

In order to present photos on large screens such as televisions, most devices come bundled with a memory card reader. In addition, Apple TV [79] provides different presentations of photo streams from the Cloud on the home television. However, the growth of different display types shows that providing applications to enhance presenting photos on different display sizes is essential.

The visualisation layouts, interaction and the size of the display was discussed in this section. People need systems to organise their photos or to let users organise their photos more easily. Therefore, techniques that have been applied to organising photo collections are presented in the next section.

2.6 Management of photo collections

As discussed in the previous sections, digital cameras, alongside other capture devices such as camera phones and wearable cameras, are significantly affecting the development of current practices surrounding personal photography. Therefore, facilitating the process of personal photo management has become increasingly important.

In order to define the issues in personal photo management, the behaviour of different families in organising both their digital- and paper-based photos has been studied [28]. The results showed that very few participants organise their digital photo collections systematically on their PC's. It has been shown that digital photos are less organised than physical photos. Therefore, the call for automatic photo management tools is strong.

After the advent of primitive organising tools such as Fotofile [53] and Shoebox [54], a subsequent user experience study [80] proposed sorting personal photos in chronological order, similar to Graham et al. [30] who claimed time as an essence for photo browsing. Their study highlighted that content-based image retrieval has not been as valuable as browsing personal photos by event names including date/time and name.

Companies such as Adobe Elements [81], iPhoto by Apple [63] and Picasa [82] by Google have started introducing effective photo management tools to the market. Online photo storage services such as Flickr [83], Facebook [84] and Shutterfly [85] have prepared facilities for users to share and organise their photos online. Recent versions of photo management applications such as iPhoto and Picasa have automated event management tools with time/date, tags, location and also face recognition functionality for labelling.

Online commercial tools have allowed users to upload their photos to servers, label them and then share them with others. Flickr and Facebook have allowed labelling of photos, and Flickr also shows the original metadata information of each photo [86]. There is no solid automatic organisation mechanism for photos in commercial tools. Personal photo management tools have still not convinced many users with few people using them as the primary photo tool for their photo collections. The rest of this section describes technical solutions and approaches to open up the techniques that have been used in photo management.

The expansion of photo collections in time has meant that revision and organisation of personal photos have become discouraging tasks. Therefore, automatic or semi-automatic grouping of images into meaningful sets has become a very important research challenge. One of the core mechanisms behind automatic organisation of digital media such as photos is clustering [87].

Cluster analysis is the process of gathering a collection of patterns into clusters based on their similarity with each other. Generally, patterns within a particular cluster are more similar to each other than patterns from outside that cluster. Typical data clustering processes extract relevant features, define data similarity metrics between features and cluster elements into stable groups. There are many taxonomies representing the clustering methodology but the two main clustering approaches that have been applied in large-scale photo management are hierarchical and partitional clustering.

Time and space complexity in hierarchical clustering algorithms such as those described in [30] are more complex than partitional algorithms; for example K-means [31] has been applied for grouping photo collections into clusters. On the other hand, hierarchical algorithms are better for non-isotropic clusters since they have well-separated results. This means that hierarchical clustering provides several layers for better representation and division of photos.

To facilitate effective photo clustering, a set of relevant and robust features should be identified. Most of the features that have been used previously were temporal, location-based, optical, content-based and text-based labels. Some of the features (i.e. temporal, location-based and optical) have been standardised as metadata and included in the JPEG format as well as integrated into the Exif metadata header [88].

Temporal information, such as the time and date of the main events in the lifecycle of a digital photo (especially the moment the photo was taken), has been utilised to organise photo collections into meaningful clusters [30, 89, 90]. Using the date and time feature has worked efficiently, such as in [12], because the computation complexity is low and there is a small difference in the results, as claimed by [80].

In AutoAlbum [12], one of the techniques to cluster photo collections is to use photo time stamps; it takes the time stamp of each photo in order to generate clusters by best-first model merging (see in Figure 2.10).

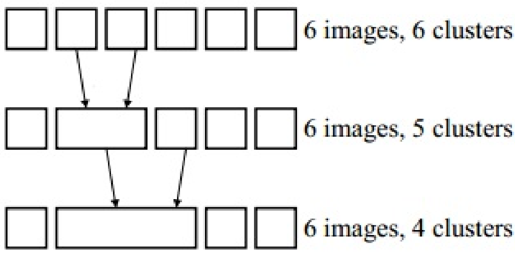

FIGURE 2.10: Time-base clustering technique used in the AutoAlbum system [12].

People tend to take photos in bursts during events such as parties or holidays, rather than distributing them over time evenly. Therefore, temporal features can be used in clustering the bursts of consecutive photos to improve the user experience of browsing and managing large photo collections. The clusters that AutoAlbum generates are not representative of such bursts.

In the study by Graham et al. [30], two level-clustering algorithms were embedded. Initially, images were clustered by a constant time difference. This means that consecutive photos are compared and, if they differ in time by more than a specified period, then a new cluster is generated. In a second step (step two), to further refine clusters, sub-clustering can be applied by comparing with outliers. In this step, a new cluster contains the images between the previous and the new outlier. Following this, the first-step clusters are merged by applying step two for a higher range of clusters. Other works such as [91] have performed adaptive clustering whereby photos are grouped by large time intervals followed by a burst or increase in the time of photos taken.

Location features inside Exif are also applied to organise and present photos [92–95]. Kalnikaite et al. [96] shows that location tags, when combined with images, are a useful context to reminiscence events from the past. Hence, using location-based features has provided better results for organising photo collections. The main problem of using location-based features is that not all capture devices have a GPS sensor to provide location information. Although this has become a standard feature of current camera phones, many users turn this functionality off to avoid increased battery consumption. Location-based features usually have been merged with other features such as temporal- or content-based features; for example, in [95], hierarchical clustering based on temporal and location features has been applied to group photos in different levels.

Another approach to facilitate organising digital photos is to use optical features stored inside the Exif file header, as described by Sinha et al. [97]. Information such as exposure time, focal length, F-number, flash, metering mode and ISO are employed. Use of these features has facilitated derivation of more high-level features without very complex computation when compared to complicated image processing techniques. In this approach, image quality is calculated and existing image annotations allow the ambient lighting scene to be determined.

There has been much work that utilises content-based features to facilitate personal photo organisation; for grouping photos, they have been combined mostly with temporal features. In [31], a K-means clustering algorithm has been developed for clustering temporal- and content-based features; the problem with K-means is that the K-value must be tuned. In a similar manner, temporal and image content features have been combined in photo clustering [89, 98]. Platt et al. [12] showed (see Table 2.1) that the use of the time feature for clustering was the most efficient technique. However, if some photos in a dataset contain a corrupted time stamp, then the combinational method gives better results. Due to the size of the datasets and the complexity of the visual features, fast algorithms for feature extraction and analysis have been proposed. In Yang et al. [99], a fast algorithm with linear complexity has been proposed. However, this algorithm does not use temporal features but, instead, it clusters similar images based on matching scale-invariant feature transform (SIFT) features [100]; SIFT is a similarity metric. An example of SIFT matching can be seen in Figure 2.11.

TABLE 2.1: Clustering performance by [12]

	Performance
Time	64.6%
Content	63.46%
Combination	75.5%

FIGURE 2.11: SIFT matching between two similar images captured from different angles.

Another technique for management of large photo collections is classification [101]. In classification, photo clusters are classified into categories such as events, mood, composition, etc. In Das et al. [101], after grouping events by the technique proposed by Loui et al. [31], the high-level time features for the event (e.g. event duration and image density) with high-level image features (e.g. indoor/outdoor, sky, snow) were determined. Subsequently, events can be classified into different categories such as vacation, party, sport and family moments. However, the accuracy for this classification technique peaks at around 70%, which users do not find reliable enough.

Another technique to categorise photos is text labelling, which is often referred to as tagging; two main approaches have been introduced in the literature. The first approach is manual tagging, where users annotate photos and related information with a stream of words called tags. Flickr [83] uses this technique alongside Exif metadata [88]. However, this approach has two major problems. The first problem is that labelling photos manually is time consuming for the user. The second problem is that it is possible that the user will embed the wrong information about the photo. Manual tags were studied by Wang et al. [34], where the semantic similarity between keywords (text based clustering) was employed to cluster photos which had been tagged manually by the user.

Because of these two drawbacks in manual tagging, researchers have proposed other approaches to labelling and annotation of large photo sets. For example Fotofile [53] has exploited face recognition to automate annotation. Recently, commercial photo management applications such as iPhoto [63] and Facebook [102] have used the same technique. Experiments have shown that face recognition is not yet a reliable outcome in this field as it is not able to always recognise and tag users correctly, as can be seen in current photo sharing websites. However, face detection [103] has performed fairly well for speeding up the process of tagging.

In the study by Sarvas et al. [92], social, location-based, temporal and content-based features were used to produce labels. Moreover, they gave an opportunity to users to refine wrongly calculated labels. This system was designed for mobile phones in order to facilitate the sharing process between multiple users. Another study [97] used optical features for generating labels.

In Google Deep Learning [13], the technology went further and merged recent computer vision and language models into a single jointly trained system, taking a photo and directly producing a human readable sequence of words to describe photos. Examples of Google Deep Learning with different error rates can be seen in Figure 2.12.

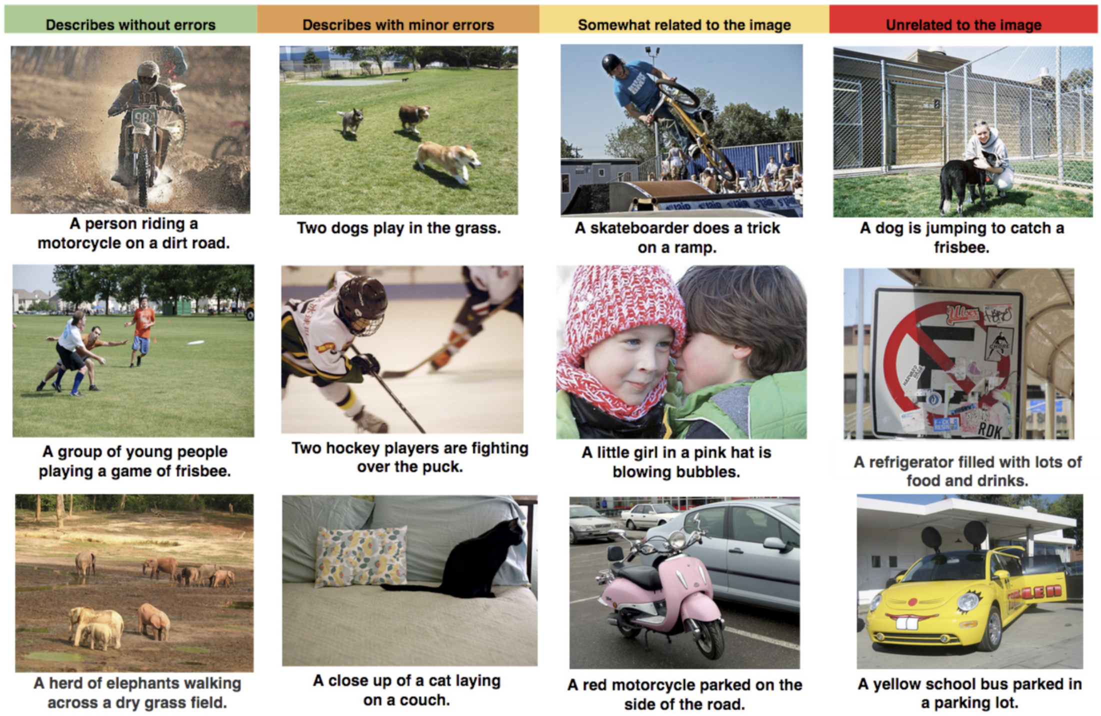

FIGURE 2.12: Google Deep Learning technique examples [13].

In this section, we explained different methods for organising photo collections. However, people still have many photos in their collection and even automatic organisation of large numbers of photos might not satisfy users. Therefore, summarisation of photo collections is used to increase user satisfaction of photo management. Summarisation of photo collections is described in the next section.

2.7 Summarisation of photo collections

Nowadays, there are many photos in our photo collections; however, we do not have time to see all these photos and we do not want or do not have time to remove them from our photo collections. Therefore, many of the photos in personal collections are visually redundant. A good system can represent only a limited number of photos from each photo collection in order to provide a better experience of viewing photos. Therefore, providing a summary of photo streams plays an important role in current photo presentation. Showing irrelevant photos in the summary of photo collections can confuse and bother the user; therefore, the first question must be what characteristics a summary should have.

It has been claimed by Sinha et al. [104] that appropriate summarisation of photo collections should contain quality, diversity and coverage. Quality represents the appeal of each photo. Diversity means that the summary should not contain repeated information. Coverage ensures that the story concept should not be changed after summarisation.

In order to select the most appealing images for summarising photos in a cluster, Korman et al. [105] considered a photo important enough to be chosen when the photographic rate increases. This means that, when one subject has been photographed many times, it indicates that the photo captures an important image. In addition, Nowak et al. [106] describe the importance of the time metadata for clustering and selecting the most representative photo from an album. Similarly, in [107], selection of the most representative photo by time features and burst is applied.

Due to selecting the most appealing photos among similar versions in a single cluster, Korman et al. [105] used the SIFT [100] feature to calculate the existence of the same objects in a scene. Moreover, the presence of people was another feature that was proposed for selection of the most important photos for summarisation. To determine the presence of people, the number of faces, size of faces and area of skin are calculated. Colourfulness and simplicity are other features that can be applied to select the most representative photo. Furthermore, in order to achieve quality and diversity, have combined composition by the rule of thirds with simplicity by calculating the number of salient regions and distinct hues with earlier features. In [108], only the number of faces and time features in the photo were used to select the most representative photo automatically.

Another technique to summarise a cluster by selection of the most representative photo has been proposed by Chu et al. [14]. In this work, near-duplicate photo pairs are calculated. After that, SIFT is employed to capture the salient characteristics over different image scales. Then, a support vector machine (SVM) is used to model the characteristics of the orientation histogram. The criterion that is utilised to choose the most representative photo between near duplicate photos is the photo which has the closest relation with other photos. This technique provides a good approach for diversity; however, it has not been implemented to support coverage of a story. An example of the relationship between near-duplicate photos in this approach is shown in Figure 2.13.

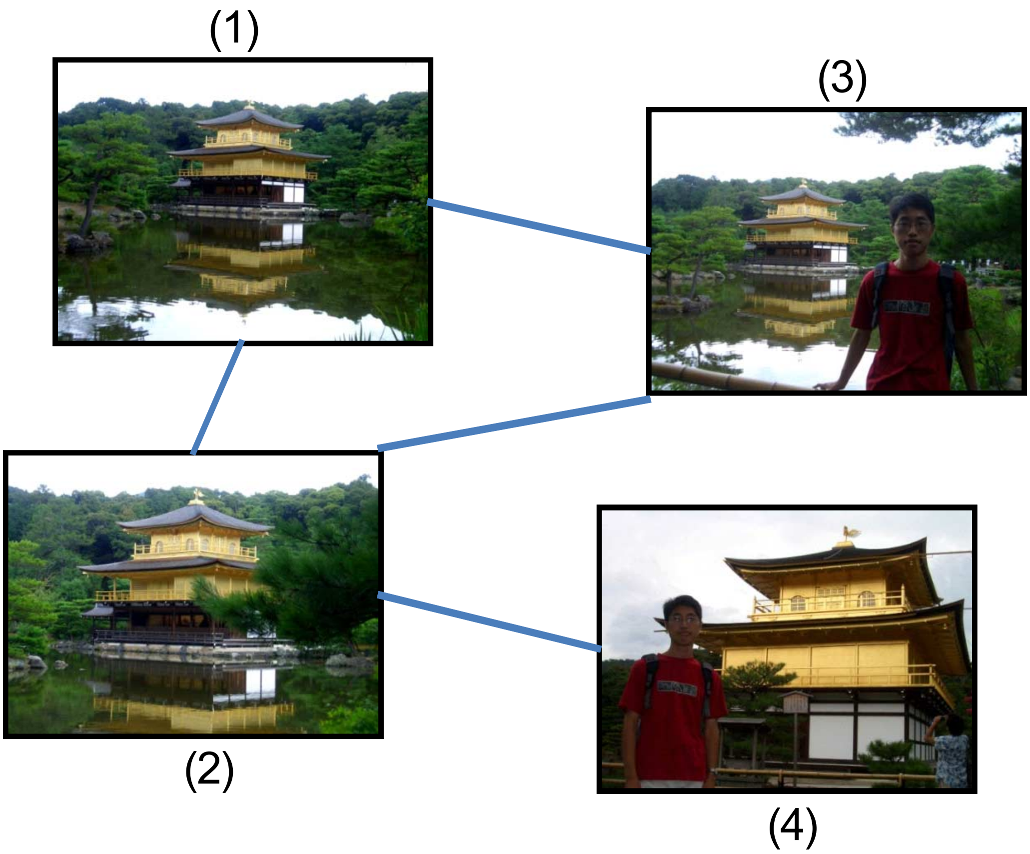

FIGURE 2.13: Example of the relationship between near-duplicate photos for selection of the most representative photo. Obtained from [14].

Another feature that has been employed for summarisation is the uniqueness of a photo. In the work by Sinha [104], uniqueness means that there are not too many photo shots from the same time in the photo collection. In contrast, in [105, 107] it is claimed that a photo is attractive when many photo shots have been taken at the same time. This contradiction shows the importance of both close and far photos in summarisation of different states and moments. Another feature that can be used to select the most representative photo is suggested in [109], where it is stated that the cluster with more than one photographer is more appealing, alongside using location metadata for summarisation of photo collections.

In this section, the summarisation of photo collections was described. However, photography is not just about organisation and visualisation of photo collections. Photo sharing is becoming a common way of maintaining closeness and relationships with friends and family, and it can evoke pleasurable, enjoyable and exciting experiences. People have fun when sharing photos containing nice scenes or friends being caught doing something interesting. Therefore, photo sharing concepts and their applications are explained in the next section.

2.8 Photo sharing

Photos are shared daily between people. Frohlich [2] proposed a framework which shows that the main elements of photo sharing are the photographer, the subject, the audience and the photo. He also defined recognition, interpretation, reminiscing and storytelling by the relationship between the mentioned main elements of photo sharing. The main elements of photo sharing and their relationships can be seen in Figure 2.14.

Photo sharing has been widely studied in HCI. Most social networking services [110] allow users to share their photos. Kirk et al. [24] found and classified the activity of people in photography in a process which they called "photowork" whereby patterns are identified prior to photos being shared. Digital photography is studied widely in [15, 29].

Frohlich et al. [28] introduced a taxonomy to analyse the different states of photo sharing in the digital era. The two main elements of photo sharing based on the Frohlich taxonomy are the time and place. Co-present sharing is when sharing takes place at the same time but different place. Remote sharing is when photos are

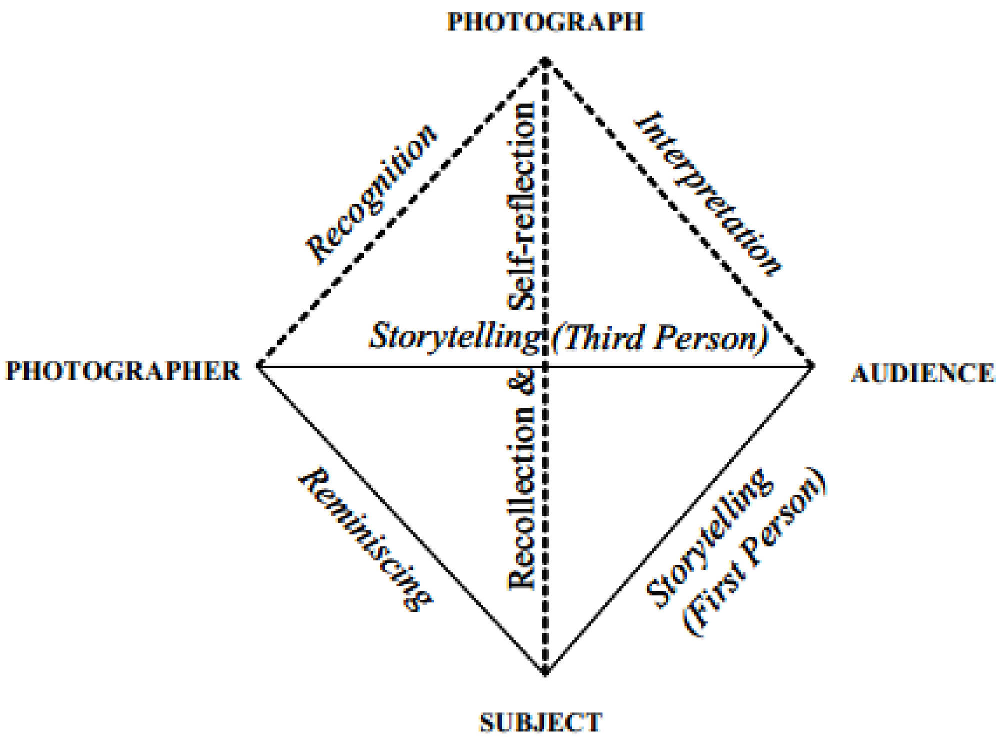

FIGURE 2.14: Main elements of photo sharing and their relationships [2].

shared at a different time and a different place. Sending is when photos are shared at a different time and different place. Finally, archiving is when photos are shared at a different place and a different time. Ongoing solutions of photoware [24, 28] should facilitate the use of all the elements from the Frohlich taxonomy in a single system and remove the borders between these practices.

Currently, photos are shared extensively in social networks such as Facebook [102], Instagram [111] and Flickr [83]. The main reason to share photos in social media [110] is self-expression. For example, in Flickr, photos are shared in order to get feedback from other professional photographers [43, 112]. Another reason for sharing photos is to give awareness to others. Taking photos seems no longer just an act of memory retention but it has increasingly become a tool for communication, of individual identification and to inform our activities [113].

The growth of social media [110] means that adjustment of privacy has become an issue. Previous studies have shown that people want to share their photos with small circles of people [114, 115] such as family and close friends. Hence, sharing photos with small groups has different motivations and needs than sharing with a wide circle of friends such as via social media [110]. Several studies [29, 71, 112] have suggested that sharing with a small group of friends mostly includes documenting everyday life, sharing memories and telling stories of meaningful and special events. Ojala et al. [39] suggested that there is a need for collective working space for sharing large sets of photos with small groups of people.

Previously, in [15–17], digital photos were shared at the same time and same place in a co-present manner [28] with small groups. In [15], the authors designed and implemented a collocated-synchronous mobile photo sharing application, Mobiphos. In Mobiphos, participants of a small group run the application on their mobile phones to support the automatic sharing of photos in the collocated group whose members are engaged in a social activity. When a user takes a photo with Mobiphos, that photo is automatically shared with every member of the collocated group. It should be noted that, by using this application, all the users should be in the same place and they are not able to share their photos when they are away. Figure 2.15 shows the Mobiphos interface; the photo that has most recently arrived from any of the participants in the small group is presented on the biggest window. Subsequently, the older photos are replaced by the newest photos that are received from any capture device; the newer photos are placed in the view finder section. The coloured photo borders indicate who captured each photo.

The advantage of this application is that it supports co-present sharing with the ability of collocated-synchronous photo sharing. Although the collocated nature of sharing is an advantage, the system does not support synchronous photo sharing when the users are at different places at the same time. In addition, although the users are able to share photos at the same time and same place, the system does not give them a chance to talk about the synchronously taken photos in detail. In a user study of Mobiphos [15], the authors did not mention the collective user experience of viewing and reviewing the photos that were taken during the study. Browsing photos is based on a timeline that can be controlled by arrow keys on the keypad of a mobile phone and it can be concluded that, if there are many photos that were taken synchronously, then it would be difficult for the participants to review older photos using just arrow keys.

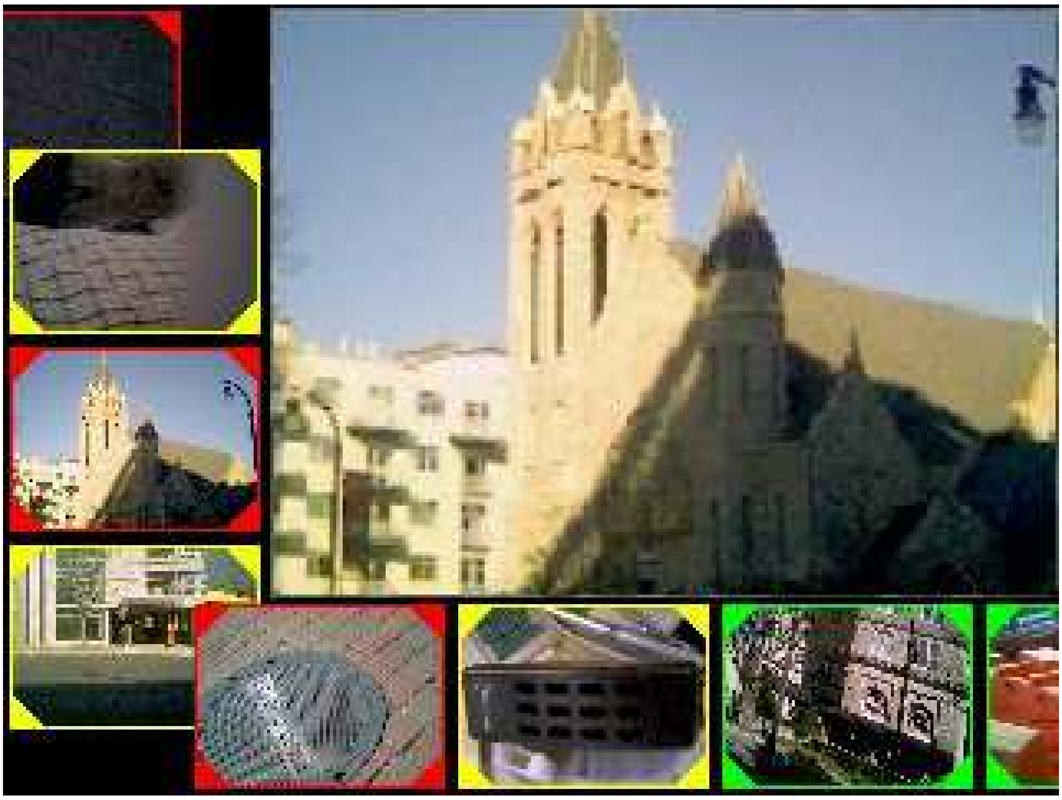

FIGURE 2.15: Screenshot of the Mobiphos interface with the thumbnail timeline in mid-animation. The viewfinder is at the top-right and thumbnails are along the left and bottom of the display. The coloured border on the images indicates who captured the photo [15].

In another co-present photo sharing example [16], "4photos" is a collaborative photo sharing device that supports photo streams from up to four users to be visualised. The device prototype was designed to be positioned on a dinner table and the aim for designing the prototype for a dinner table location was that the dinner table naturally configures people to gather for social occasions such as dinner and drinks. The prototype, which can be seen in Figure 2.16, is a cubic photo display that has a photo display screen on each side. Each side of the prototype has an infrared proximity sensor which can detect gestures and movements towards the display from each side; it also has a rotatable section at the top of the device to rotate the photos. This prototype used past Facebook photos of participants; this had the potential to cause some privacy issues as some participants were worried about the use of photos that they did not wish to show to others. However, overall, this device was useful as a conversational resource among users who intended to share their photos and talk about them during mealtimes in a co-present sharing environment. This system does not support real-time photo sharing in the way that Mobiphos [15] does, but, instead, it creates a good environment for communication while viewing photos, which Mobiphos does not do.

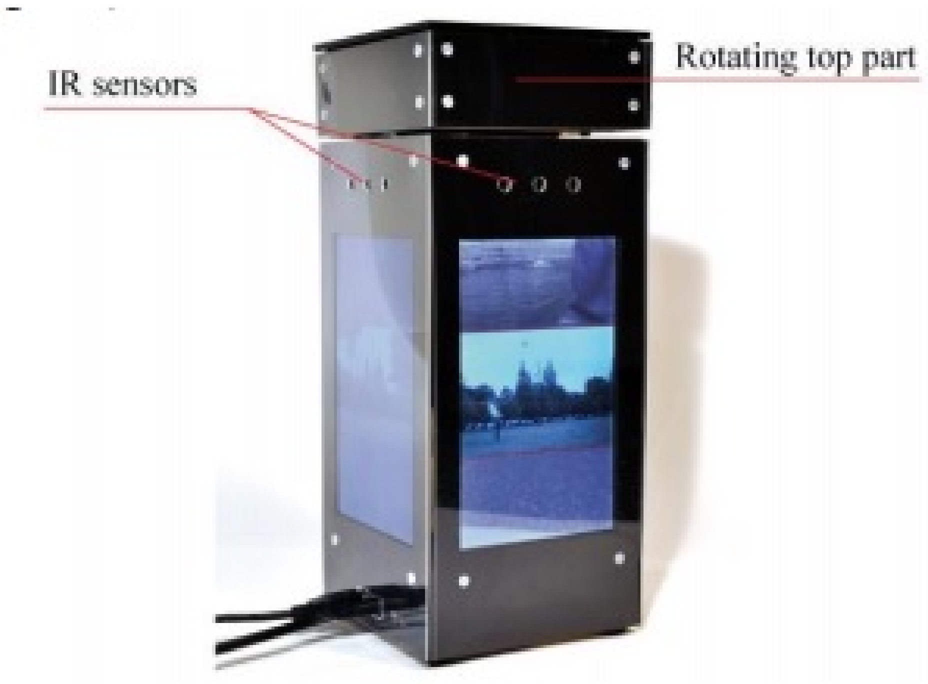

FIGURE 2.16: 4photos prototype [16].

Kun and Marsden [17] designed an application that allows users to share photos with other co-present users by synchronising the display on multiple mobile devices. In this system, each user can share a photo and then other users can see that photo on their mobile phones when they are together. Kun and Marsden introduced three techniques: host-token, three-second and ad-hoc. In host-token, the person who has the permission can show their photos on the screen of all mobile devices. However, in three-second, each user has three seconds to show his photo. In ad-hoc, there is no permission and all users can show their photos whenever they decide. Kun and Marsden found that, for applications of this nature which need to support storytelling, some form of host-token is the most appropriate technique. They also observed that users were more likely to pass control of sharing photos in co-present space from different devices when asked for it verbally. The interface of the application for co-present sharing of photos from the past can be seen in Figure 2.17. This application provided a good platform to share photos at the same time and place, but it does not support sharing photos at a different place but same time. Moreover, unlike [15], Kun and Marsden's application did not support real-time photo sharing. The advantage of this type of sharing, when compared to 4photos [16], is that the user has control in selecting the photo that they want to share. On the other hand, the random selection of photos by 4photos brings other advantages; by bringing in photo mementos from multiple Facebook accounts, 4photos enables more symmetric opportunities, which leads to a constant passive shifting of audience-presenter via an ambient display rather than a manual selection of photos.

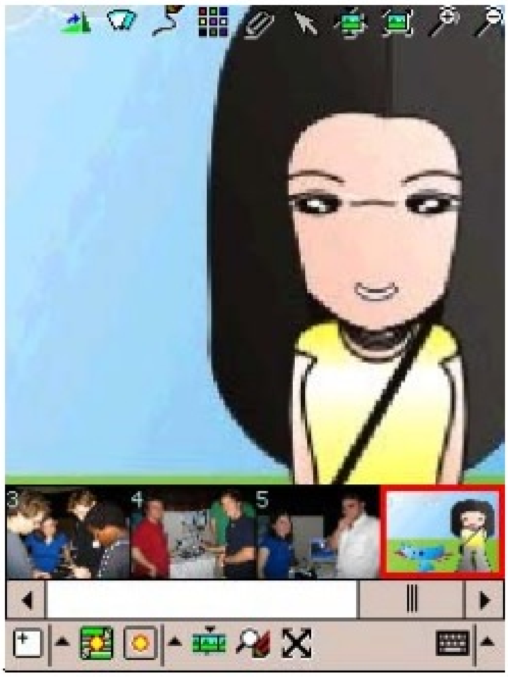

FIGURE 2.17: Interface of the co-present photo sharing application [17].

Early commercial photo web sites, such as Kodak Gallery [116], Snapfish [117] and, following that, iCloud [118], were designed as online archives for family photos in order to support sharing photos at different places and times. Moreover, applications such as mail services, Whatsapp, Viber and Snapchat enable users to share their photos at different places and times as photos are sent in [28]. A similar method of sharing was followed in [71, 119, 120]. MobShare [120] (see Figure 2.18) is an application for adding camera phone photos into an organised web album immediately and notifying other users by email. The main contributions of this application have been immediate sharing, tagging by phone address book, discussion environment, combination and comparison of photos by photographers. MMM2 [119], another sharing application, is a mobile application to facilitate the sharing process at different times and places. These two applications support remote sharing when the action of sharing takes place at the same time but different places. These two applications are both server-based and they store the photos in the Cloud [121]. In another study [122], two levels of interaction are studied, i.e. HCI (remote sharing) as in MMM2 and Mobshare and human-human interaction (co-present sharing) as in 4photos.

FIGURE 2.18: Mobshare [18] interface (top) and MMM2 interface (bottom).

For sharing photos in small groups, a photo sharing device [71], as can be seen in Figure 2.19, has been designed to be used by elderly people so that their family members can share their photos with them. The device is a digital photo frame and users are able to share their photos via MMS or Email. This application supports the sending and remote sharing categories described by Frohlich et al. [28].

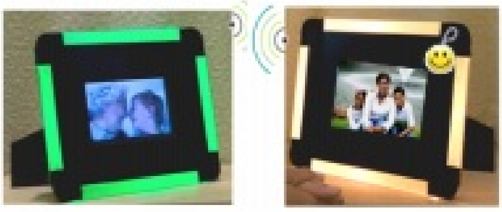

FIGURE 2.19: Display designed for sharing photos from small groups for use by elderly people [19].

Recently, people possess more than one digital camera, such as a camera phone and a point-and-shoot camera. Families have different cameras in the home, which can be used by different members of the family. Moreover, friends attending the same event can share their moments. Therefore, huge numbers of photos can be generated concurrently from multiple sources, as described by [39]. To solve this problem, Jang et al. [18] proposed a new approach to display shared photos taken from multiple cameras that were present at the same event. Firstly, whole camera photos (basis cluster) are grouped by one manually clustered camera role (unit cluster). In the next stage, the most representative photos from the basis clusters are compared with those from the unit clusters. Next, those photos are integrated (unified cluster) for all camera rolls. Finally, similar photos are rearranged, as in Figure 2.20, by collecting the photos with high similarity in a unified cluster and classifying them into sub-clusters. The drawback of this approach is that photo stream continuity is lost during rearrangement (see Figure 2.20) such that the stories of the top and bottom photo streams are different.

Although there is a solution to share photos taken at the same place and time, there is no solution to share photos taken at the same time but different events. Therefore, there is a gap in applications that support visualising and sharing of photos that are taken by different people: (i) at the same time and same place or (ii) at the same time and different places or (iii) at different times and different places.

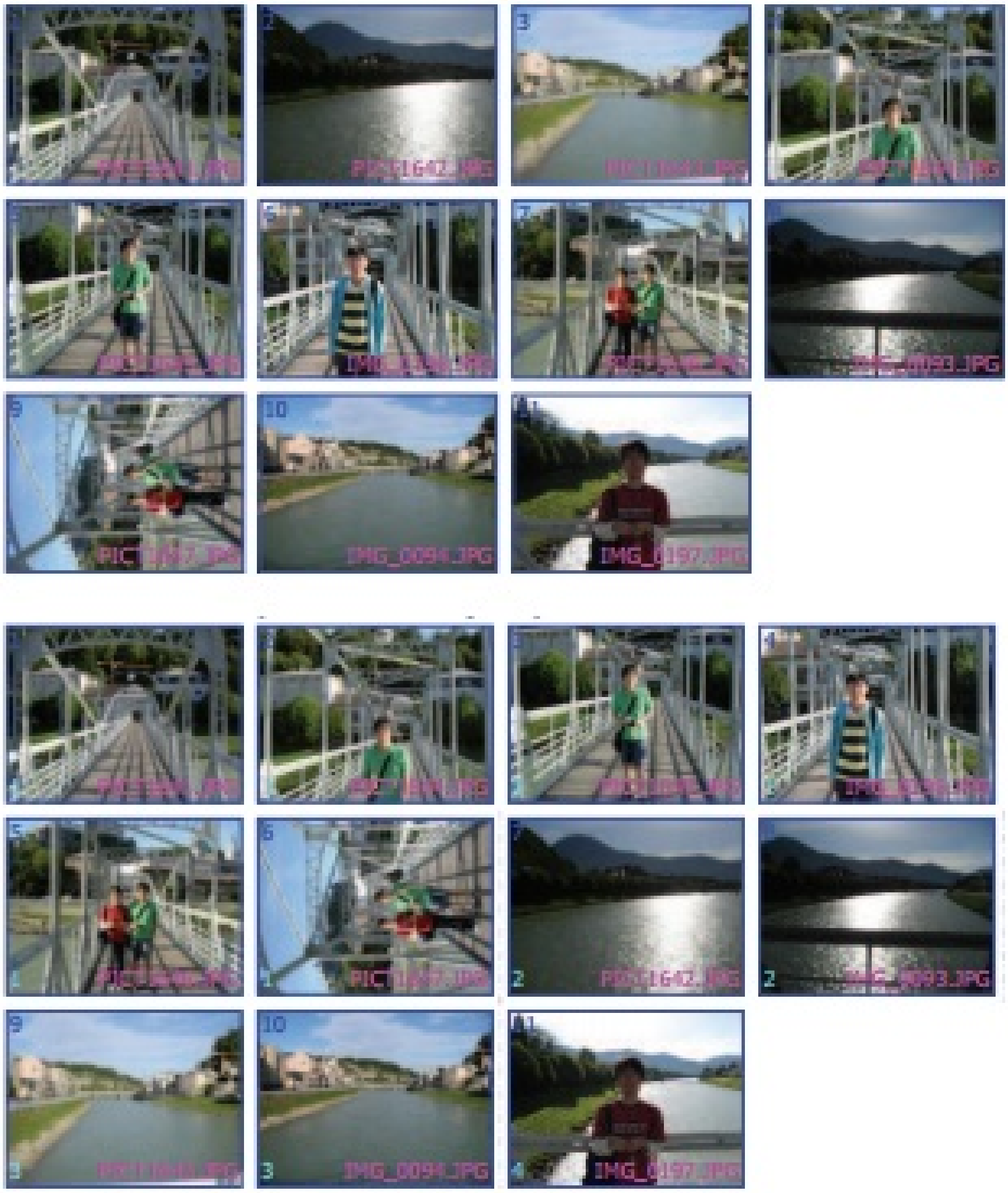

FIGURE 2.20: An interface for sharing and adjusting photos from multiple capture sources at the same event. Top: Unified cluster. Bottom: Rearranged cluster. Taken from [18].

2.9 Summary

This chapter has covered the state-of-the-art in research related to digital photography. Firstly, the two main paths of analogue and digital photography were described. After that, based on the previous study understanding photowork [24], the study of digital photography was classified into four main categories: organising, sharing, capturing and visualisation. Each of these categories was explained in detail. Figure 2.21 summarises the study approach for digital photography that was covered in this literature review.

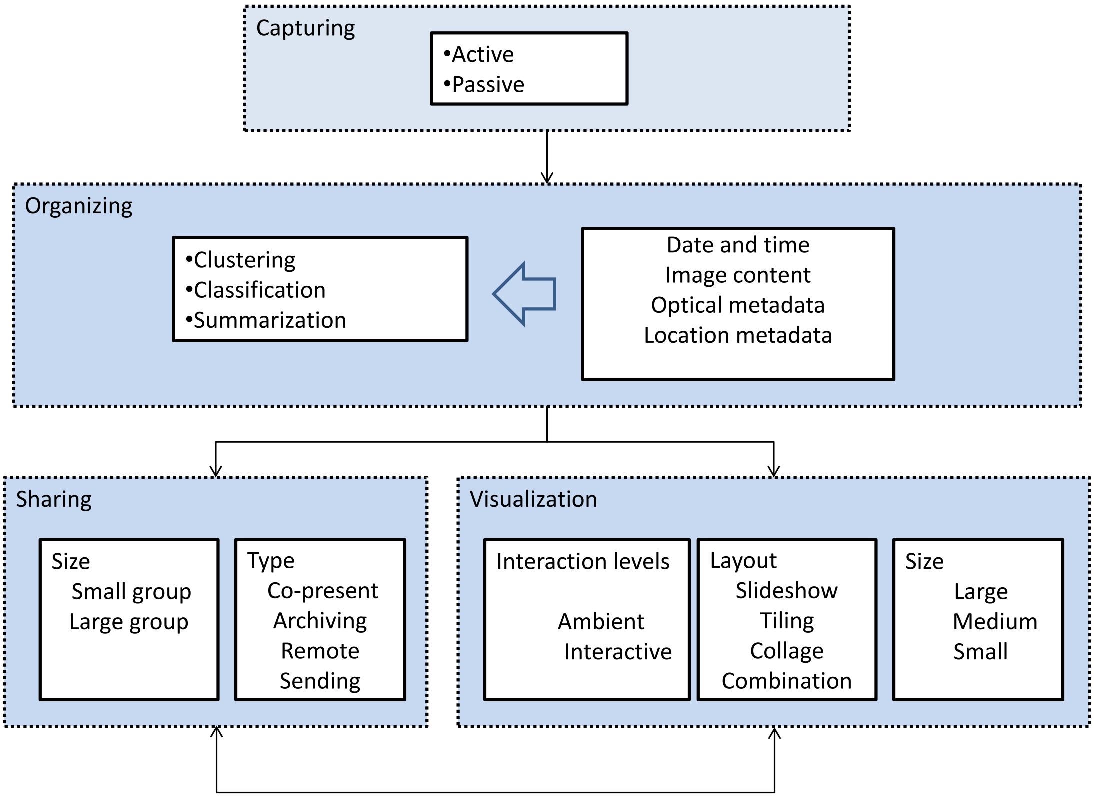

FIGURE 2.21: Summary of the study approach for digital photography covered in this literature review.

In the first section, two types of photography were identified: passive and active. In passive photography systems, such as SenseCam, the human does not direct the camera to take photos and, instead, the system takes photos automatically based on timers or sensors. In active photography, the user directs the capture device to take photos, such as with a camera phone or a point-and-shoot camera. In this chapter, the benefits of passive photography alongside the camera phone in active photography were explained. It can be concluded that the future of photography will be based on these two types of photography and that, although passive photography is not common, it might be very popular because of its particular benefits.

In the second section of this chapter, visualisation in digital photography was described. It has been found from the literature that there are four main techniques to present digital photos: collage, slideshow, tiling and a combination of these techniques such as a tiled slideshow. For collage, photos are placed and displayed in similar or different sizes on one screen, while for tiling, the photos are shown mostly in tile or thumbnail format to offer more space on the screen for the user to browse photos. The previous studies also showed that slideshow is a good technique for ambient displays, decoration photo display tools, reviewing old photos and storytelling. The combination of these methods, such as tiled slideshow, can be used to show more than one photo of the same event in each slide during the slideshow.

Also in the second section of this chapter, two types of displays for visualisation of photos were introduced: interactive and ambient displays. In interactive displays, users interact with features that the designer provides for them on the display in order to browse and view photos. In ambient displays, the user interaction with the system is decreased and the system presents photos to the user automatically without the user's interaction.

In the third section of this chapter, it was explained that there are three main important techniques to organise photos: classification, clustering and summarisation. In clustering, photos from the same categories are collected in one place to allow the user to see more related photos of interest together. In summarisation, as the number of photos grows in time, the collections become abstracted based on user interest or automated algorithms that identify the most representative collection. Moreover, in classification, photos from the same category are given a meaningful name automatically from a trained data set. Examples of such meaningful names and categories are: outdoor, indoor, party, happy etc. The difference between classification and clustering is that classification gives a meaningful caption to photo albums while clustering just collects the related photos into different groups without any meaningful caption.

All of these techniques for organising photos take advantage of at least one of the time, location, optical metadata and image content features. However, time is the most important, prominent and basic feature by which to organise photo collections.

In the last section, it was explained how sharing photos is very common and how people share their photos on an everyday basis. Photos can be shared with large or small groups of friends and sharing photos with small groups of friends is common in the current photo sharing trend. Moreover, it is apparent from the literature that there is a need to share photos within small groups of people such as friends or family members. The main elements of photo sharing are the subject, photographer, audience and the photo. Following that, we explained the types of photo sharing based on time and place, and concluded that good photo sharing platforms should support co-present sharing, remote sharing, archiving and sending photos to one place. It was also found that there is no current application that is able to display multiple photo streams from different people in one place.

Having all these observations in mind, it is concluded that people use multiple capture devices, they have very large photo collections and they desire to share their photos with a small group of friends such as family members or close friends. There are applications that enable users to share their photos in collocated environments in real time or to share and re-organise photos that were taken at the same event. However, there is no application to support users to share and visualise their photos in both remote and collocated environments. Moreover, current applications do not support visualisation of multiple photo streams from different people in one place. Therefore, we identify that there is a need for an application that supports sharing and visualisation of multiple photo streams that have been collected from multiple sources.

From this literature review, the foundation of the research that is presented in this thesis is described:

1. There is a need for photo sharing applications that display multiple photo streams that have been collected from different people or from different capture devices.

2. Time is the main aspect of photo organisation.

3. Multiple photo streams have been shared previously when they were taken in collocated environments. A valuable application will allow multiple photo streams to be shared and compared in both collocated and remote environments based on the main characteristics of photo organisation; the primary characteristic is time (same time, different place or same time, same place).

4. Multiple photo streams from different people can be presented in one place to bring awareness from one's own photo stream and other people's photo streams.

5. A good photo sharing application may use a combination of interactive and ambient displays in different conditions.

6. Slideshow format is the most common technique for displaying photos on an ambient display or when the user wishes to view the content of the photos in more detail. Moreover, slideshow format is the basis of photographic storytelling tools.

7. A good photo sharing and visualisation application should support both passive and active photo collections.

8. A good photo sharing application should support co-present sharing, remote sharing, sending and archiving in one place.

9. Creating applications to support photo sharing with a small group of people because of privacy issues is essential.

10. Using the multiple narrative technique in photo storytelling might be the future of the photo visualisation applications.

Based on these findings, a study, design and analysis of a system for synchronised sharing and visualisation of multiple photo streams is presented in the following chapters. An overview of the adopted methodology is given in the next chapter.

Chapter 3

Methods

3.1 Introduction

This chapter presents in detail the quantitative and qualitative research paradigms and research methods that were selected for the studies presented in this thesis. Particular aspects of the research methods that are discussed in this chapter are: quantitative and qualitative research approaches, data gathering techniques and data analysis procedures. The approach adopted in this thesis was designed to combine the objectivism of the quantitative research and the informative reflections of the qualitative research. The following sections discuss the nature of the methods that were used to study the application of sharing and visualisation of multiple photo streams and the reasons for their selection.

3.2 Iterative research and design

3.2.1 Interaction design

The term 'interaction design' was defined by Sharp [20] as: "Designing interactive products to support the way people communicate and interact in their everyday and working lives". In addition, interaction design is about developing a user experience that improves the way people communicate, interact and work. Winograd [123] described the interaction design as designing spaces for human communication and interaction, and Thackara [124] sees interaction design as why and how our daily interaction works using computers. The main goal of interaction design is concerned with how to design a system and a user experience by using a range of methods, techniques and frameworks.

Interaction design is vital for all disciplines, fields and approaches that are concerned with researching and designing computer-based systems for humans [20]. A concept that comes with interaction design is user experience; this means how a designed product or software is used by someone in the real world and, as Garrete [125] said, every thing that is being used by a human has a user experience. To be more precise, user experience concerns how people feel about a product and their pleasure, interest and satisfaction when using it.

The process of interaction design involves four basic processes [20] :

1. Identifying the needs and establishing the requirements for the user experience.
2. Developing alternative designs that meet those requirements.
3. Building interactive versions of the designs so that they can be communicated and assessed.
4. Evaluating what is being built throughout the process and the user experience it offers.

In addition, a simple interaction design lifecycle model includes four components, starting with identifying needs and establishing requirements. This is performed by reviewing and analysing current literature and designs and is, then, followed by the remaining three components: design, building and evaluation. The relationship between these components, which leads to the final product, can be seen in Figure 3.1. In this thesis, we took advantage of the interaction design process in order to design and build an application for visualisation of multiple photo streams and evaluated it by designing and performing user experience studies.

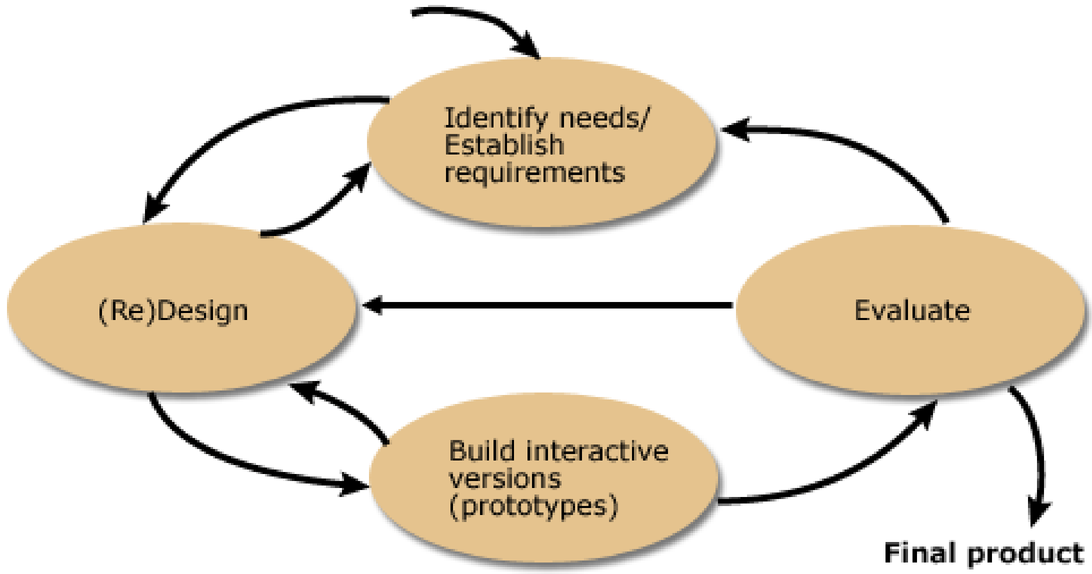

FIGURE 3.1: Simple lifecycle model for interaction design [20].

3.2.2 Systems development lifecycle model

The lifecycle model that was chosen for the development and evaluation of the systems in this thesis (see Figure 3.2) is shaped by a simple interaction design lifecycle model [20], which can be seen in Figure 3.1 and was implemented with a phase lifecycle model of software development [126]. In this thesis, we proposed three versions of the systems and that is why we introduced a phase lifecycle model for software development alongside an interaction design lifecycle model. Furthermore, a phase lifecycle development framework is good for unclear and unfamiliar projects that are complex and we have little knowledge about [126]. Therefore, in our approach, we used these two techniques to handle the requirements, the software design and the implementation alongside the user experience study.

In the proposed lifecycle model for the iterative development of our systems, three phases were identified; in each phase, the main elements of the interaction design lifecycle, which are requirements gathering, design, prototyping and evaluation,

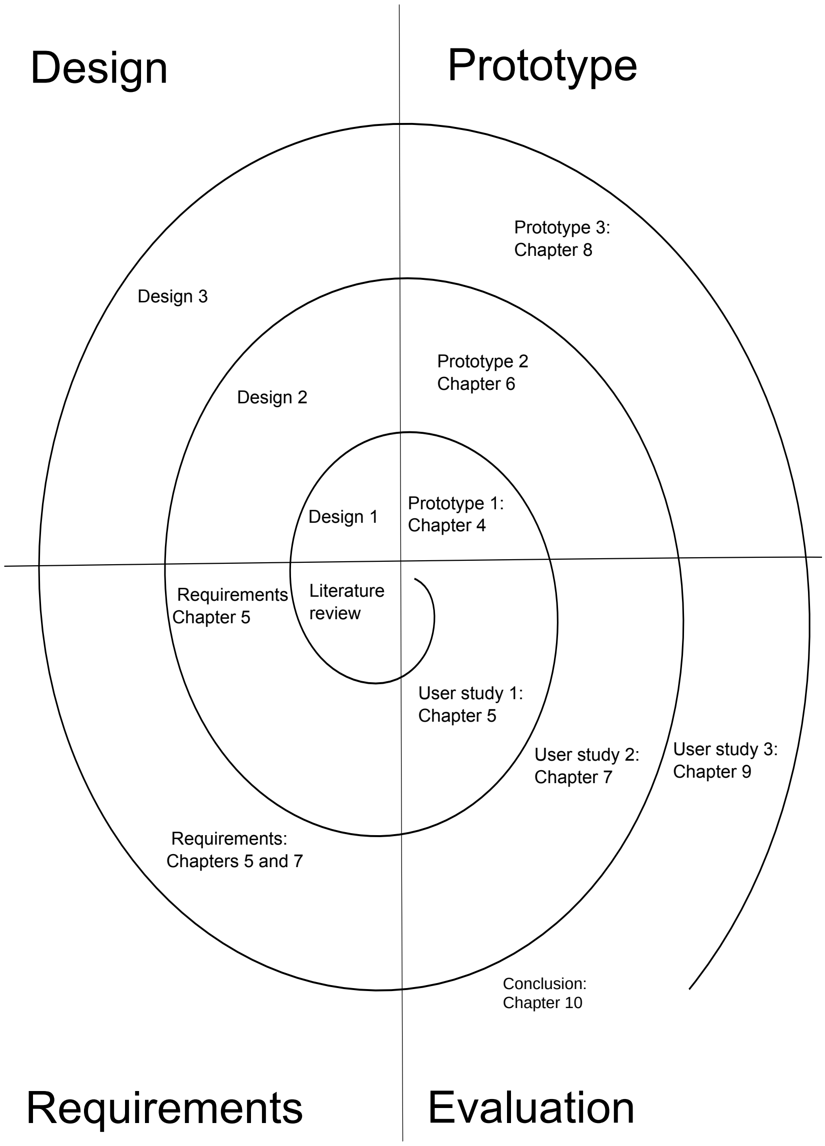

FIGURE 3.2: Lifecycle model for systems development.

were applied. From the evaluation of each phase, the requirements for the next phase were identified.

Phase 1 Phase 1 starts with identifying the requirements for visualisation and sharing of digital photos. From the literature review (Chapter 2), we found that there is a need to organise, share and visualise photo collections. Furthermore, we identified that, in current photography practice, people tend to share their photos more than view their own photo collections. Therefore, large numbers of photos from different people are generated. In the literature, we found that people possess multiple capture devices and, alongside the social networks, they have photos that they consider as part of their own photo collections. Moreover, people wish to know what is happening to others and there is a need to share photos with small groups of people such as family or friends.

Based on this information, we decided that there is a need to design and implement an application (Chapter 4) to visualise multiple photo streams from different people in one place; this would create an environment to enable the user to see their own photo collection alongside those from other people in one place and compare their past photos in time. The connectivity between people was the main characteristic of this design for photo sharing. Therefore, our first system was a web-based photo sharing service that enabled people to upload their photos to a website and then to view multiple photo streams obtained concurrently from multiple users in slideshow mode.

After the implementation of the web-based application for sharing and visualisation of multiple photo streams, we recruited three groups of family, friends and close friends to test our system. We conducted a semi-structured interview alongside the observation method and analysed the data mostly qualitatively to evaluate the current application and offer potential ideas for future work (Chapter 5). The evaluation part of Phase 1 revealed many possible future studies and two of them were performed for the implementation of new versions of the system in Phases 2 and 3. At the end of this phase, we derived the values and requirements for the sharing and visualisation of past photo streams within a small group of friends alongside the user requirements for the design of a future photo application.

Phase 2 In Phase 2, the requirements were shaped by the lessons learned from the user study in Phase 1. Visualisation of photo streams in slideshow mode was pleasing for the participants but several types of photo transitions were designed in the first version of the system. From the user study, we identified the problems of these transitions and decided to add logarithmic and optimise transition modes. Moreover, the desired time transition was enhanced by summarisation desired time and logarithmic desired time transitions. There were other transition modes arising from the study in Phase 1, e.g. the continuity transition mode, as described in Chapter 6.

In the next stage of Phase 2 (Chapter 7), the transition types were evaluated in a laboratory user study test using a usability test for user experience. In addition, the analysis of interaction logs and semi-structured interviews is presented. The user study comprised quantitative and qualitative approaches. The results showed the effectiveness of the new transition types. Together with the requirements of Phase 1, the most suitable transition was applied to the design and implementation of the system in Phase 3. At the end of this phase, the question of how to find optimal temporal parameters for visualisation of multiple photo streams was addressed.

Phase 3 Chapter 8 of this thesis describes the system that was designed and built from the requirements and information produced in Phase 1 and Phase 2. Here, an interactive digital ambient display was designed and built as a decoration tool for synchronous visualisation and live sharing of multiple photo streams.

This system was evaluated thoroughly in three field studies (Chapter 9), addressing the user experience of the system in three different user groups: close friends, extended family and workplace colleagues. Group interview techniques and interaction logs were used to collect information and the data were analysed qualitatively and quantitatively. At the end of this phase, design recommendations for optimal user experience of ambient visualisation of multiple photo streams within small groups of people were derived and presented.

3.3 Design methods

3.3.1 Design and prototyping

The first or preliminary version of a device from which other forms are developed is called a prototype [127]. A prototype can be a sketch drawing of a product or a well-designed hard-coded application. A prototype allows users to interact with a product or application to gain some experience of the use of the product in the real environment [20]. Therefore, by refining the prototype, the final product is developed. There are two types of prototyping: low-fidelity and high-fidelity prototyping [20]. Low-fidelity prototyping produces a kind of prototype that does not look like the final product, such as being constructed from paper or cardboard, while high-fidelity prototyping uses materials that make it look very similar to the final product, such as being hard-coded software. The final product or application can be made from either of these two prototypes. A low- vs. high-fidelity prototype can be seen in Figure 3.3.

Rudd et al. [128] described the advantages and disadvantages of low- vs. high-fidelity prototypes. The main advantage of a low-fidelity prototype is lower development cost. Moreover, it enables the designer to evaluate multiple design concepts. However, it has limited error checking capability and it is poor in detailed specification. In summary, the usability test of low-fidelity prototype is limited. For a high-fidelity prototype, the functionality of the system is complete and it is fully interactive, which makes it user driven. A high-fidelity prototype can be used for exploration and testing, and it feels like a final product to the user. However, it is more expensive to develop and time-consuming to create.

In this thesis, for the implementation of our final product, we applied both low-fidelity and high-fidelity prototype designs. First, we designed our applications using a low-fidelity prototype technique on a piece of paper; after that, our applications were designed as a high-fidelity prototype and then, the final version was implemented for the user experience study.

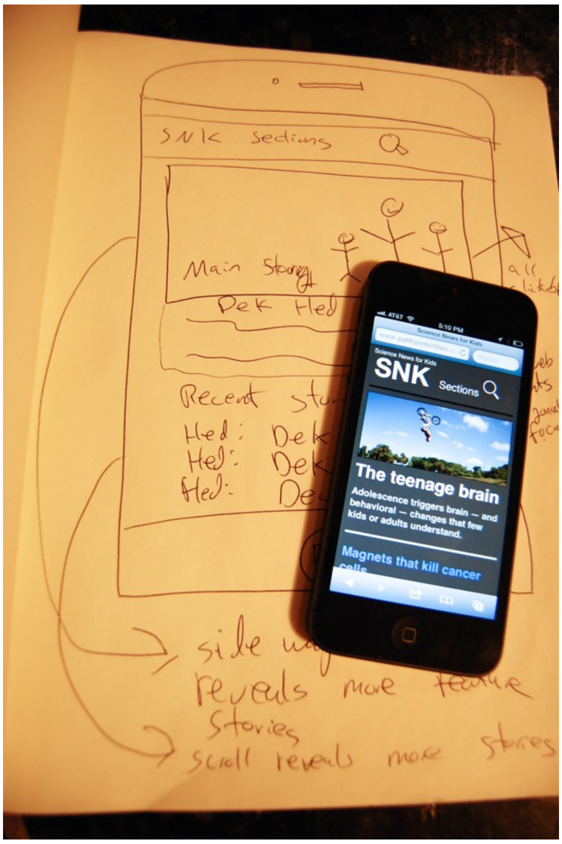

FIGURE 3.3: Low- vs. high-fidelity prototype example [21].

3.3.2 Implementation

Prototypes were designed using both low-fidelity and high-fidelity techniques. After that, the designed prototypes were implemented as a system in all three phases of our studies. The implementation tools that were used in this thesis were C# [129], HTML [130], MATLAB [131] and SQL server [132].

In Phase 1 (Chapter 4), the core engine was C# alongside HTML for interface design. An SQL server was used to store and manage the data, which comprised digital photos and associated information. In Phase 2 (Chapter 6), MATLAB was used to implement the interface and to control it. MATLAB was used due to its prominent image processing algorithms that were used to enable the interface of photo stream visualisation. In Phase 3 (Chapter 8), a C# application-based tool was used to enable users to share and visualise photo streams. Figure 3.4 shows our implemented interfaces in different phases.

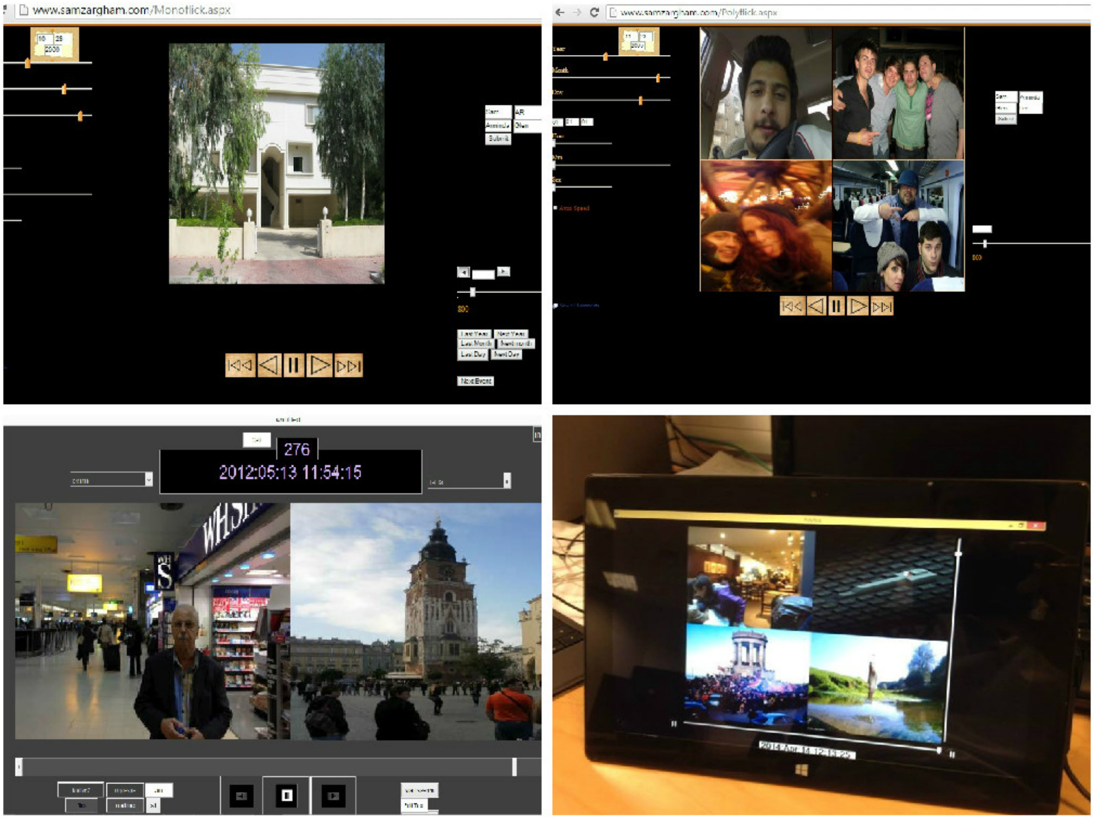

FIGURE 3.4: Example of our implemented applications. Top-right: C# and HTML (Phase 1), top-left: C# and HTML (Phase 1), bottom-left: MATLAB (Phase 2), bottom-right: C# (Phase 3).

3.4 Research methods

3.4.1 Qualitative research

Qualitative research is a common research technique used not only in sociology and anthropology [133] but also in HCI, technology experience and user-centred design [134–136].

The main aim of applying qualitative research is to uncover and understand deeply what is behind a poorly understood experience as a means of developing new and interesting concepts.

Qualitative research can probe complicated or detailed experiences to complement statistics and quantitative methods [137]. This kind of research draws attention to phenomena, meaning and description from data such as audio or video recordings of speech (recorded interview) or observation of what people do (observation techniques) [138].

Qualitative research [133, 139–142] can be summarised as below:

1. Qualitative research concentrates mainly on the process of a social experience that is created specifically to provide outcomes.

2. In qualitative research, the main finding is what participants perceive and interpret as the meaning of the experience that they were part of and, in this case, interview and observations are the techniques used to list and identify the participant's perspective on the topic of research.

3. Researchers in qualitative research, as opposed to the interview questionnaire and protocol, play the main role and provide the channel for data gathering and analysis during an interview. Therefore, the researcher should be well prepared and have a very deep understanding of the field to obtain good results.

4. Field study and research is one of the main elements of qualitative research, whereby participant behaviour during their experience of a natural phenomenon is observed.

5. The reporting of qualitative research is subjective and descriptive, such that rather than using numbers or statistics, the data are reported in more tangible media such as words, speech, video and pictures.

6. The reasoning method that a researcher should use during qualitative research is inductive rather than deductive. This means that in qualitative research, instead of confirming a hypothesis and a theory, the research andthe analysis of the experience of the participants will generate a pattern and a theory.

Based on these explanations, the most fitting approach to investigate the visualisation of multiple photo streams using our implemented systems is the qualitative research. In terms of photo capturing, themes were found by Okabe [143], who investigated camera phone use, and by Lindley et al. [144], who investigated the user experience using SenseCam. Mobiphos [145] is a collocated mobile sharing and visualisation application and a user experience study was perfomed on it using qualitative research methods. 4Photos, a photo sharing device, was investigated qualitatively in [73].

3.4.2 Data gathering techniques

When there is a need to investigate the experience of people, data are required for analysis. The most common techniques to gather data in order to understand the experience of people include: interviews, focus groups, participant observation and quantitative data such as system logs and diaries [20]. The data gathering for this research comprised of semi-structured interviews, acquisition of system logs and field observation.

Semi-structured interviews

The main goal of this study was to gain an insight into people's perception, and an understanding of their behaviour and experience, while using our photo sharing and visualisation tool. In order to investigate current photographic practice and how our system was used, semi-structured, interviews were used mostly for the first and third versions of our system.

The semi-structured interview technique has various advantages: it is interactive, communication is face to face, it allows greater depth of understanding of the issues that are investigated and it offers the interviewer an opportunity to gather more information [20, 133].

In semi-structured interviews it should be noted that not all of the participant's answers can be predicted; hence, the interviewer needs to be more creative and ready to ask challenging questions that were not in the planned interview paper, as the interview evolves.

This notion of a semi-structured interview might change the structure of some interview sections and can reveal fascinating subjects that might otherwise be forgotten when using a full structured interview technique. Many HCI studies use this technique; for example, in [73, 144, 146].

In [73], a semi-structured interview technique was used to investigate how the use of a photo sharing tool during meal time affects people's behaviour and eating culture. Similarly, in [144] semi-structured interviews were applied to acquire information about people's activities and feelings when they used SenseCam as a passive camera.

It can be claimed that semi-structured interviews are very powerful for gathering informative and rich data, allowing the interviewer to follow the valuable and interesting information acquired from the participants, so that relevant topics can be investigated more thoroughly.

The semi-structured interview is dynamic and gives flexibility to investigate subjects in a manner not driven by the interviewer but instead, in a manner created and covered by the interviewee. As explained by Minichiello et al. [147], the interview is an especially appropriate method for data acquisition to understand the consequences of human experience.

Field observation study

The observation method for data gathering has been utilised by many researchers to observe people during an experiment. Patel et al. [15] designed a collocated sharing application and investigated through observation how their system was used; they found new approaches that they applied to use the system. Taylor et al. [148] applied observation methods to their research in order to find how teenagers use mobile phones for digital gift giving.

Observational methods offer a means of data acquisition that involves the researcher observing the participants during the experience [149]. The advantages of observation are flexibility and the potential to create a research topic rather than starting with a hypothesis; the researcher can make observations in order to create research questions due to the descriptive, rather than structured, emphasis of the method.

The findings of observations are very strong in terms of validity due to the ability of the researcher to collect information about very detailed behaviour during the experience; as Trochim [150] stated, validity is the best characteristic of observational methods.

One disadvantage of observation is the replication of the object of study and the potential to be time consuming. The results of observation might be true for some, but not all, people; therefore, they cannot be generalised to others. Another problem with observation is that the researcher might just observe what he wants to observe and miss other important subjects during the observation; recording the observation can solve this problem.

According to [150], there are various kinds of observation: direct, unobtrusive and naturalistic. In direct observation, people know that they are being observed and they might, therefore, change their behaviour rather than being themselves; a long-term observational study might be able to solve this problem. This type of observation might result in another disadvantage, namely that a short period of observation might not give the same results for other people, so that results cannot be generalised.

Unobtrusive observation is a method whereby the participants do not know that they are being observed; therefore, there is no concern that people might change their behaviour while they are being observed. The problem of generalisation is solved but still only within a group of people with similar characteristics, such as computer engineers in a particular company. Finally, the main problem with this kind of observation is ethical issues.

Naturalistic observation is a technique for observing people in their natural environment. This method is used to avoid interfering with the behaviour that the researcher wishes to observe. This method is used mostly in laboratory research. One of the advantages of naturalistic observation is that it lets the researcher observe the subject in a natural setting; disadvantages include the fact that it is not easy to determine the exact cause of behaviour and that it is not possible to control variables outside the observational environment.

In this thesis, the direct observation method was used in Chapter 5, where participants create a photographic life-log to see how the use of our application changes their photography practice.

Interaction logs

Interaction logging applies to studies of applications that have been developed to record user activity in a log that is interpreted later [20]. There is a variety of actions that can be recorded from computer mouse movements, button presses, action time stamps, number of visitors and movements.

McLaughlin et al. [151] designed an interactive web-based art museum; the number of website visitors, website browsers used and country from which the website was accessed were recorded for seven months. In another study [71], photo sharing application logs were stored. For example, this study recorded data on how many photos were shared, the content of the stored photos, the type of media the photo was shared with and the time of photo sharing.

A key advantage of logging activities rather than using direct observation is that the former is unobtrusive and does not affect the behaviour of the participant while they are interacting with the system; it is not, however, as detailed as observation. Moreover, observing participants without their consent has ethical issues. Another advantage of logging activities is that a large amount of data can be stored automatically without human effort.

Usability testing

It has been claimed by [20] that usability testing is an approach that emphasises the property of being usable; therefore, in such a test, the product is tested rather than the user. In a usability test, the product is tested in a controlled environment such as a usability laboratory. The goal of this kind of test is to test if the product under development is usable by the user through defining user tasks [152].

From this kind of study, quantitative performance can be measured and the following types of data, based on Wixon and Wilson [153], can be obtained:

- Time to complete a task.
- Time to complete a task after a specified time.
- Number of errors per task.
- Number of errors per unit of time.
- Number of users that make a particular mistake.
- Number of users completing a task successfully.

One example of usability testing is described in [154], where a usability test found a significant difference between younger and older adults in time completion and task completion relating to Facebook settings. In Chapter 7 of this thesis (Phase 2), usability testing is used to estimate user performance by setting tasks for participants.

3.4.3 Data analysis

Thematic analysis

The qualitative analysis method used in this thesis is thematic analysis, which is a technique for identifying, analysing and reporting themes (patterns) within data. This technique organises and describes qualitative data in detail [155]. However, there are various types of thematic analysis and there is no clear agreement about what thematic analysis is and how it is performed [155–157]. Many other qualitative analyses are basically thematic but they are named differently, such as content analysis [158]. Thus, identifying recurring patterns or themes was applied for analysing the data we gathered.

In a study by Ojala and Malinen [39], participants were interviewed about their current practice of photography and how they shared their photos with small groups; the results were shown as themes. The same technique for analysing and presenting data was used in [15, 159, 160].

Sometimes patterns or themes form the primary set of findings for analysis and sometimes they are just the starting point for more detailed investigation of the data [20]. In order to identify themes in qualitative analysis, the researcher should have knowledge of the data and have read them many times; this way themes emerge and evolve over time.

One important aspect of conducting this kind of analysis is to keep clear and consistent records of what has been found alongside a detailed description of the themes. If the description is sufficiently specific, then there will be multiple well-evidenced themes; however, a set of observations that do not address the goal may result. The patterns arising from data analysis may be the behaviour of the user group, place, situation of the experience and so on. In order to generate themes, the data should be coded.

To generate prominent themes and results, the following six stages of thematic analysis must be performed [161]:

1. Familiarisation with the data.

2. Generation of initial codes.

3. Searching for themes.

4. Reviewing themes.

5. Defining and naming themes.

6. Report production.

According to Braun and Clarke [161], thematic analysis has many advantages. Firstly, it is very easy to learn and it conveys flexibility during the data analysis. The researcher can use it with little or no experience of qualitative research and the results are generally accessible to educate the public. Finally, it is a good method for summarising the key features of large datasets such as long transcribes and it is able to generate unanticipated insights.

Quantitative analysis

Quantitative analysis is the analysis of a situation or event by means of mathematical and statistical modelling [162]; while this technique is used mostly in financial market analysis, it is also widely used in HCI and user experience research [163].

In the current study, we undertook quantitative analysis of the gathered data. The data are presented in Chapters 5, 7 and 9. In Chapter 7, the information from the interviews is presented as quantitative data, while in Chapters 7 and 9, interaction log data are presented quantitatively alongside the interview data. Moreover, in Chapter 7, we designed a study that investigated participant recall of photos after viewing multiple photo streams as a usability approach to user experience. In this type of study, participant performance, answers and judgments regarding the system were analysed quantitatively.

The statistics are not explained in detail in this section but here we note only that statistical techniques that are used commonly in HCI research were used for the quantitative analysis. Average, percentage, median, mode, t-test, ANOVA test and diagrams for presentation of these results are well-known descriptive statistics in HCI. A quantitative approach has been used previously to analyse raw data in HCI research [19, 164, 165]. Anthony et al. [164] quantitatively analysed 187 non-commercial videos depicting a person with a physical disability interacting with a mobile touchscreen device that were uploaded to YouTube.

3.5 Ethics

Part of an interview procedure is to obtain agreement or consent from the participants taking part in the study [166]. The consent form reminds the participants that their participation in the study is voluntary and that their interview data will be treated with confidentiality and anonymously.

Since the interview involved voluntary participation, the participants were informed about the following:

- Researcher's name and contact details.
- Name of the organisation (University of Surrey).
- Information sheet for sharing and visualisation of multiple photo streams.
- Consent form, which contained the confidentiality and anonymity requirement of the participant's data.
- Permission to use shared photos for publications.
- Permission for withdrawal from the study at any time.

The ethics approval can be seen in A.7 and all the data from the study sessions were type-recorded with the permission of participants and stored securely; anonymity of the participants was protected in all reports, including this thesis.

Chapter 4

Synchronous visualisation of multiple photo streams

4.1 Introduction

Due to the widespread proliferation of digital cameras and camera phones, the large majority of people use only digital formats and platforms for their personal photography. In addition, the emergence of wearable cameras; for example, SenseCam [144] and Google Glass [46] have enabled users to capture events of everyday life without any interaction, thus creating, passively, large numbers of digital photos. Finally, seamless connectivity over the Internet and social media platforms has enabled sharing of digital photos publicly or with small groups of closely related users, such as friends and family.

People share their photos on an everyday basis in order to represent themselves, tell their story or look back at their old photos to reminisce about past events. In addition, people are interested in other peoples' photos in order to stay informed and to communicate with them. This trend is best depicted by an ever-increasing uptake of both sharing and observing photos over social media sharing platforms, such as Facebook and Instagram. However, there is a gap in the design and implementation of photo sharing services supporting sharing in small close-knit groups and visualisation from multiple sources.

Therefore, in order to create a photo sharing and visualisation application that supports small-group sharing from multiple photo sources, a novel social media sharing website was designed and built. The reason for designing an application for sharing between small groups of people was that in the literature [39] we found that there is a gap in designing new systems for the sharing and visualisation of photo streams captured from close groups such as friends. It was designed as a web-based interface with a photo sharing system aimed at small social networks, i.e. close friends and families. The platform utilises social and temporal metadata of photos to facilitate intuitive visualisation of multiple photo streams obtained from different sources. The literature review identified a lack of applications capable of concurrently showing multiple photo streams from different people. In addition, there has not been, to date, any investigation of the user experience related to this challenge. In order to fill this gap, we designed a photo sharing application so that users were able to view each other's photos simultaneously and synchronously. Our system for synchronous visualisation of multiple photo streams is unique not only because it shows multiple photo streams of the different people taken at the same time, same place or same time and different place but it also lets users compare their past photos as a visual story telling tool in a unique interface.

4.2 System design

The main aim of the initial system design was to respond to the research question regarding the values and requirements of sharing and visualisation of past photo streams with a small group of friends. Seamless sharing of photos between a small group of users and their synchronous visualisation was at the focus of the design process.

Firstly, a seamless sharing functionality is catered for. The system is designed as a web-based photo sharing platform, implemented as a web-browser application, in order to allow common internet users to share and visualise their photo streams.

Secondly, a feature of ordering photos according to the time and date they were taken was implemented. The reason for that was the relevance of photo stream's temporal order, as it has been the main criterion in organising and visualising personal and/or shared photo collections [30].

Therefore, this section describes two newly designed photo sharing interfaces. Single- and multiple-window slideshows were designed using two different spatial layouts in order to support enhanced presentation of multiple photo streams. This design works for historical photo collections of the users. For example, it enables the visualisation of up to four people's entire photo collections, each comprising thousands of photos, using the time stamps of each photo to place them on the parallel timelines of each photographer; this allows the user to browse up to four albums simultaneously in order to see what each of the users were doing at any time period in the past.

This design raises new questions about how fast, and with what novel transitions, slideshow format photo collections from multiple people can be played back. There may be large time gaps between photos in real-time and there may be little difference between similar photos taken in bursts, which may lead to a problem of inactivity and redundancy. These problems have been addressed by new algorithms to give a notion of time for event change, showing photos that have been taken in bursts faster by a proportional transition time or by calibrating the total slideshow time within a given time by a desired time transition feature and informing the event change via the event informer feature.

The layouts of the working process of the two implemented prototypes, illustrated in Figure 4.1, were designed to support the sharing and visualisation of multiple photo streams by performing the following steps:

1. Gather automatically all available contextual features from the Exif [88] header at the upload time (time/date metadata, social information).

2. Store photograph, date, time and social information such as photo owner, tags and location in the server database.

3. Sort uploaded photos by date and time of the taken photos.

4. User toggles between multiple-window slideshow and single-window slideshow.

5. User chooses who will be able to see their photos.

6. User selects the starting date/time point on the timelines.

7. User chooses one of the following options: proportional transition, desired time, event change informer and normal slideshow.

8. User plays the synchronised slideshow forwards or backwards in time.

9. Start the synchronised slideshow from chosen photo streams and present the information such as date, time, camera brand, owner of photo, tags and location beside the photo.

4.2.1 Single-window slideshow

The single-window slideshow comprises one slideshow window. The main contribution of the single-window slideshow is to show either the photo stream of one user or multiple photo streams of different users in one slideshow window. An example of how the single-window slideshow works can be seen in Figure 4.2. In this example, the four users are shown by a diamond, square, circle and triangle. Each user photo stream is shown over time. In the single-window slideshow, photos from multiple photo streams appear chronologically in the slideshow window, one by one.

On the interface of the single-window slideshow, there are four elements for setup: selection of people, timelines, transition types and control buttons. The other

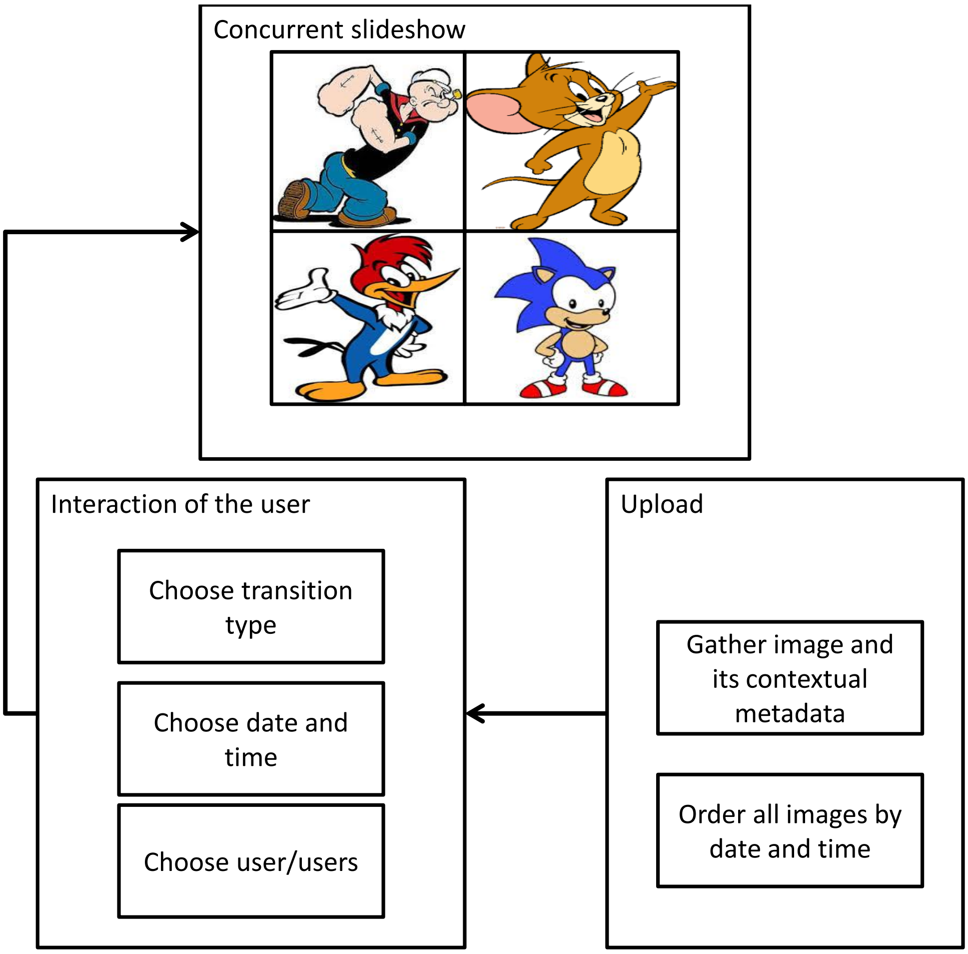

FIGURE 4.1: Slideshow process of single-window slideshow and multiple-window slideshow. After uploading the photos by the client, contextual metadata are stored in the database and the photos are ordered by time. The user, then, chooses the date/time, other users and transition type to view the slideshow. To try, follow this link: http://www.samzargham.com.

element on the interface is the information box, which is located on the right side of the interface and presents information such as date/time, location, name of the photographer and photo tags.

There are four drop-down menus on the top right side of the interface that let the user choose up to four people. There are six sliders as timelines of the interface, which are situated at the top left of the interface. The timelines enable users to set the starting point of the slideshow. Moreover, they can be used to narrow down the search for finding events based on the time that photos were taken. The timelines represent the year, month, day, hour, minute and second. Therefore, by choosing the date and time using the six timelines, the closest photos that were

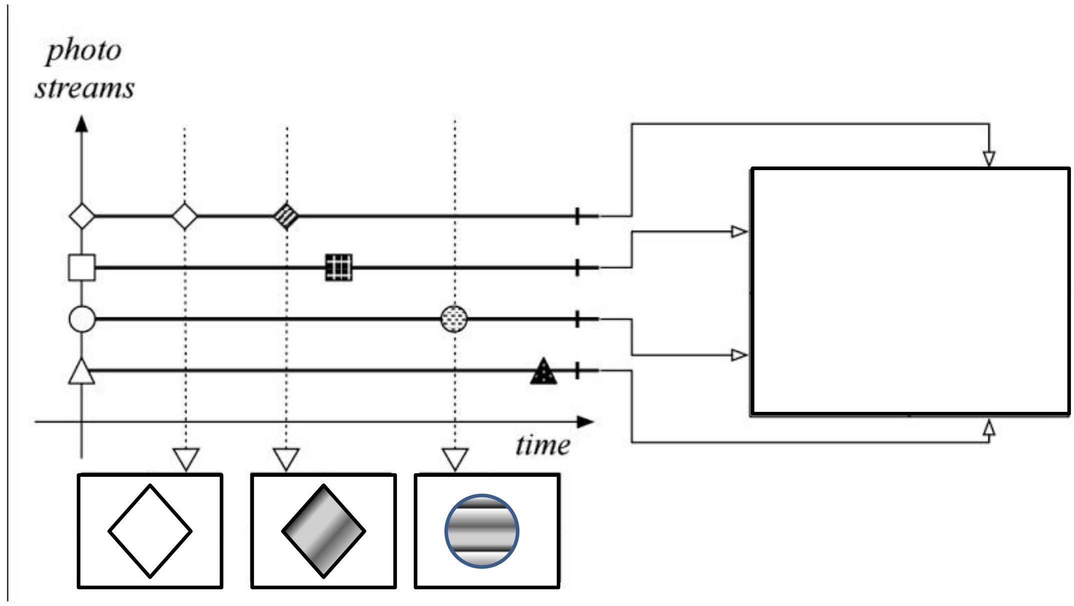

Figure 4.2: Example of the single-window slideshow.

taken by multiple users on the chosen date appear on the screen. The text-based date/time is shown on top of the slider to support the narrative.

There are radio buttons on the bottom left of the interface, which are designed to let the user choose the transition type between proportional transition time, desired time and event informer. The control buttons, which are situated below the slideshow window, comprise the following: play, play backward, skip forward, skip backward and pause.

After the user clicks on the play forward or backward button, photo streams of several friends or family members are shown chronologically in slideshow mode in one slideshow window. The user can pause the slideshow via the pause button to view a photo in more detail. Also, the user can see photos one by one using the skip-next button.

By clicking on the play button, the timelines disappear and, instead, the information bar appears on the screen; the control buttons stay on the screen. By pressing the pause button, the timeline comes back to the screen.

The size of the slideshow window depends on the size of the photo. Figure 4.3 illustrates the interface of the single-window slideshow.

FIGURE 4.3: Single-window slideshow interface.

4.2.2 Multiple-window slideshow

The multiple-window slideshow (see Figure 4.4) was designed and implemented to enable users to view multiple photo streams concurrently for up to four adjacent slideshow windows. Each window is dedicated to an individual. The multiple-window slideshow was designed to provide a new sharing practice using a richer layout. In the multiple-window slideshow, unlike the single-window slideshow, instead of showing photo stream of multiple people in one slideshow window, users have the opportunity to view their photo streams concurrently in up to four slideshow windows; each window relates to one user so that it can potentially increase the awareness of other people who shared their photos. To clarify, when a new photo from a chronological photo streams arrives, it will be shown on the slideshow window of the person who uploaded that photo. An example of the process of visualisation of photo streams in a multiple-window slideshow can be seen in Figure 4.5. This example shows four photo streams from four different people over time and how the photos of the streams are placed in the slideshow windows.

FIGURE 4.4: Multiple-window slideshow interface.

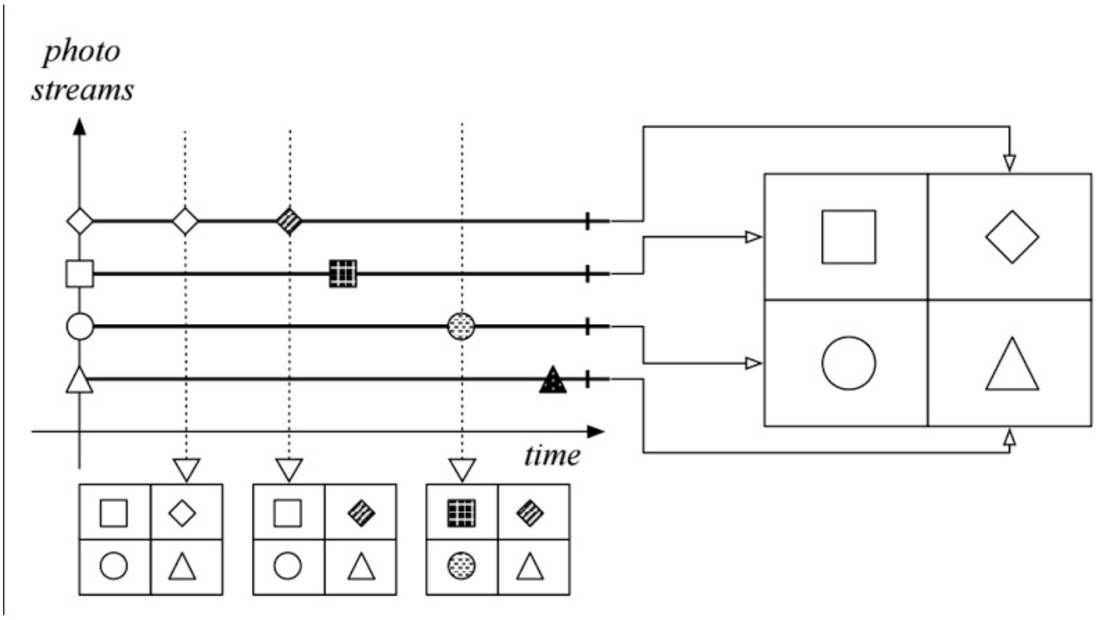

FIGURE 4.5: Example of how the multiple-window slideshow works.

The multiple-window slideshow interface supports the presentation of up to four multiple photo streams. For two people, the interface shows two symmetrical slideshow windows. For three people, one slideshow is situated next to two slideshow windows, which are connected to each other vertically. The size of the slideshow windows are four fixed-size photos with a width and height of 300 pixels. The photos are stretched to fit into a square. Figure 4.6 illustrates the position of the slideshow windows in different cases. Other features such as control buttons and the information bar appearance and disappearance are the same as for the single-window slideshow.

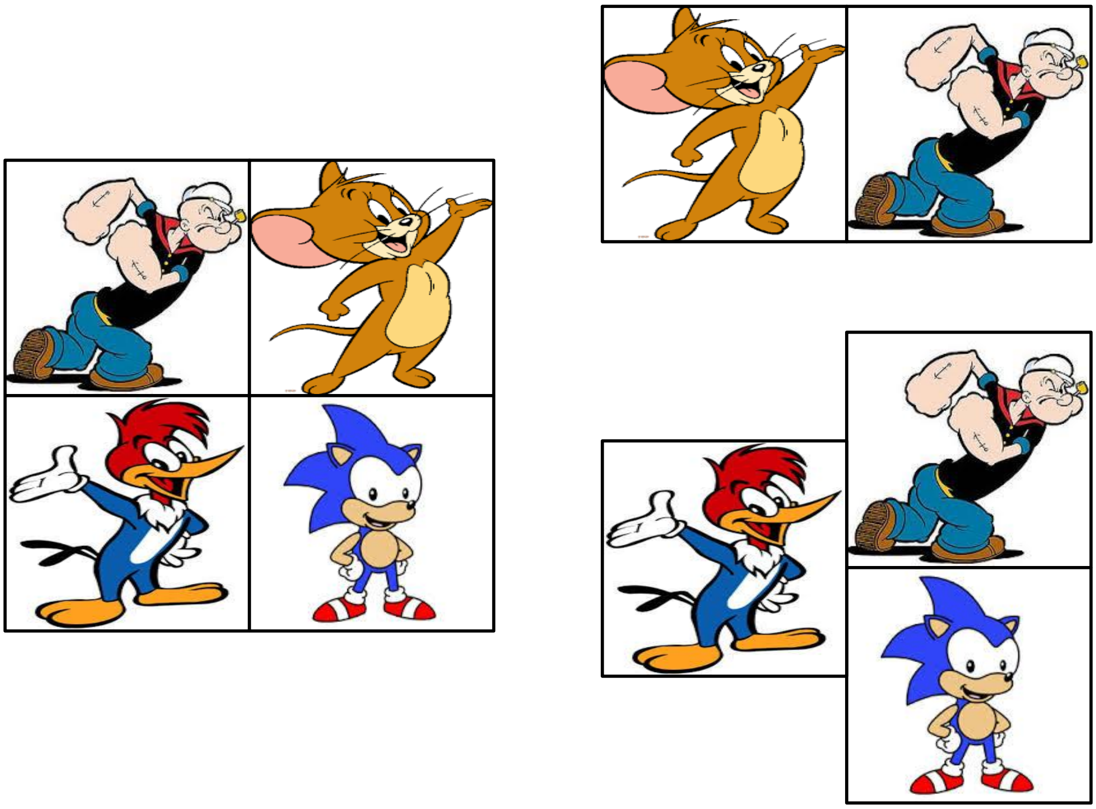

FIGURE 4.6: Multiple-window slideshow positions with two, three and four users.

As described in the literature review, taking photos has become increasingly popular as a means of communication. Therefore, the hypothesis was that a multiple-window slideshow can connect people better in the collective sharing of individual experiences via a parallel presentation of their corresponding photo archives. All the setting elements in this interface were the same as for the single-window slideshow.

4.2.3 Upload page

The first page of the system interface is the upload page. In this page, the user uploads photos using the website upload function. The user enters her/his user name, tags the photos and uploads multiple photos. Information such as the actual photo, tags, user name, location tags, date and time are stored in the system database. It should be mentioned that the person who uploads the photos is considered to be their owner. After uploading photos, the newly uploaded photos, alongside the older uploaded ones, appear on the screen. From the upload page, the user selects the use of a single- or multiple-window slideshow for visualisation of multiple photo streams. Figure 4.7 shows the upload page interface.

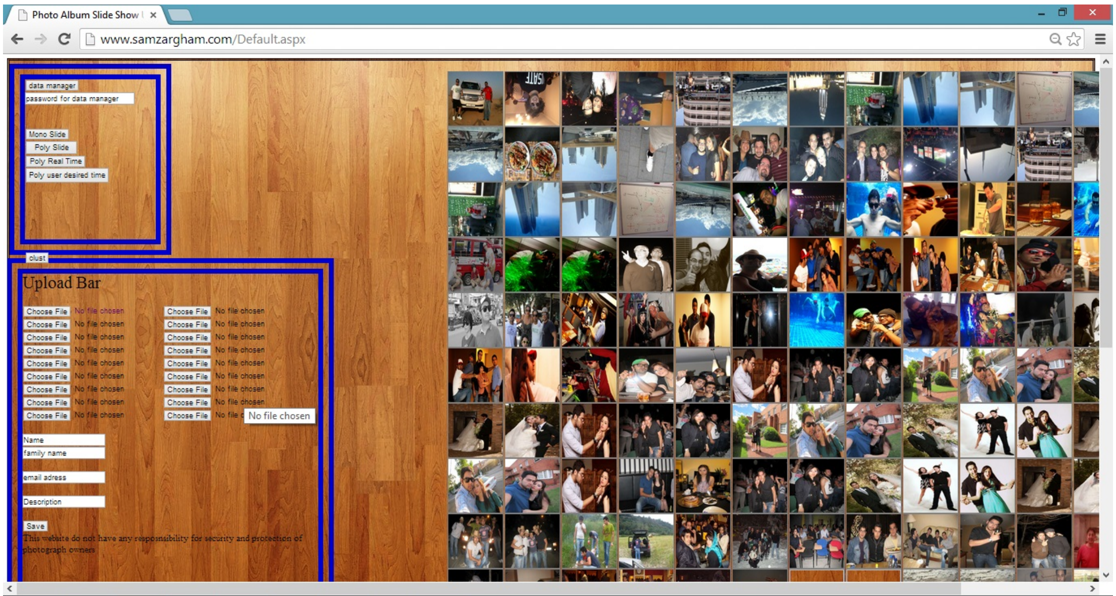

FIGURE 4.7: Upload page of the system as a conventional depiction of a photo collection.

4.2.4 Transitions

Transition functionalities such as normal slideshow, proportional transition mode, desired time and event change informer have been integrated into single/multiple window slideshow applications as follows:

- The normal slideshow transition is based on the traditional slideshow used on Windows machines, namely two seconds per slide.

- The proportional transition mode is designed to give the notion of time difference between slideshow intervals. This implies that the greater the time offset between photos, the greater the delay that is used to reflect slideshow transitions. The scale of the delay can be controlled by a slider, which is placed on the interface below the radio buttons for selecting the transition type. The slider appears if proportional transition is chosen. If the transition is too long, the user has the option to skip the slideshow by clicking on the skip-next button.

- The desired time feature was introduced to let the user choose the overall timespan of slideshow presentation. The speed of transition in this case is adjusted by the desired time duration that the user chooses to review all photo streams. By choosing the desired time from the radio buttons, a text box appears under the radio buttons to let the user choose the total slideshow time.

- The event change informer is intended to inform the user when an event based on temporal clustering is changed, by displaying the message: "Event Changed". This is consistent with similar works in the literature based on clustering [98].

4.3 Implementation

4.3.1 System architecture

The system is implemented as a client-server model. The architecture of this application is sketched in Figure 4.8 and is a classical n-layer application. The four layers are the data, application, presentation and client layer.

A client accesses the system by a web browser, which is in the client layer. The presentation layer contains the user interface of the system. The upload page and single- and multiple-window slideshow interface are all in the presentation layer (interface of the system). This layer has been coded with HTML in ASP.net workspace.

Photos and information about them is stored in the data layer. In other words, this layer contains the database of the system, which was created on a Microsoft SQL server.

In the application layer, there is a set of components for mediating the presentation layer. This means that the core and logic of the application is in this layer. Upload management, search, metadata Exif extractor, different transitions and slideshow logic, and database management were coded by C# in this layer.

4.3.2 Structure of the database

The structure of the database comprised four tables. The table names were User, Photo, Group and Photo Exif. In the User table, information about the user, such as first name, last name and the user name, is kept. The User table was connected with the Group table, which kept the information about the group name and the people who join that group. The Photo table included the photo name and information such as tags, comments and description, and it was connected to the User table. The Photo Exif table included some information about the Exif header file such as the date and time the photo was captured, and the location tags. The Photo table was connected to the Photo Exif table. Figure 4.9 illustrates the database tables and their relations.

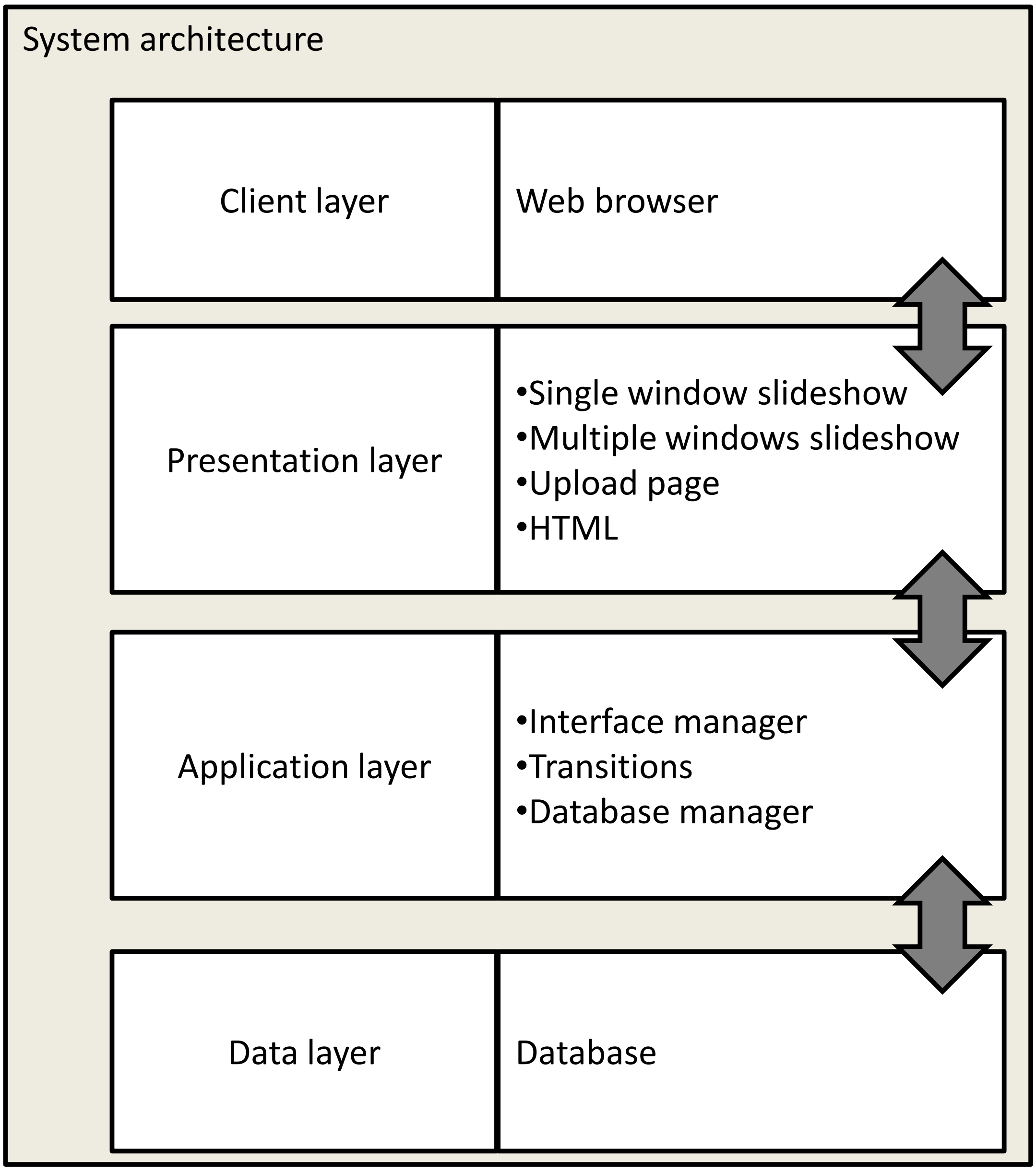

Figure 4.8: Architecture of the system.

4.3.3 Transitions

There were four transition modes that were applied to the slideshow system: normal slideshow, proportional slideshow, desired time and event informer. The implementation of each transition is described below.

Normal slideshow comprised the transitions in two seconds but the proportional transition mode brought the notion of time between slideshow transitions as described in the design part. The time difference between two consecutive photos

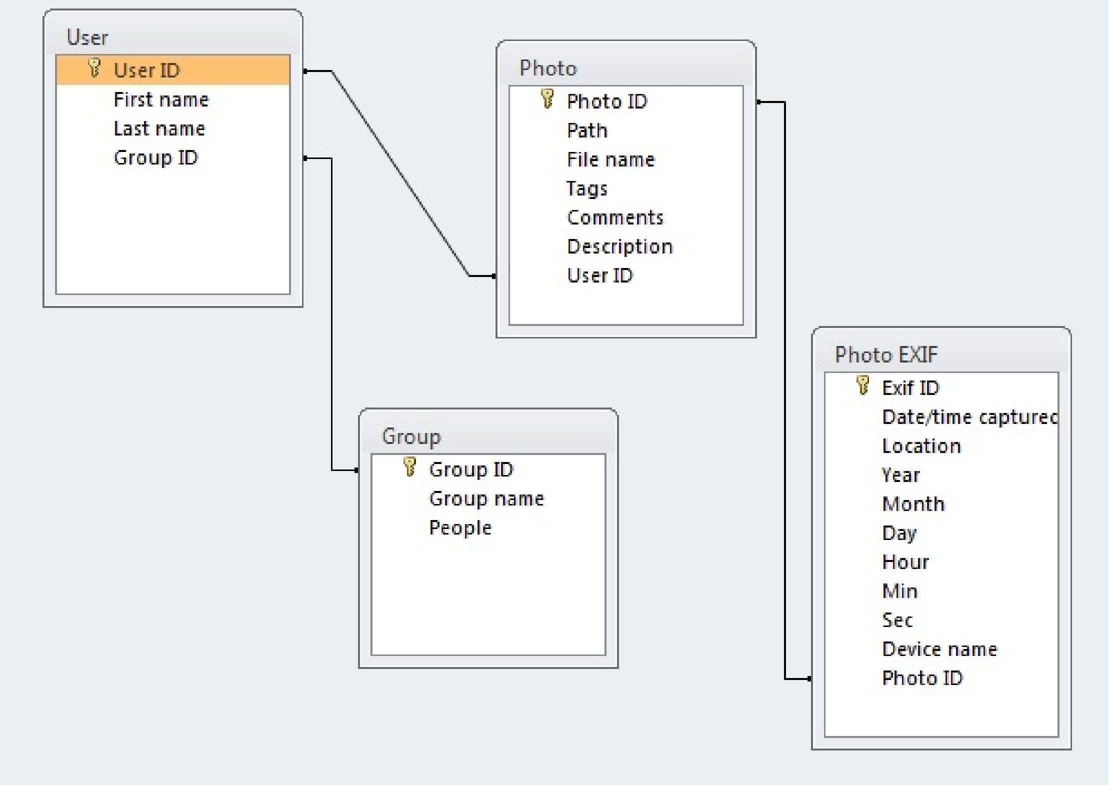

FIGURE 4.9: Structure of the system database.

(Δ_t) is first calculated and then divided by a coefficient (k), which can be controlled from a slider on the interface to generate a new transition time (T_i), where i is the photo number in the sorted photo collections between slides. The time is obtained by converting year, month, date, hour, minute of the taken photos into seconds. Equation 4.1 illustrates the calculation of the transition interval.

$$T_i = \frac{\Delta_t}{K} \tag{4.1}$$

In the user desired time mode, the user chooses the length of the slideshow presentation. Afterwards, the transition between each slide (T_i), where i is the photo number, is adjusted by dividing the desired chosen time (D_t) to the number of photos (N). Equation 4.2 shows the transition calculation formula.

$$T_i = \frac{D_t}{N} \tag{4.2}$$

The event change informer has been adopted from Phototoc [98] to the cluster photo stream based on temporal features. The goal of this time-based clustering algorithm is to detect the noticeable gaps of time between consecutive photos. A cluster is then created from those gaps and is considered to be an event change. In this method, the local average (T_{avg}) of temporally nearby gaps is compared to the gap (Δ_t) and when Δ_t is much bigger than T_{avg}, a new cluster is created as a new event. Equation 4.3 illustrates the clustering condition technique.

$$\Delta_i > T_{avg} = k + \frac{\sum_{i=1}^{n-1} \Delta_{ti}}{N} \tag{4.3}$$

where N is the number of photos in photo streams, k is a suitable threshold (set equal to five experimentally) and i indicates the number of photo in the sorted photo collection.

4.4 Summary

In this chapter, a web application for sharing and visualisation of multiple photo streams was proposed. The application comprised an upload page where users were able to upload their photo streams to the website. The latest photos were shown on this page. From the upload page, the user was able to go to a single- or multiple-window slideshow page. The main goal of the single-window slideshow was to show either the photo stream of one user or multiple photo streams of different users in one slideshow window. In the multiple-window slideshow page, the photo streams from different users were shown concurrently in slideshow mode. In this page, there were up to four slideshow windows, each dedicated to a different user. The interactive application enabling the user to choose the start date of the slideshow by six sliders was designed. Furthermore, the user could choose the type of the transitions which were normal, proportional, desired time and event informer; each could bring different experiences for the user. In the next chapter, the user experience study applied in this web-based application will be presented.

Chapter 5

User experience study of multiple photo stream visualisation

5.1 Introduction

This chapter presents a photo streaming service designed for visualisation and sharing of multiple photo streams. Moreover, it aims to identify the weak points of the system in order to redesign and apply new features into future systems. Therefore, this section covers a study of the current practice in digital photography. It also includes findings about the use of the proposed interfaces, including a single-window slideshow for showing multiple photo streams and a multiple-window slideshow for showing multiple photo streams from up to four people simultaneously on one page. Furthermore, participant experiences of the transition modes designed for the system were evaluated.

The study approach was a qualitative study. Semi-structured interviews were conducted alongside observations in order to gain a holistic understanding of the photographic practices of small groups and the user experience of the system.

5.2 Participants and tasks

To investigate the current practice of photography and the use of the system, three groups were recruited to the study: close friends, friends and family.

The first group was five close friends who were asked to upload as many photos as they wanted to share with their close friends onto the system. They were advised to share all the digital photos they had, but they were also free to create a selection if they wanted to. The reason to encourage this group to upload as many photos as possible was to evaluate the system in normal behaviour of participants as in reality people do not preset the amount of their uploaded photos in the system. They were also asked to upload their new photos onto the system whenever they took them.

It was planned to determine the impact of this system on sharing archived photos that were taken a long time ago (personal archive) and those taken recently among close friends. The user ages were in the range 23 to 30 years old with mean of 26.6 years and standard deviation of 2.7 years.

They were all graduates from different departments of the University of Surrey and they all knew each other from their time at university. The group was comprised of two females and three males. The participants in this group were recruited via an email asking for volunteers who would like to share their photos with their close friends. Once they agreed to take part in the study, the participants were asked to read and sign a consent form. Participants were given a 4GB memory stick upon completing the last interview. Information about Group 1 participants is given in Table 5.1; names are not the real participants' names.

The second group comprised ten friends who were asked to upload their personal photo archives as much as they were able and to share them with their friends. Participants in this group were not such close friends as the first group participants.

Table 5.1: Group 1 participants

No.	Name	Number of photos uploaded	Gender
P1	Arminda	3436	F
P2	Sinem	2735	F
P3	Lee	591	M
P4	Anthony	252	M
P5	Glen	2116	M

Members of this group were also asked to create photo diaries using photos taken over a 48-hour period. The purpose of this task was to create a dataset of photo diaries to see whether this application can be applied as a storytelling tool.

All participants were research students or researchers from different departments of the University of Surrey. The group was comprised of six males and four females. The user ages were in the range 25 to 32 years old with mean of 28.1 years and standard deviation of 1.9 years.

The participants in this group were recruited via an email to research students in the Electronics Department who then invited their friends to join the study. They were asked if they would like to share their photos with friends. Once they agreed, they read and signed a consent form. Information about Group 2 participants is given in Table 5.2; names are not the real participants' names.

Table 5.2: Group 2 participants

No.	Name	Number of photos uploaded	Gender
P6	Soh	150	M
P7	Ala	236	F
P8	Mehr	50	M
P9	Martin	408	M
P10	Ana	792	F
P11	Amir	94	M
P12	Far	571	F
P13	Pour	89	M
P14	Had	141	M
P15	Lina	1002	F

The third group was comprised of five members of an extended family. Three members of the family (the father, mother and daughter) lived in the United Kingdom; the grandmother lived in another European country and the niece lived in another continent. This created a good opportunity to evaluate the platform for a family who were living together in part and, on the other hand, were extended. The family was asked to create a 48-hour story of their life via photos and to upload them on the website in order to evaluate how an extended family uses the application. They were also asked to upload their past photos if they so wished. The group was comprised of four females and one male. The participant ages were in the range 5 to 65 years old with mean of 32 years and standard deviation of 23 years. The family was suggested by a friend of a study conductor. Once they agreed to participate in the study, they read and signed the consent form. Information about Group 3 participants is given in Table 5.3; names are not the real participants' names.

Table 5.3: Group 3 participants

No.	Name	Number of photos uploaded	Gender
F1	John	620	M
F2	Helen	516	F
F3	Catherine	29	F
F4	Elizabeth	18	F
F5	Nina	707	F

Table 5.4 summarises participants in all three groups.

Table 5.4: Summary of participants' information

	Group 1	Group 2	Group 3
Time span of photos	6 years	5 years	72 hours
Relation	Close Friend	Friend	Family
Age range	23-30	25-32	5-65
Number of participants	5	10	5

5.3 Procedure

After participants uploaded their photos, they were asked to use the system for two weeks. The interface was explained to them when they signed the consent form. Meanwhile, they were able to upload new photos. Group 2 participants, whose task was to create photo diaries, were asked to start the study when we sent them a text message to start taking photos.

After using the system, participants were invited individually for interview, except for participants in Group 3, who were interviewed together. The interviews took place either in the participants' houses or in a meeting room situated in the Department of Electronics at the University of Surrey. The interview session had three phases.

As can be seen in the interview guidance A.1, in Phase 1, participants were asked questions about their current practice of photography; this phase was planned to take about 20 minutes, on average. In Phase 2, phase participants were asked to interact with the system for about 20 minutes and to talk about it. Their interaction with the system was also observed. In Phase 3, participants were asked questions and discussed their ideas about the system; this phase was planned to take about 45 minutes, on average. All interview sessions were video recorded for data analysis. The aim of deploying the system into 20 users was:

- To identify personal photography practice and tools.
- To describe sharing in photography practice and the tools in current use.
- To understand the management process of photo collections.
- To understand the use, usability, problems and interest in the single-window slideshow interface.
- To understand the use, usability, problems and interest in the multiple-window slideshow interface.

- To understand the use, usability, problems and interest in different transitions.

5.4 Data analysis

Theme analysis [20] was used for analysing the qualitative data from the interviews, undertaken in several stages. The first stage of the analysis was to listen to all the interviews. The next step was to transcribe the interviews. The transcribed data were then reformatted in the order of all answers by all participants to each question in the interview schedule. In other words, for question one, the answers from participants P1 to P5 in Group 1 were listed and then the same procedure was followed for question two from the interview schedule. Each group had its own reformatted transcription. The transcriptions were read once and then reread carefully. Once the reading was complete, several passes were made through the data to code the data and define themes and categories.

5.5 Results

This section deals with the results of the qualitative and quantitative analysis. Firstly, we started with the current practice of participant photography and, then, the user experiences of the participants during photography (in Groups 2 and 3) and within the system (all groups) were described.

5.5.1 Current photography practice

Organisation

Across all three groups, the main action taken for management of photos was to create folders on their computers; indeed, all the participants were using folder-based management. They were asked about how they label their folders. Their primary technique for organising photos was time, as found in Miller et al. [43]. They also mentioned the following four methods for organising their photos:

- Time
- Event name
- Location
- Capture device name

Fourteen out of twenty (70%) participants did not create sub-folders in the main folders and they said that they left their photo collection folders with their names on the photo folder. Nevertheless, six out of twenty (30%) participants used sub-folders for clearer organisation. P13, a participant from Group 2, said:

> "I create a folder and give it a name. Then, copy/paste the pictures from my camera and rarely look at them again."

There were just three MacBook users (F1, P14, P3), who claimed that, alongside creating folders on their external hard drive, they use a photo management tool, iPhoto application in this case. They claimed that iPhoto displays their photos chronologically and they do not need to manage their photos on their MacBook. The Windows and Linux users did not use photo management applications.

One way of storing photo collections was to use internal/external hard drives. However, two of the participants mentioned online Cloud services for storing their photos. P5, a participant from Group 1, said that he kept most of his photos on Facebook. He said that he set the 'privacy' parameter to 'private' for those photos he did not want to show to the public. He also stated that Facebook shows albums chronologically by the time of the upload, which made it easier for him to search collections by name and upload time. The problem he mentioned about Facebook was that the time of capture and the time of upload are different. For example, he uploaded a folder from two years before he started his studies, but it appeared on the current date. F1, the father in the family group, used a premium Flickr account to store his personal and family valuable photos.

Sharing

All participants stated that they share their digital photos with friends and family. There were two main reasons for sharing photos:

1. Sharing their personal photos with friends or family for visual communication and awareness.
2. Sharing photos of events with the people who participated in that event.

The sharing platforms that participants mentioned were physical memory, email, Messenger, MMS, Dropbox, Flickr and Facebook. Email and MMS were used to share small numbers of photos while Messenger, Dropbox, Flickr, and Facebook were used to share both small and large numbers of photos. Thirteen out of twenty (65%) participants claimed that their main photo sharing platform was Facebook. Therefore, the most common way to share photos between participants was Facebook. They said that they upload photos on Facebook and tag their friends. When they tag their friends, then their friends will have those photos in their account. P3 said:

> "Whenever we went out, P1 took most of the photos. She tagged me on Facebook and this is the way I get my photos. The way that I share my photos with my parents is Facebook. I share them on Facebook and my sister shows my photos to them."

Photo acquisition

All participants in this study had at least one digital capture device. The family group members had a digital camera, which was shared between the mother and father of the family. They each also had a camera phone; the daughter had her own point-and-shoot camera, the grandmother had recently started using a digital camera and the niece had an SLR as well as a point-and-shoot camera. All members of this group said that the point-and-shoot camera is the main device for taking photos.

In the family group, participants considered that all photos belong to the entire family and that they find photos based on the device rather than the photographer. F1 said:

> "The pictures of all cameras belong to the family. It is not important who took the pictures. Sometimes we are too lazy to manage the pictures and we leave it as it is....Because all pictures belong to the family, sometimes I want to filter our pictures based on the capture devices."

In Group 2, eight out of ten participants had a digital camera, while nine participants had a camera phone. P7, a member of Group 2, like most of the other participants in this group, had a camera phone alongside her digital camera. She said:

> "A camera phone is more accessible for emergency moments. I use my camera phone when I do not have my camera with me but normally I take photos with my digital camera to have better quality photos."

In Group 1, all five participants had digital cameras and their digital cameras were their main device for taking photos. In addition, three out of five members had a camera phone. P3 said:

> "I have an iPhone 3G and sometimes I take photos with my iPhone but my main capture device is my Cannon camera."

Sixteen out of twenty participants claimed that a digital camera is the main device for taking photos, and four out of twenty participants said that a camera phone is their main device for taking photos. Another source of personal photo acquisition was sharing platforms such as social network websites. P5, a member of Group 1, said:

> "When we go out, I am not the person who takes photos; my friends usually take the photos and share them with me via Facebook."

There were many passive photographers among the participants. A passive photographer is a person who relies on other people to take photos and, after that, collects the photos that were taken via social networks, email, remote sharing applications and physical drives. In the family group, the mother of the family (F2) took fewer photos than the father (F1) and the father was the one who took the most photos in the family. The father uploaded the photos onto Flickr and then sent the link to other members of the family.

In Group 1, all participants except P1 said that most of their photos were taken by friends and then shared on Facebook; however, they also had many photos from their own cameras. P1 had her digital camera with her everywhere. P1 said:

> "Normally I am the person who takes most of the photos, but I ask other photographers to share their photos with me. I want to see more photos."

In Group 2, seven out of the ten participants were passive photographers; they said that most of the time their friends take photos and then they collect them from photo sharing platforms. P9 said:

> "I bring my camera with me to special events but still most of the times I am too busy to take enough photos. My friends share the photos with me on Facebook or Dropbox."

Therefore, multiple photo sources such as different capture devices and shared photos on sharing platforms such as social networks exist. Thus, in the future, multiple photo streams from different sources should be managed, otherwise organising photos from multiple sources will be a cumbersome task. 75% (five out of twenty) of the participants claimed that photos from sharing platforms are their primary photo source and just 15% said that their main source of photos is their own camera.

5.5.2 User experience

Photo sources in the study

In this study, participants used different photo sources to upload their photos into the system. In Group 1, participants uploaded their past photos from 2005 to 2011. The average uploaded photos by each participant was 1826 with the standard deviation of 1369. The capture device most frequently used for taking those photos was a normal digital camera. The photos uploaded by P1 and P5 were from their digital camera while those uploaded by P2, P3 and P4 were from both a digital camera and a camera phone. However, they said that most of the shared photos were taken by a normal camera as photos taken by their camera phones were of low quality.

In Group 2, participants uploaded their photos from 2005 to 2011. The average uploaded photos for each participant was 353 with the standard deviation of 332. However, most of the photos were for the 48-hour photo diaries. For eight out of the ten participants, the photos taken before the photo diaries were from digital cameras whereas the remaining two participants said that they used both camera phones and digital cameras.

For the photo diary photos, six out of the ten participants used just camera phones, two participants used just digital cameras and two participants used a mixture of digital cameras and camera phones.

In Group 3, the average uploaded photos by each participant was 378 with standard deviation of 330. All participants used a digital camera for their photo diaries. F1 used a camera phone alongside a point-and-shoot camera and F5 used an SLR camera alongside a point-and-shoot camera. No-one in this group uploaded any photos from their past and they mentioned that their historical photos were managed based on the capture device rather than the photographer. Therefore, at this stage, it was apparent that a weak point of our application is the absence of a feature to show photos based on the capture device in addition to showing photos based on the photographer.

Past photo experience

Participants in Group 1 shared most of the photos they had taken previously. However, their perspective about this application was different from that of the participants in Groups 2 and 3. The participants in Group 1 considered this application as a tool that shows past photographic events from multiple friends concurrently. They did not have any intention in creating photo diaries and the photos presented in the application were captured by the current photography practices of the participants.

Participant experience in this group was based on three elements: memory, awareness and completeness. The participants said that this application created a flashback to see what happened to them individually in past. They viewed the photos that had been unviewed for a long time and they remembered their past. P1 said:

> "Wow, I almost forgot these photos."

The main feature the participants mentioned was knowing what they were doing in the past while their friends were doing something else at the same time. For example, while viewing the photos, P2 and P3 noticed that, while P2 had been at a family party, P3 had been at a basketball match. Another interesting example was when P5 and P1 were viewing the photos; they both realised that there was a moment when they were both on a university-organised ski trip but they did not know that they were both there. P5 was shocked when he saw the photos of P1 also at the skiing event that had taken place before they knew each other and said:

> "I like this feature that we can compare our past photos...I should tell P1 we were both there."

Completeness was another factor mentioned by the participants. They believed that the system provided a better understanding of an event when they were taking photos collectively. For example, P1 and P3 took photos when they were in Spain for holidays and, after that, they liked to compare their different perspectives of the same event using our system.

P1 and P2, were in Spain for Christmas holidays. The completeness of an event through views from different photographers surprised them. P2 said:

> "We were together in the whole trip. Therefore, combination of these two photo streams let us not miss any scene and face."

Figure 5.1 shows some photo examples Group 1 participants provided for this study.

Photo diary experience

The participants in Groups 2 and 3 had the experience of creating their own photo diaries. All participants in these two groups preferred to create a new photo diary rather than upload photos from their past. The reason for this in Group 2 was that they were not very close friends and, therefore, not all of them wanted to share their previous photos with each other. In the family group, the participants said that their past photos were taken by a single group member and that they classified their photos by the photographic device rather than the photographer.

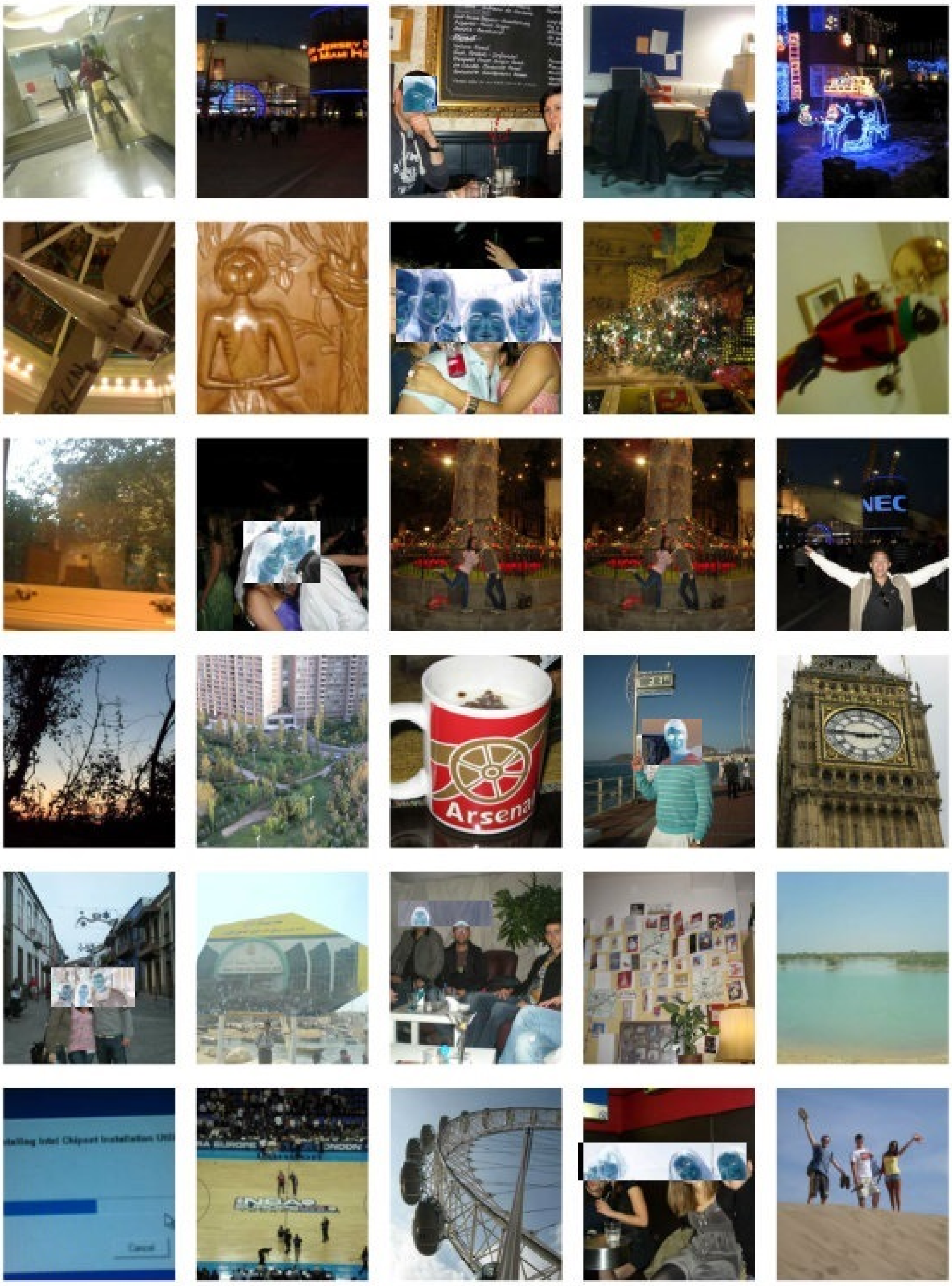

FIGURE 5.1: Example of photos taken by Group 1 participants.

By creating photo diaries, the participants in Groups 2 and 3 experienced nice moments during dataset creation and subsequent viewing, as now described.

At the time of capture Most of the participants in our study seemed to develop a sense that the photos taken were part of a shared collection that would be presented later as a group-photo story package in our system. During the study, they were sometimes alone and sometimes together as a group.

As an example of the times when they were alone, P9 started to take a photo from our application interface with thumbs up and then from the Facebook webpage with thumbs down to start his photo diaries story. After that, he captured all his activities from waking up in the morning to going to the gym and then a birthday party, where he joined other participants, at night.

Some participants sometimes took photos collectively. In some of the events, participants were observed and their behaviours were noted. The collective nature of photography sometimes led to a discussion and planning about who should take what photo. In Group 2, six of the participants were at a birthday party where they tried to assign tasks to each photographer such as to take photos from different angles or distances from the birthday cake. In Group 1, while F1 was driving his car with the family members, he set his camera timer to take photos from the front window of the car. Meanwhile, F2 and F3 took photos of the inside of the car and the outside corners. There were moments when participants were in the same location but they did not discuss or plan photo taking and they just took photos of their own favourite targets; sometimes the targets were similar without any planning. In Group 2, some of the participants focussed on taking photos of foods without any pre-planned action.

In Group 3, when the grandparent of the family was leaving the United Kingdom from the airport, F1 and F2 took photos of that moment.

The collective nature of photography also created playful moments for the participants. They continuously took photos of each other's faces in serious and awkward moments. P6 acted as though the camera was a laser gun and he was trying to find and shoot a target.

Figure 5.2 illustrates some example photos that Group 2 participants took during the study; photos from the family group participants are shown in Figure 5.3.

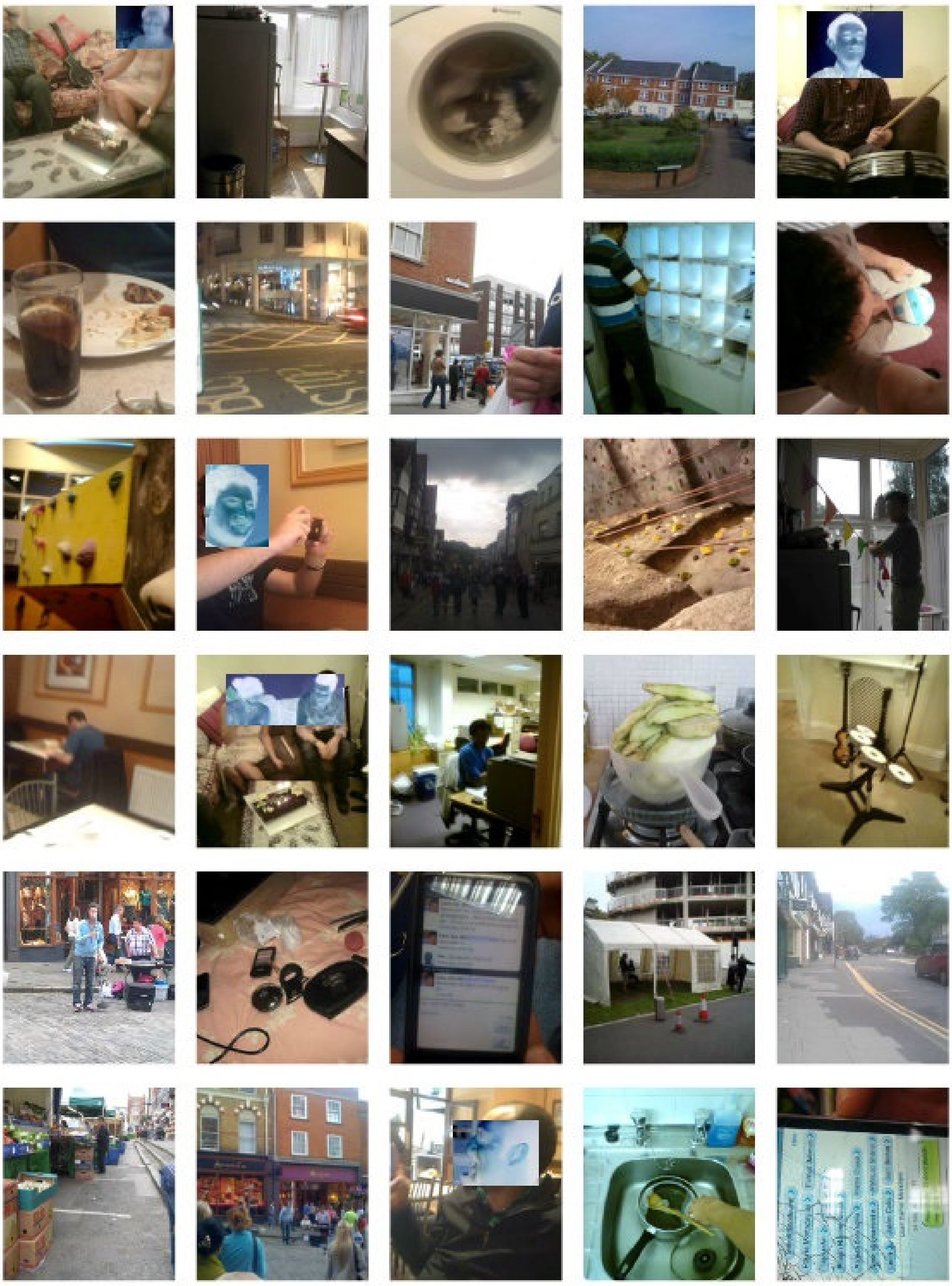

FIGURE 5.2: Example of Group 2 photos.

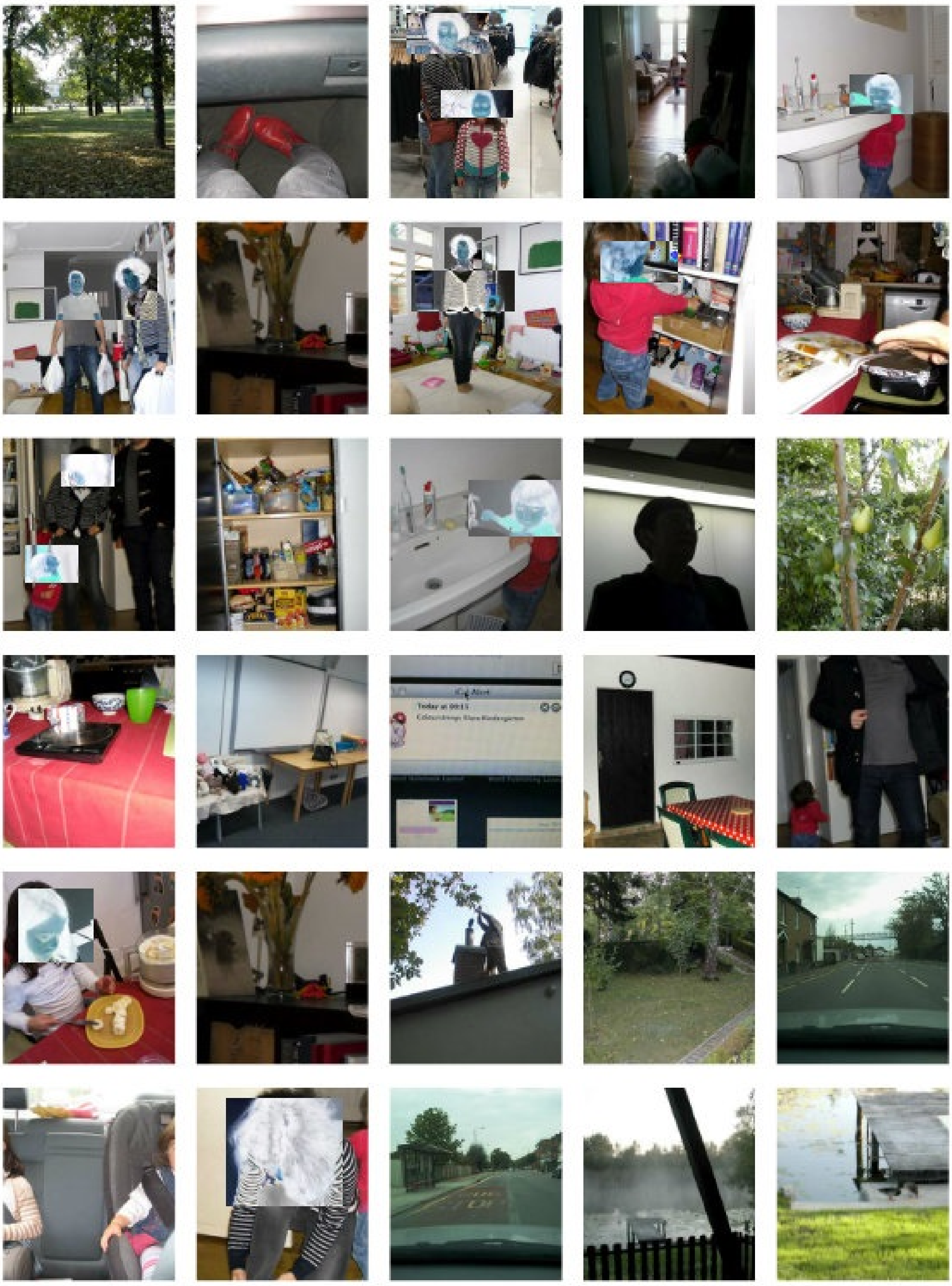

FIGURE 5.3: Example of family group photos.

During viewing Participants in Groups 2 and 3 all agreed that they had a good experience while they were viewing the photos using a single- or a multiple- window slideshow. They all mentioned that the chronological synchronous visualisation characteristic of the system brought them a sense of awareness of what others were doing while they were doing something else. P13 said:

> "It was like a movie from different directors. I could see different movies about two days of our lives with different story lines at the same time."

P11, a member of Group 2, also said:

> "I can follow the story of our lives. Other members were drinking coffee in town centre of Guildford after lunchtime and then I could see how each of them went home while I was sitting on my sofa and taking photos of my washing machine."

F1, a member of the family group, said:

> "I like it when I see my mother's photos before travelling here and compare it with our photos."

In addition, the participants were able to see the photos they took collectively. Some of those photos showed different perspectives of the photographers and some others had been discussed and planned before being taken. This means that their photo collections, when they were together, became more complete. P10, a member of Group 2, said:

> "The website showed us all the photos of the birthday party event in one place from different cameras. It is cool to see them all in one place."

F2, a member of Group 1, said:

> "It is fantastic that all of our photos are here. It normally takes ages to get photos of others after an event or normally they forget to share them. Now, I have access to all of them."

User experience of single-window slideshow

Collocated experience The main contribution of the single-window slideshow was that it showed one or different users' photos in one slideshow window. The results showed that the single-window slideshow surprised people when the streams were from the same time and place (collocated). After viewing the photos, 100% of the participants believed that viewing photo streams taken at the same time and place by a single-window slideshow was satisfying. The reasons were completeness of event and discovering photographic perspectives of their friends. The value in the ability to share a collocated experience in a single-window slideshow was the completeness of events.

Remote experience Unlike the collocated experience, the results showed that the single-window slideshow did not fully satisfy the participants when the streams were from the same time but different events (remote experience) as much as for collocated experiences. This study showed that although the participants liked to know what happened to others while they were doing something else in a different place and at the same time, the appearance of the unrelated photo in the single-window slideshow changed the mood of the participants. 90% of the participants believed that changing from the collocated state to the remote state was intrusive. However, they never denied an interest in having awareness of the activities of other members.

P4, a member of Group 1, was viewing the photo streams of two other participants (P3 and P1) when they were in a sunny Canary island and suddenly a photo from P5's stream, which was a photo of a snowy road in London, appeared. He said:

> "There is a problem with single-window slideshow. I like to know what P5 was doing in London, for instance, when we were in the Canary islands for the New Year but it is really weird when a photo from another scene breaks this."

In another case, P8, a member of Group 2, was in London while some other members were at the birthday party of P7; P7 said that she was viewing her birthday photos taken by different people but suddenly a photo of a TV taken by P8 appeared and, therefore, she found this experience discouraging. F2 and P5 were the only participants who found the single-window slideshow in remote experience very pleasant and promising.

Asymmetric transition Asymmetric transition occurred in the single-window slideshow when the numbers of photos from some participants were much larger than those from other participants. In other words, the problem occurred when one person took many photos of an event and other users did not take any photos at a similar time. Therefore, photos from other participants appeared on the screen with a delay.

The benefit of the single-window slideshow was that it provided a sense of awareness and completeness between participants from their past photos in a collocated and remote experience. However, the probability of a comparison between events was low, creating Asymmetric transition so that the became boring by showing one photo stream only; this happened mostly in Group 1 because these participants uploaded their past photos only and did not create new photo diaries during the fixed time of the study. Therefore, the number of photos taken at the same time was lower for Group 1 than for Group 2 and 3 participants, with a correspondingly lower collocated and remote experience.

P1, P3, P4 and P5, all members of Group 1, commented that for a year there were only photos from P2. They believed that it was fine to know what others did in their past. However, the stream was too long and discouraging. Moreover, they stated that there were many photos from others that they did not have any feeling about and did not like to view. However, they still had an interest in viewing their own old photos. P3 said:

> "There were around 100 photos from P1 with her friends; I am interested in viewing her pictures but not all of them."

User experience of multiple-window slideshow

Collocated experience In the multiple-window slideshow, photos were shown concurrently in up to four slideshow windows and each window was for a single person. The same as for the single-window slideshow, the multiple-window slideshow was good for viewing collocated experiences and events were more completely when the photos were from the same time and event. An example of a collocated experience in a multiple-window slideshow can be seen in Figure 5.4. F1 said:

> "This interface showed the moment that I was taking the photos from the outside of the car and my daughter was taking photos from inside the car in a collage shape that I really liked."

This study showed that the only advantage of the multiple-window slideshow for collocated experiences was that it was easier for participants to understand who took the photos from each slideshow window rather than reading the names. P4 said:

> "In this, I can easily distinguish who took the picture without looking at the names on the screen."

F4, the grandmother of the family, who was the oldest user, said that she liked the multiple-window slideshow because there were more photos on the screen and she could see more photos of an event at a time.

FIGURE 5.4: Sample of collocated experience in a multiple-window slideshow.

Remote experience We found that in the single-window slideshow, when a photo appeared from the same time but different event (remote experience), it was not pleasant from the users' perspective. However, this weak point in the single-window slideshow was an advantage for the multiple-window slideshow because participants could see up to four photos taken at different events at the same time in one layout. An example of a remote experience in a multiple-window slideshow can be seen in Figure 5.5. During viewing the photo streams in a multiple-window slideshow, P4 said about the moment when he was on the Canary island and P5 was in London:

> "I can compare better now, this one is much better than the one before (single-window slideshow)."

Figure 5.5: Example of remote experience in a multiple-window slideshow.

As the multiple-window slideshow did not have the problem of intrusiveness of a remote experience, the change between remote and collocated experience became alluring. P8 said:

> "We were together sometimes and we were leaving some other times. This (multiple-window slideshow), was showing this very well."

Asymmetric transition Asymmetric transition occurred in the multiple-window slideshow when some users had more photos of an event or overall in comparison to the users in a group. This led to two problems. The first problem was the same as for the single-window slideshow, whereby the photos of just one person over a long period of time were shown and the photos of other users were shown after a long delay. This study showed that the participants wanted regular changes between slideshow windows; the more changes between slideshow windows, the better the experience.

The second problem was that some slideshow windows were frozen on the photo that did not belong to the time of other slideshow windows. In other words, some photos on slideshow windows might belong to a different time and different place, which broke the feeling of time concurrency during viewing.

In Group 1, participants should not wait too long to see shared moments and their own photo stream. During the study, two participants had many photos of many events. Therefore, their slideshow windows were sliding more than those of other participants. Common questions that participants in Group 1 asked during viewing their photos using multiple slideshow windows were:

> "Why is my slideshow window not sliding?... Why do other slideshow windows not slide?"

To solve this problem, participants suggested decreasing the number of photos that others had when there was no remote or collocated experience.

Another problem was when a photo in one slideshow window did not relate to other photos in terms of timing. P5 said:

> "There were some photos that stayed for a long time...they were no more related to the newest photo."

The showing of photos that were unrelated to photos from older events was not always a disadvantage. During the presentation, there was a moment that P5's photo of a basketball match was on the screen. Then, a photo from P1 which belonged to the time that she was in another country appeared. The time difference between these photos was a month. Although P5 realised the one month time difference between these two photos, he liked to consider that the moment was from the same time and different place, and when we reminded him that it was not exactly at the same time, he said:

> "Wow, when I was here (home) she was still in Spain...I would like to believe that they were at the same time...this makes it more interesting as their capture times were not too far."

This illustrates how people create a new story for themselves based on the concept of collective memory [167]. Although this was just one participant's statement, investigating this in more detail may make for a good future study. From this participant's statement it can be concluded that there is a potential advantage in keeping photos from slightly different times in the slideshow windows to allow the user to create a new collective memory.

Transitions

Proportional transition By enabling the proportional transition in the single- or multiple-window slideshow, the users had the opportunity to view the slideshow with automated transition intervals. When the time difference of consecutive photos was small, the transition was fast, and when the photos were distant in time, the transition was slow. For example, it took ten milliseconds for the transition between photos taken at very similar times and it was possible to take more than 20 minutes for a one-year gap between consecutive photos.

All of the participants seemed to feel that proportional transition provided a sense of time between slides. From the point of view of the participants, proportional transition offered them an easier connection between photo streams. Participants believed that they could distinguish the different events by the intervals of the slideshow. They were also able to judge how far ahead in time the next event would be. During the interview, F1 mentioned the experience he had during viewing the photos. He realised that there was a slight delay between the transition from the last photo of the night and the first photo in the morning of the next day. He said:

> “I felt that slideshow had a delay between the night and morning.”

P7, a member of Group 1, said:

> “This (proportional transition) was a kind of smart system which gave me the notion of time and feeling the change of event. In some events, like P11’s sky diving photos, photos were taken in a row (in burst). Therefore, the speed was fast and I felt it was a movie.”

P12, another member of Group 2, commented that she liked proportional transition in events for which photos were continuous, such as the photos P10 took when she went back home from all of her moments. She added that she liked the feeling of event change.

The proportional transition had one problem; namely, when the transition between slideshows was too long. In some conditions, the transition was more than ten minutes and the users pressed the skip-next button for another photo.

P9 said:

> “Proportional transition is like autopilot mode in airplanes. The system will do everything for you. However, waiting too much for the next photo was annoying and I just skipped the photos on that moment manually.”

Regarding the issue of waiting too long for some transitions, P14 said:

> “I like to feel the time in slideshow but you need to set a time limit for when the slideshow is too long.”

We asked the participants to use our website as their screen saver using a third-party application. We aimed to see if proportional transition could successfully be used on longer timescales. None of the participants; when we asked them for the reason, they stated that they usually turned off their computers while they were not using them. Therefore, they proposed that it would be better if the website was in a system with the decorative purpose, such as a digital photo frame. In that case they would be likely to use it. When we asked them if they use proportional transition time in a photo frame, they answered that it would be a good idea. Although our main goal was using proportional transition time for ambient display use, participants preferred to use it in order to watch photos faster in time and skip the lengthy transitions. Overall, proportional transition time was accepted by the participants but they all believed that long-time transitions with the current use of reviewing photo streams from the past should be limited.

Event informer The event informer clustered photos into different temporal events and then informed the user with a message that the event changed during the slideshow. The transition in the event informer was two seconds per slide. Generally, participants liked the idea of event informer. They were able to see the change of events in photo streams so that they were visually ready for a new event after seeing the message "Event Changed" P14 said:

> "It is a good idea to inform me when the next event is, as there were many photos that I could not understand if they belonged to the previous event or not. I can be ready for something new and not mixing the photos from different events."

Participants stated that the proportional transition time had an advantage in terms of showing shorter or longer time differences between consecutive photos by the transition interval. Therefore, they were able to know how far in time the next photo will be from the current photo. On the other hand, the event informer did not have the problem of a long transition interval. P7 said that the proportional transition is more natural compared to the event informer because he could feel the event change rather than see it. The main goal in designing this transition was to obtain a comparison between the feeling of the event change via proportional time and showing the event change by a visual clue via event informer. However, the user preference between these two was not statistically different. In addition, interview data presented that participants liked the idea of feeling the event change using proportional transition because of the novelty of this idea and the new sense that it gave to the user.

Desired time The system supports reviewing photos by relying on a specific feature: the user desired time. In such a feature, the streams were shown over the time that the user has chosen. The user desired time was useful when the users needed fast revision of their lives in a specific period of time.

In the study, the participants' selected desired time was between 1 and 10 minutes. P7 selected 2, 5 and 8 minutes. She was satisfied with 8 and 5 minutes but 2 minutes was too fast for her. She said that she liked this new experience and it was useful for her when she wanted to see her photos faster. However, she said, when she set the desired time for 2 minutes: ”It was like a jet, no, not this fast”.

Most of the participants selected a short slideshow time and saw this feature as a kind of fast revision of past events in their lives. P14 said:

> “Fast change reminded me what happened in our lives very fast. This is what I wanted from this feature. I do not need any detail. It is just a good, fast way of remembering our past.”

The desired time in comparison to the proportional transition and the event informer had both advantages and disadvantages. An advantage was that participants could see their past faster and, also, that they had control over the overall time span of the slideshow presentation. A disadvantage was that they could not notice when an event changed, as with the event informer, and they did not have a notion of time, as in the proportional transition time. Therefore, P9 suggested combining this feature with the proportional transition to bring the feeling of event change by choosing the desired time.

P5, a participant from Group 2, mentioned the problem of internet connection when the desired time was set to less than 3 minutes. He said:

> "My home broadband is not very fast. The photos were not loading during the slideshow. I can enjoy this feature now in the lab. You can add a feature to remove some photos rather than making the slideshow faster."

Group 1 had the most uploaded photos on the website. Therefore, they could see what happened to them in fast mode, which they liked very much. However, P1 suggested an improvement to the system using the desired time: to slow down the transition when it reaches same time experiences. P1 said:

> "The moments that photos are from the same time, I prefer to see the slideshow slower, the past photos can be passed fast."

P8 wondered why, instead of the desired time, the normal slideshow could not be used with the capability of changing slideshow intervals manually. Then, he could manage the slideshow as he wanted and see photos that he liked more in detail.

One thing that we anticipated for the desired time was extending the duration of the desired time and using it as a decoration tool such as a digital photo frame at home. However, as was the case with the proportional transition delay, the participants were not interested in a longer presentation time and they used this transition to watch their photos as fast as possible with good recollection. They stated that they would use this feature when they had a device such as a digital photo frame at home but not on their personal computers. However, they liked the idea of a digital photo frame and viewing past photos in a selected overall time as a decoration.

In chapter 6, we introduced logarithmic and summarisation desired time transitions to add the feeling of the event change during the presentation and to solve the problem of the presentation being too fast due to the short presentation time in current desired time transition.

User preference in transitions During the interviews, we asked the participants to score the transition types from 1 to 5. The results showed that the highest score was for the proportional transition time, with average preference of 3.5 and standard deviation of 0.6. The next transition was the desired time, with average preference of 3.4 and standard deviation of 0.59. The average preference for the event informer was 3.15 with standard deviation of 0.67. Finally, the normal slideshow had an average of 2.65 and standard deviation of 0.67.

After applying the t-test between the two least preferred transitions, the results showed that the average preferences between the normal slideshow and the event informer were significantly different ($t(19) = 2.09$, P <0.02). The t-test between the event informer and the desired time showed that the average preference between them was not significantly different ($t(19) = 2.09$, P <0.2). Therefore, it can be concluded that the preference means between the proportional transition, the desired time and the event informer were not significantly different, while the preference means between these transitions and the normal slideshow were significantly different. This shows that people like these added features and they also like to use each of them in the right place. For example, they preferred to use the proportional transition time to feel the event change and notion of time by just viewing the slideshow. On the other hand, they preferred to view large numbers of multiple photo streams using the user desired time in short presentation times. In addition, the event change informer conveyed the understanding of event change, making this transition a preferable choice for the users. Therefore, all these proposed transitions can be applied to future photo visualisation tools for slideshow, as each has its own values. Figure 5.6 shows the average of user preference in different transitions. In the future, these transition types can be studied in more detail using quantitative methods to understand which transition is better in what situation adding a more accurate evaluation of user preference in different conditions. For example different criteria such as acceptance, fun, atmosphere, experience and aesthetics based on [168] have the potential to be evaluated with different scores. In this study, however, only the overall experience and user preference is evaluated while in future larger study by applying statistics of age and gender can be applied.

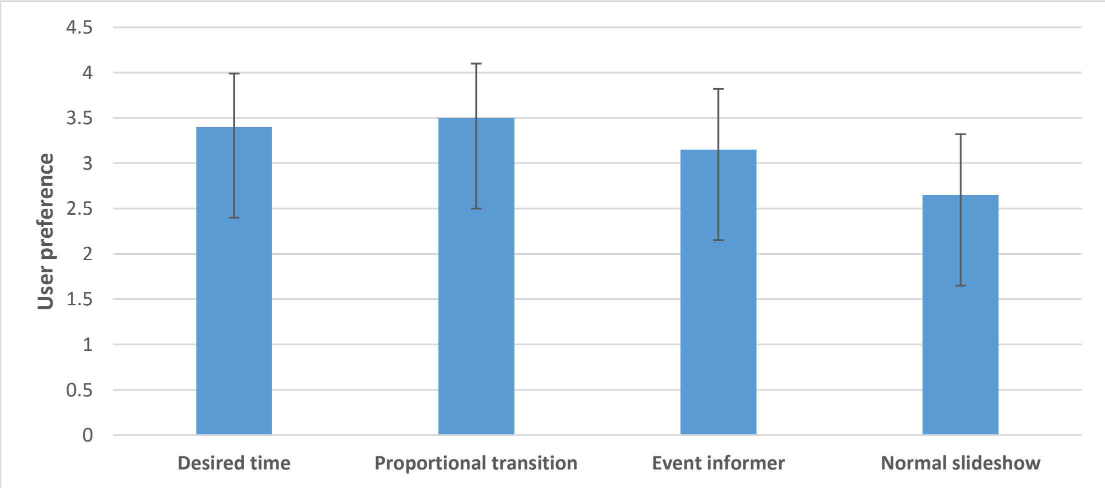

FIGURE 5.6: User preferences of transition types.

Adding visual status

The upload page comprises an upload bar that lets the user upload multiple photos. The recently added photos of friends and the user are shown on the screen in grid view. This is the way that the interface shows recently uploaded photos. However, in both single- and multiple-window slideshows the date is set to the first photo in chronologically sorted photo streams. The user should set the timelines to the current day to see the latest photos from different participants. One design recommendation from this user study was to show the latest uploaded photos of the participants in the multiple-window slideshow mode and let the users update their latest visual status using the multiple-window slideshow. It should be mentioned that, to date (September 2011), Facebook and Twitter have not yet released adding photos as a status in their interfaces and participants are just able to upload photos into their Facebook albums. The reason that participants suggested this was that they did not want to see the latest uploaded photos on the upload page and they needed a simpler interface to see the latest visual statuses rather than switching between different pages of the website. The user journey also supported that they believe in the simplicity of the website rather than switching between different pages. Moreover, they favoured the idea of using the system as an ambient display and they suggested adding this feature in order to see others' latest activities using a dedicated screen in their home as a decoration tool.

Timeline design

One aspect that participants mentioned was timeline design. There were six timelines and the participants were able to choose the start date of the slideshow. At first, participants were confused by using many timelines to choose the starting date and they also did not know at what date exactly they took some photos. In addition, the year and month timelines were the most useful compared to the day, hour, minute and second timelines. F1 suggested designing a single timeline slider for enabling the user to change the date of the photo streams. In addition, user journey experiment showed that using six timelines was complicated and the system needs a new design to be more intuitive and the solution that we took the advantage in the next system design was single timeline.

5.6 Summary and discussion

This chapter described the web-based interface, implemented to share and visualise multiple photo streams. This interface, which contained the upload page, a single-window slideshow, a multiple-window slideshow, and transitions, was tested by twenty users and their experience within the system was evaluated.

The single-window slideshow showed multiple photo streams in one slideshow window. The advantage of the single-window slideshow was in collocated experiences, where the photos were from the same event at the same time. In this mode, all photos of the same event from different people were shown on the screen and without missing any scene from the same event at which they participated. However, there were two states that users did not like in the single-window slideshow. The first was remote experience, which means when a photo from the same time but different event appears in the middle of the main event. Although this state brought awareness (knowing what happened to someone else at the same time when the reviewer was doing something else), when an unrelated photo appeared, the majority of the participants regarded it as a design problem that distracted them. The other problem was Asymmetric transition, which occurred when some participants had more photos than others and, therefore, their photos were shown more than others on the screen.

The problem of remote experience in the single-window slideshow was solved in the multiple-window slideshow interface. In this interface, photos were shown concurrently in up to four slideshow windows. Therefore, participants could follow what was happening from their photo streams whether they were collocated or remote by the time of photo capture. The same as in the single-window slideshow, Asymmetric transition occurred when one participant had more photos than other participants; this was a problem of both single- and multiple-window slideshows and we found that summarising multiple photo streams over the time of capture solves this problem.

Another problem that participants mentioned was when a photo that was unrelated by date and time appeared in the interface of the multiple-window slideshow. For example, when one participant did not have any photos taken during a particular time interval, other participants' photos changed while the first participant's old photo remained on the screen; the photo that was unrelated in time should be removed from the slideshow window. Moreover, participants suggested that the most recently uploaded photos should be shown on the interface of multiple- and single-window slideshows rather than on the upload page.

We also designed four transition modes: normal slideshow, proportional transition time, event informer and desired time. The proportional transition time provided a sense of natural event change for the participants during the slideshow. However, the slideshow was, in some cases, either very fast or very slow. The event informer showed a message of event change during the slideshow and, therefore, participants could identify photos that did not belong to the same event. However, it was not as intuitive and natural as the proportional transition. Normal slideshow was boring and time consuming for the participants. In addition, the desired time introduced viewing photos in a desired time the user selects for the presentation. However, it did not give a notion of time for event change or show photos that taken in bursts faster. Another problem of the desired time was when the total slideshow time was short and the server was not able to load all photos during the slideshow.

The participants' experience with transition modes showed that the proportional transition was the favourite. However, the satisfaction of the proportional transition was not significantly different compared to the desired time and the event informer, while these three modes gained significantly higher interest scores than the normal slideshow. For example proportional transition was suitable for ambient display use while user desired time mostly used to watch many photos in shorter total slideshow time. However, desired time had the potential to be used in ambient mode as well. Event informer, also increased the experience of slideshow by informing the changing the events during the slideshow for smoother presentation of photos. Therefore, it can be concluded that, in the future, all these transitions can be applied as potential features to slideshow applications to enhance user experience when viewing multiple photo streams, as each transition has its own separate value.

The results of this study in terms of privacy showed that close friends did not have any problem in sharing their old photos with each other, while the group which were just friends did not wish to share all their old photos. However, participants were interested in photo diaries and they enjoyed viewing them later in our application. The family group did not have any problem with sharing their old photos but they did not know who took the photos and they organised their family collections by the capture device rather than by the person who took the photos. The study showed that creating a photo story in a collocated environment was enjoyable and reviewing photo streams via our application made it even more interesting; the participants could follow the stories easily and explore what was happening to others while they were doing something else.

Potential challenges and new requirements from this user study are listed below.

Interface

- Photo summarisation across multiple photo streams to solve the problem of Asymmetric transition. Asymmetric transition occurs when one user has more photos in their photo stream than other users. Therefore, participants proposed that there is a need to summarise photo streams to create a balanced slideshow between users.

- Image re-targeting (selection of the most representative part of an image) for keeping the aspect ratio of a photo or loosing less important parts of a photo when resizing. In multiple-window slideshow, the aspect ratios of the photos were changed to fit the screen. Although not all the participants had a problem with this, we received some recommendations to select the most representative parts of the photo or to re-target the photos.

- Adding a visual status feature to the system for live communication via photos. The system's visual status was on the upload page. Moreover, the intention of the design of this system was to enable users to view their past photo streams. However, we found from the user study that showing the latest photos on the slideshow window to notify other participants from the latest visual status of different users is an interesting requirement for a future design of the system.

- Making the display ambient by designing the application on a photo frame size display. We aimed to let the participants use our photo sharing website as an ambient display when they were using different transitions for slideshow. However, they did not do this as they needed a dedicated display that they could use for this purpose. Therefore, creation of an ambient display for photo sharing was another requirement that we found from this study.

- Designing a single timeline rather than six timelines. Participants stated that using six timelines for selecting the starting date point of the slideshow is not practical and they recommended to change it to a single timeline.
- Solving the problem of when an unrelated photo from a different time and event stays in the slideshow window. In the multiple-window slideshow, there were times when one photo in one slideshow window did not belong to the current photo set on the screen. Therefore, participants suggested removing the photo that did not belong to the current time of the slideshow.

Transitions

- Solving the problem of proportional transition when the transition is too slow or too fast.
- Solving the problem of not loading photos from the server because of internet speed or server business when the transition speed is fast.
- Adding a feature to make the normal slideshow intervals manually controllable.
- Summarisation of multiple photo streams when the speed of the slideshow is too fast in the desired time.
- Combining the desired time and the proportional transitions.
- Combining the desired time and the event informer transitions.
- Slowing down the transitions in collocated and remote experiences and compensate by making the transition faster in the Asymmetric transition state.

In the next chapter, the temporal aspects of the design of multiple photo streams will be described. These aspects comprise the different slideshow transitions from manual to the desired time, summarisation of multiple photo streams and continuity detection.

Chapter 6

Temporal aspects of photo stream visualisation

6.1 Introduction

Our previous system resulting from Phase 1 of the design supported the presentation of multiple photo streams obtained from different people. Its motivation was to allow multiple users to keep in touch through a kind of visual comparison of concurrent photos from their photo collections within small groups such as friends or family members. The photos were displayed in a dynamic collage in the four quadrants of a dedicated ambient display, with photos in each quadrant arriving in real time as photos were taken.

This system could be used to review a historical collection of photos from each member of the group, in lock step. Six sliders allowed users to change the photos on the display to a particular point on the timelines and a replay button allowed them to animate the display at different speeds.

Users enjoyed seeing their photos alongside those of their friends or family members, particularly when they had attended the same events at which they all had taken photos or when they took photos of different events that occurred at approximately the same time. However, users had some problems controlling the rewinding and re-display of synchronised photos at different speeds. Photo streams are typically 'bursty' and non-linear [91], and, in the proportional transition mode, users found it difficult to find a speed setting that was not too boring (with nothing happening in certain quadrants) or too fast (with photos speeding past too quickly to see them). Participants also suggested to utilise the combination of transition modes in Phase 1. Hence, we recommended the development of algorithms to warp the time of photo display in different ways in order to optimise the user experience of photo review.

Another problem that users mentioned during the evaluation of our system in Phase 1 was that in the concurrent visualisation of photo streams, some participants had more photos compared to others and, therefore, just the photos streams of those who had more photos taken were sliding on the screen. To solve this problem, the suggested solutions were summarisation of multiple photo streams to squeeze the time of the presentation, to adjust the distribution of the photos between slideshow windows, to emphasise the visualisation of the events happening at the same time (collocated and remote experience) and to show redundant photos faster.

We have designed and implemented a system for visualisation of temporally synchronised photo streams captured and shared by different users, and visualised in an interactive interface. This section introduces the proposed interface design of two side-by-side temporally synchronised photo streams.

6.2 Design and implementation

As initially presented in the work on requirement analysis for visualisation of multiple photo streams, there is a clear demand for visualisation of photo streams from different sources due to the emergence of passive photo capture and life-logging practices [169]. Based on these requirements, a novel interface is proposed that lets users observe their photos chronologically and concurrently in a grid of adjacent windows. This design enables awareness of concurrent events and experiences within small groups of users whether or not they are collocated, bringing a whole new shared experience to the users.

The findings from Chapter 5 showed that users like to see multiple photo streams using proportional transition time because they can recognise the changing of an event naturally via the notion of time via the speed of the slideshow transition. The proportional transition slideshow was a good transition to use for a digital ambient display with a long time of presentation, but the speed of the slideshow was often too fast or too slow. In addition, users suggested that photo streams could be displayed by a manual selection of fixed intervals rather than by the two-second interval. Moreover, they suggested to summarise photo streams or to speed-up the transition when there is no collocated or remote experience.

In this study we applied six transition modes to the system. The concurrency of the presented photo streams in three of the transitions is achieved by transforming intervals between capture time stamps of two consecutive photos from the presented streams into intervals between the appearance of the respective photos in the interface. The fourth transition was based on the continuity between consecutive photos to show continuous photos faster in time as a short video. The fifth and sixth transitions enabled users to choose the total slideshow time and then the presentation of photo streams was adjusted based on the desired time by eliminating the redundant photos or decreasing the transitions. The transitions, termed *transition modes*, were: fixed, proportional, logarithmic, continuity, logarithmic desired time and summarisation desired time.

From Study 1, participants mentioned the problem of the speed of the Internet network or server for loading photographs. They said that when the transition speed increases, sometimes they were not able to load the photos fully and some of the participants could not view the photos when they were taken in bursts. Therefore, in this version, the system was designed as an application-based system rather than a website to support slideshow transitions with a faster processing time.

6.2.1 Upload page

The upload page in System 2 enabled users to copy their photo collections onto the system. The first element was the username and password section. The user was registered with the system and was asked to enter their username and password on this page. After that, the user was able to browse in order to upload a folder or photos which were in their computer. After clicking the upload button, the photos were copied to a folder, which was shared with a small group of users, and they all were able to access that folder and update it while they were connected to the Internet. The user was able to access the upload page by clicking on the upload page button from the initial guide screen when the program was operating.

6.2.2 Display

The display page comprised a variety of elements. The user could access the display page by pressing the display button from the initial guide screen. In this page, there were two side-by-side slideshow windows, which presented the photo streams concurrently. The only difference in the presentation compared to the previous system in Phase 1 of the design was that in the current system, if a photo in one slideshow window did not belong to the event of the current photo in another slideshow window, then the photo that was unrelated to the current event was replaced with a black screen, showing that there was no concurrency between two photo streams.

This was adopted from Phototoc [98] to cluster a photo stream based on its temporal features. The goal of this time-based clustering algorithm was to detect the noticeable gaps of time between consecutive photos. A cluster was then created from those gaps and assumed to be a change in event. With this method, the local average (T_{avg}) of temporally nearby gaps is compared to the gap (Δ_t), and when Δ_t is much longer than T_{avg}, the new cluster is created as a new event. Equation 6.1 illustrates the clustering condition technique.

$$\Delta_i > T_{avg} = k + \frac{\sum_{i=1}^{n-1} \Delta_{ti}}{N} \tag{6.1}$$

where N is the number of photos in photo streams, k is a suitable threshold (set equal to five experimentally) and i indicates the number of photo in the photo stream.

At the top of each slideshow window, there was a drop-down menu where the user could choose the person who took the photo; after that, the user could narrow down the selection by choosing the capture device the person used to take photos with.

There was a single horizontal timeline designed for the current system, adopted from the lessons learned from the previous study. In the initial system, there were six timelines for selecting the start date of the presentation or searching through photo streams; however, in the current system, one timeline was designed where the user could go through all photo streams in chronological order.

There were five control buttons. Three of them (play, play backward and pause) were under the timeline. The pause button was in the middle of the play-forward and play-backward buttons. The other two buttons were skip forward and skip backward and they were situated on the left and right side of the timeline.

There was an information bar at the middle top of the slideshow windows that presented information such as date and time, number of photo and transition type.

There was a vertical slider on the right of the screen that let the user change the speed of transitions. In order to choose the transition type, there were six buttons: logarithmic, proportional, fixed, continuity, summarisation desired time and logarithmic desired time. By clicking on any of these buttons, the name of the current transition type appeared on the information bar. Figure 6.1 presents the display interface.

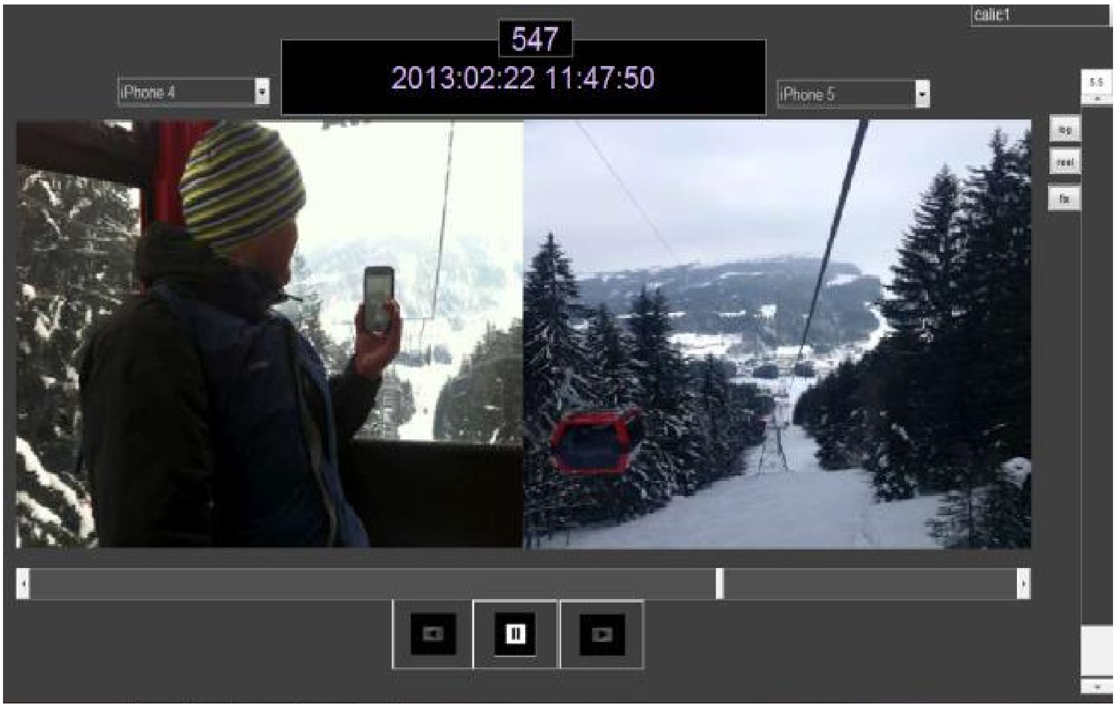

FIGURE 6.1: Twin photo stream interface used in the study.

6.2.3 Transition modes

The main contribution of this system was the six transitions designed for visualisation of multiple photo streams. Manual transitions are logarithmic, proportional and fixed transitions, and enable the user to control the speed of the slideshow manually by a slider located on the interface. The fourth transition, continuity transition, shows the continuous photos in faster transition. For the desired time transitions, logarithmic desired time and summarisation desired time, users choose the total slideshow time of the slideshow and the system adjusted the transitions by eliminating redundant photos or speeding up the slideshow using logarithmic transition. In this section, all transitions are described in detail.

Manual transition mode

The manual transition mode comprises the fixed, proportional and logarithmic transitions. All of these transitions enable the user to adjust the speed of the slideshow during viewing multiple photo streams by the characteristic of that specific transition. Each manual transition is now explained in detail.

Fixed transition The fixed transition mode provides an experience similar to a typical slideshow by assigning fixed intervals between transitions of two photos in the interface. Users can set the fixed interval between 0.001 to 5 seconds, using the vertical slider, and the range used in the experiment was 0.1 to 10 seconds. This is the baseline mode since users can relate to it as a concurrent slideshow of two photo streams.

Proportional transition In the proportional transition mode, the presented transition interval (t_i), as presented in Equation 6.2, is calculated by dividing the difference in the capture time stamps of two consecutive photos (Δ_t) by a constant coefficient (k), which can be set by the vertical slider from 1 to 10000 and is in the range 1 to $5 * 10^6$. By setting the scaling coefficient equal to one, the interface presents the photos in real time, i.e. at the same speed as they were taken. The proportional mode directly offers a notion of time between events but can result in extremely short or long transitions between two photos.

$$t_i = \frac{\Delta_t}{K} \tag{6.2}$$

In Figure 6.2 the diagram of the function of the proportional transition with the time difference of (Δ_t)) between 1 to 1000 and the coefficient between 1 to 1000 can be seen.

Logarithmic transition In the logarithmic transition mode, the presented transition interval (t_i) is calculated as the logarithm of the time difference between the

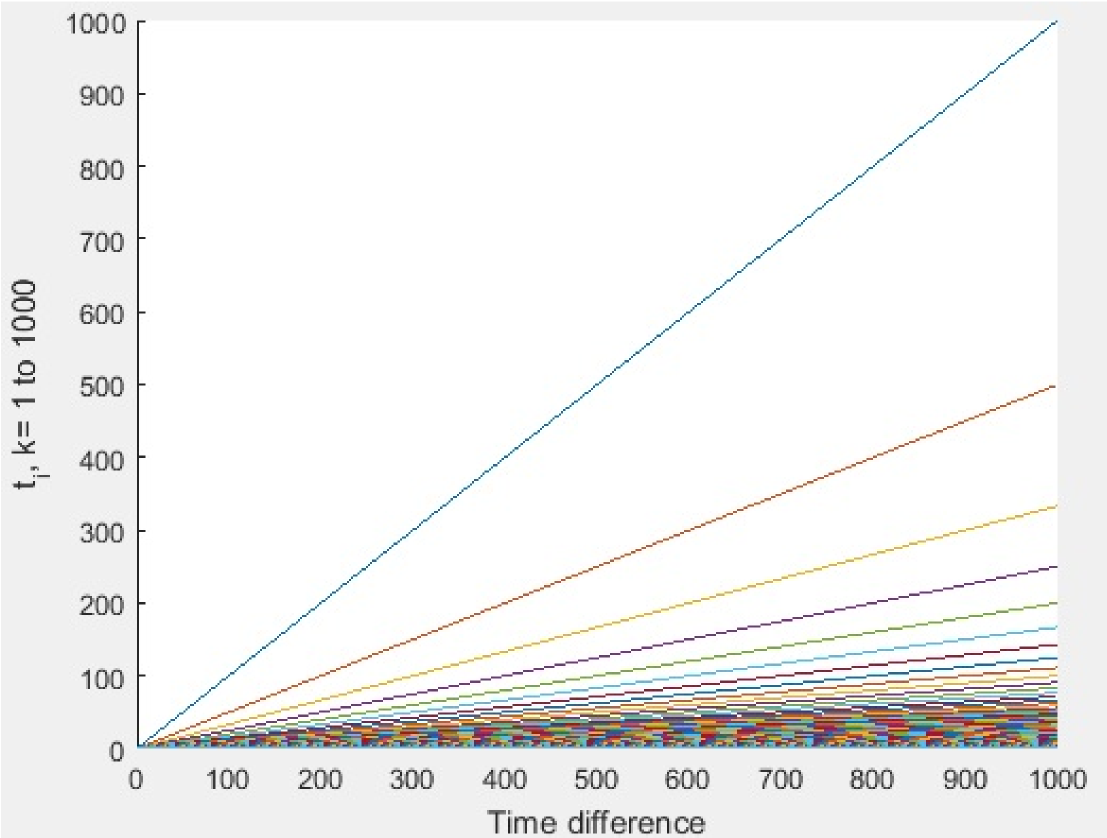

FIGURE 6.2: The proportional function with the difference of (t_i) from 1 to 1000 and the coefficient between 1 to 1000

capture time stamps of two consecutive photos (Δ_t), as given in Equation 6.3. Users can use the vertical slider to set the base (b) of the logarithm between 1.1 to 1000, thus speeding up or slowing down the playback. This mode balances the feeling of time in the streams and the user's experience, depending on the value of the base b.

$$t_i = \log_b \Delta_t \tag{6.3}$$

In Figure 6.3 the diagram of the function of logarithm transition with the time difference of (Δ_t) between 1 to 1000 and the base of the logarithm between 1 to 1000 can be seen.

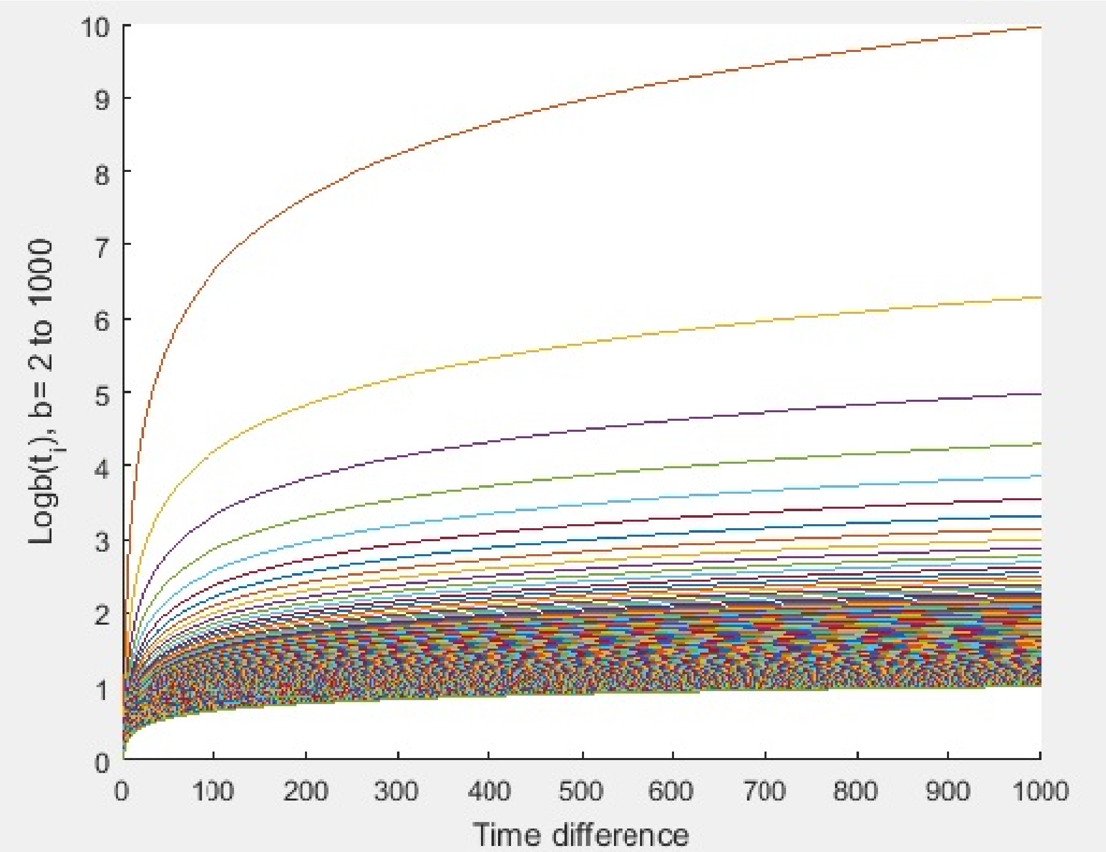

FIGURE 6.3: The function of the logarithm with the difference of (t_i) between 1 to 1000 and the base of the logarithm between 1 to 1000

Continuity transition

An important finding that emerged from observations of the fast proportional transition mode in Study 1 was visualising events whose speed of content change was slower than the rate of capture, i.e. the produced photo stream appeared continuously. Triggered by this finding, a notion of "continuity" was introduced, denoting a finite incremental change between two photos in a photo stream so as to produce an effect of event continuity when presented at a rapid visualisation rate, i.e. in a time-lapse video fashion.

In order to detect which photo pairs are "continuous", three algorithms were implemented and evaluated. All three algorithms produced a measure of continuity between two photos. The first algorithm was based on the dense optical flow estimation method [170], which tries to calculate the motion between two photo frames taken at times t and $t + \Delta_t$ at every pixel position. The overall measure of continuity is, thus, inversely proportional to the sum of motion vector intensities. Optical flow is the pattern of motion of objects, surfaces, and edges in a visual scene caused by the relative motion. Therefore, we selected this algorithm to evaluate whether or not it is suitable for detecting the motion between photos.

The second algorithm was based on the SIFT feature matching method [100] between two neighbouring photos. Here, if there are a significant number of matched features between the two photos and if the displacement of the matched features is within predetermined limits, the algorithm averages the motion displacement of the features, which is inversely proportional to the "continuity" measure. The SIFT descriptor is invariant to translations, rotations and scaling transformations in the image domain and robust to moderate transformations and illumination variations and also experimentally, the SIFT descriptor has been proven to be very useful for image matching. We therefore selected and evaluated SIFT for the detection of continuity between still images from people's photo collections.

Finally, a recent dense correspondence estimator SIFT Flow [171] was used to derive a dense flow using invariant features, while the continuity measure was derived from the energy optimisation function. In dense SIFT, we get a SIFT descriptor at every location, while with normal sift we get a SIFT descriptions at the locations determined by [100]. Therefore, we decided to obtain the flow using this technique to detect the continuity and compare the performance with normal SIFT and optical flow.

In continuity transition, the system provided the manual selection of a fixed interval by a vertical slider between two discrete consecutive photos and 0.2 seconds between two continuous photos. The 0.2-second interval was chosen experimentally but future studies should consider the idea of the interval value of continuous photos.

Desired time transitions

In order to speed up the total slideshow time and to give a notion of time to the user, the logarithmic transition time was proposed and, from the logarithmic transition time, the logarithmic desired time transition was built.

The logarithmic transition time means that the greater the time difference between two consecutive photos, the greater the delay of the slideshow transition. Therefore, if two photos are taken in close time, the transition speed increases. Moreover, the logarithmic transition time gives a notion of time during presentation, which means that the user will understand when an event in the photo stream is changing by the transition. As explained earlier, the major attribute to speeding up and down the slideshow using the logarithmic transition time is the base of the logarithm. A larger logarithm base leads to a faster slideshow transition.

Having a technique to let us feel the event change between multiple photo streams and viewing photos taken faster in bursts means that the transition time between each slide should be calculated with respect to the desired total slideshow time (T) the user selects. From Equation 6.4 and, subsequently, Equation 6.5, the base of the logarithm is calculated and, consequently, the speed of slideshow will be set by the desired time during the presentation. The minimum total slideshow time in logarithmic desired time based on our lab computer is calculated by dividing the total photos to 10 experimentally. The user is free to select any amount for the maximum slideshow length. The lab computer had 4GB of memory with Intel i3 cpu.

$$\sum_{i=1}^{n} \log_b \Delta_{ti} = T \tag{6.4}$$

$$b = \sqrt[T]{\prod_{i=1}^{n} \Delta_{ti}} \tag{6.5}$$

In summarisation desired time, some redundant photos which belong to the Non-concurrency state are eliminated (see Figure 6.4). The elimination degree depends on the total slideshow time the user chooses. In this technique, multiple photo streams from different people are merged into one stream. After that, they are sorted by date and time. Having sorted photo streams in a single photo stream in the first level of clustering, the photos are clustered by the device name or the user name of the people who uploaded them. This will help not to eliminate the collocated or remote experience states during the presentation of photos.

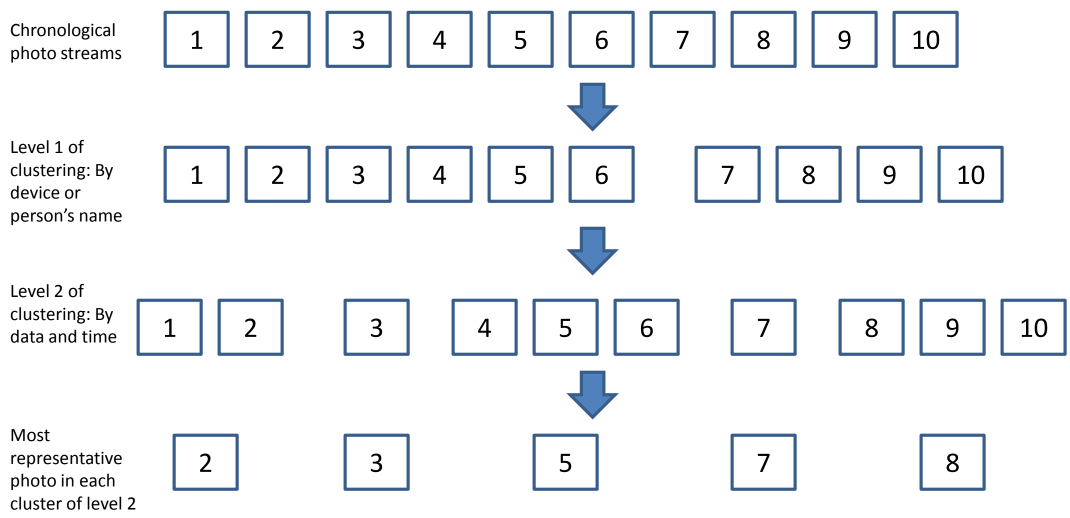

FIGURE 6.4: Summarisation process of redundant photos, where the user selected five seconds as a total slideshow time for ten photos and the transition between slides was set to one second.

In the second level of clustering, photos of each cluster were sub-clustered by the date and time difference between consecutive photos using K-means clustering [87]. In K-means clustering, K represents the number of clusters and should be set before clustering the photo.

In order to obtain K, the rounded T_i is first calculated by dividing the desired total slideshow time by the transition each slide user selects. Following that, by dividing this calculated value T_i by the total number of clusters (N), the number of sub-clusters (K) is calculated, as seen in Equation 6.6. In addition, if the number of the recommended sub-clusters is larger than the number of photos in each cluster, all photos in that cluster are sub-clustered and the remaining clusters are added to the value of K of the cluster with the largest number of photos. Moreover, if the result is a non-integer, the number of clusters is calculated by the ceiling function and, following that, the sum of the remaining decimals from the non-integer number are added to the value of K of the cluster with the largest number of photos. Hence, the value of K for sub-clustering in each first level cluster might be different.

For example, in Figure 6.4, 5 (five second presentation with one second transition) was divided by 2 (number of first level clusters) giving the result of 2.5, which should be the value of K in each sub-cluster. Therefore, the value of K for the cluster with the largest number of photos (six photos) was 3 while the value of K for the smaller cluster (four photos) was 2. The minimum total slideshow time in summarisation desired time based on our lab's computer is equal to the number of clusters in first level of clustering. The user is free to select any amount for the maximum slideshow length. The lab computer had 4GB of memory with Intel i3 cpu.

$$K = \frac{T_i}{N} \tag{6.6}$$

In the next level, the most representative photo from each sub-cluster was selected and shown in slideshow mode. The main criterion for the selection of the most representative photo from a sub-cluster was completeness. However, completeness is a subjective characteristic that can mean different things to different people. Since there is not a definite way of calculating such a metric, an approximation method was developed in order to select the most representative photo.

After clustering photos in two levels, each cluster contains photos of a similar topic and event. The most representative photo among those photos is that which describes the whole event most completely. Therefore, the selected photo contains most of the objects that were presented in photos within the cluster and it should be the most similar photo to the other photos. Therefore, the similarity metric

SIFT flow [171] was used. Figure 6.5 shows the result of the selection of the most representative photo using the SIFT flow.

FIGURE 6.5: Selection of the most representative photo in an event using our algorithm.

6.3 System architecture

The system architecture was comprised of two stages: the upload stage and the display stage. In each stage, there were three layers, namely: presentation, application and data.

The presentation layer of the upload stage included an interface that enabled the user to select the photos they wanted to upload into the system after entering their username and password. In other words, the presentation layer was the interface of the upload stage and was designed using the GUI designer from Matlab version R2012a.

The application layer in the upload phase had the logic of the system. In this layer, the system got the photos the user selected for upload and saved the username of the person in the author section of the Exif header file of the photo. After that, the system ordered the data layer to save the photo. The application layer downsized the photos to 400*300 pixels in order to speed up the process of the presentation layer and of the application layer in the display phase, while maintaining the quality of the photo. In addition, the application layer removed the photos that did not include the date and time of capture as metadata in their Exif header file. This layer was coded by Matlab.

The data layer was a shared folder in the hard disk of each user. The photos were saved in that shared folder and users were able to access the shared photos with each other through that folder. Therefore, the system enabled the system to use the capability of fast processing for the application and presentation layers by using a folder in a physical memory; the remote connectivity between users was maintained.

The presentation layer of the display stage included the main interface of the system, which comprised visualisation of twin streams with the aid of control buttons, viewing photo streams with transitions modes, adjusting the speed and search via a timeline. This layer also provided the ability to select the name of the people and their capture device for the presentation of their photos. This layer was created using the Matlab GUI designer.

The application layer, which was the engine behind the interface, was concerned with controlling the elements of the presentation tier. This layer gathered information such as the date/time created, the name of the person who uploaded the photo, the capture device name and photo features. For deduction, this layer generated information such as time difference between photos, clustering photos by date/time alongside the transition modes logic. Figure 6.6 shows the system architecture.

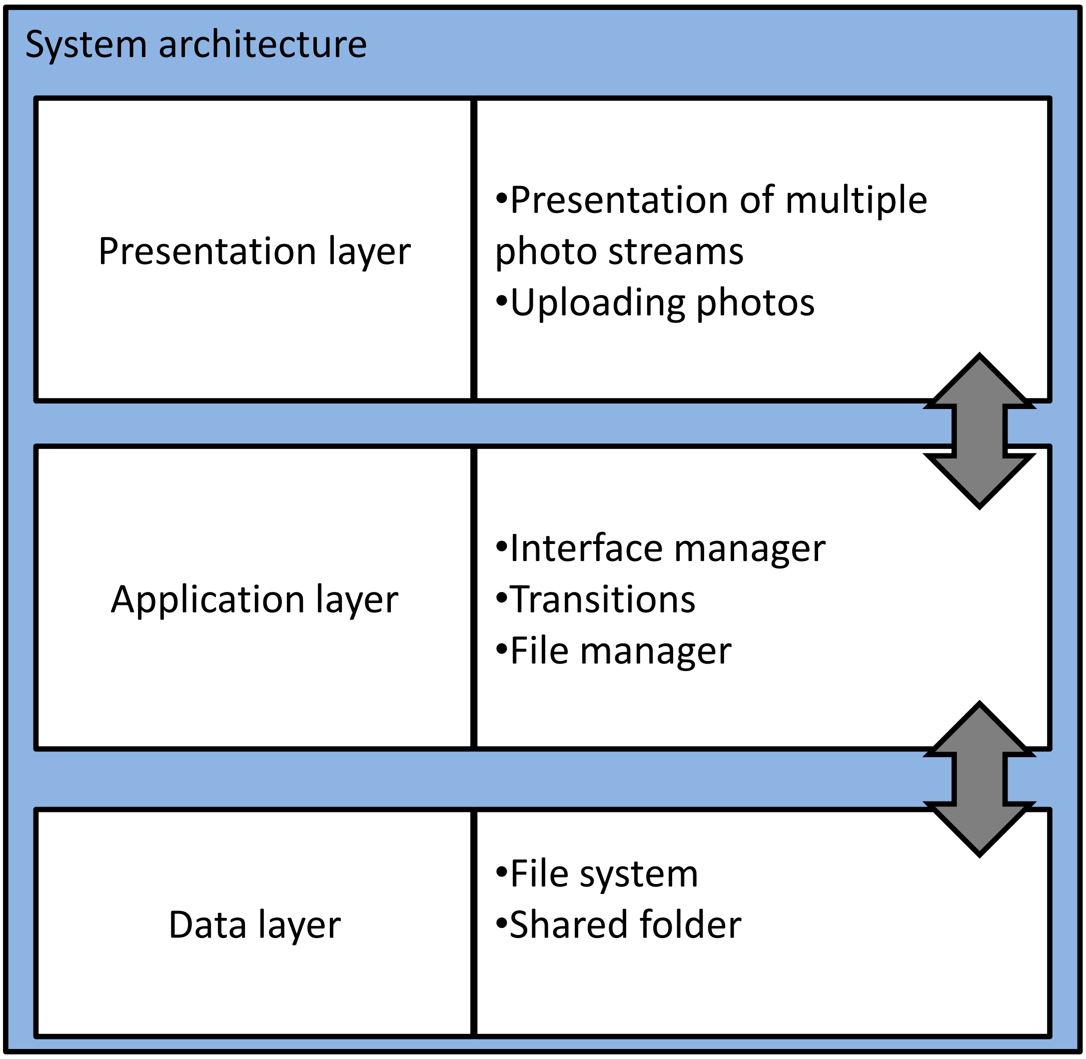

Figure 6.6: System architecture.

6.4 Summary

In this chapter, a system for visualisation of multiple photo streams was built and the initial interface that was designed in Chapter 4 and evaluated in Chapter 5 was improved. We designed a single timeline for the current system from the lessons learned from Study 1 in Chapter 5.

One contribution of this chapter was adding logarithmic and fixed transitions alongside the proportional transition to the system. The fixed transition mode provided an experience similar to a typical slideshow by assigning fixed intervals between transitions of two photos in the interface. This enabled users to set fixed intervals, using the vertical slider.

In the logarithmic transition mode, the transition interval in the slideshow was calculated as the logarithm of the time difference between the capture time stamps of two consecutive photos. Users could use the vertical slider to set the base of the logarithm, thus speeding up or slowing down the playback. This mode balanced the feeling of time in the streams and user experience, depending on the value of the base. For example, the transition for photos taken in bursts would be faster while the transitions for photos taken far apart in time would be slower. This was implemented to solve the problem of the proportional transition time, when the transitions were too slow or too fast, as mentioned in Chapter 5.

During the visualisation of multiple photo streams, one of the problems users mentioned in Chapter 5 regarding the multiple window slideshow was when a photo in one of the slideshow windows did not belong to the current time of the slideshow. Therefore, we clustered the photo streams and if a photo did not belong to the current cluster, it was eliminated from the slideshow window.

Another problem mentioned in the previous study in Chapter 5 was that during the slideshow when the Internet connection was not fast, loading the photo took a long time. Therefore, we created a shared folder between remote computers. Thus, when a new photo arrived, it was placed in that shared folder in each computer, thus enabling the application to access the photos from the local hard disk rather than the server and, consequently, enhancing the slideshow experience.

Another improvement participants suggested in the previous chapter was to add a feature to show continuous photos faster, like a movie, as all of them had photos that were continuous; for example, a skydiving photo stream or photos taken in bursts. Therefore, in this chapter we took advantage of three algorithms to show photo streams like a time-lapse video as if they are continuous: SIFT, SIFT flow and optical flow. All three algorithms produced a measure of continuity between two photos.

Finally, from the lessons learned in Chapter 5 regarding the elimination of redundant photos mostly in the Nonconcurrency state, combining the desired time transition with the proportional algorithm and speeding up the presentation in the Nonconcurrency state, we came up with two new transitions: summarisation desired time and logarithmic desired time.

The logarithmic desired transition time used a logarithmic transition to show multiple photo streams by the desired time chosen by the user. The transition between each consecutive photo was adjusted depending on the time difference between them and on the total slideshow time the user selected.

The summarisation desired time comprised elimination of the redundant photos when the presentation of multiple streams was not in a collocated or remote experience. In this technique, photos were clustered in two levels using K-means clustering according to the photographer or the capture device and time stamps. The number of clusters was determined by the total slideshow time chosen by the user. Ultimately, the most representative photo (most complete photo) from each cluster was selected using the SIFT flow algorithm.

In the next chapter, the interface of our system and its affects alongside temporal features, namely manual transitions, continuity detection and desired time, will be evaluated.

Chapter 7

Study of temporal aspects in photo stream visualisation

7.1 Introduction

In the previous chapter, we designed a system to show multiple photo streams concurrently, between two users, according to the time the photos were captured. The system had a single timeline to let the users review multiple photo streams and to compare what happened between them earlier. Moreover, six different transitions were utilised in the system. The first three transitions were fixed, proportional and logarithmic transitions; these were named manual transitions because users were able to control the speed of the slideshow manually using the vertical slider we designed. The fourth transition was the continuity transition, which showed continuous photos faster. The other two transitions were logarithmic and summarisation transitions, which enabled users to decide the total length of the slideshow and where the system eliminated redundant photos or speeded up the slideshow using the logarithmic transition.

In the first section of this chapter, three manual transitions, alongside the benefits of the system for visualisation of multiple photo streams, are evaluated. In the second section, three algorithms that form the basis of the continuity transition are evaluated and the best algorithm is selected for the continuity transition. Finally, the logarithmic desired time transition is compared with the summarisation desired time for different total slideshow times.

7.2 Manual transitions

Three manual transitions were designed and explained in the previous chapter, namely: fixed, proportional and logarithmic. In this section, we evaluate our application for the visualisation of multiple photo streams using the three proposed manual transitions. Here, the user experience study comprises a combination of a task-based study for the evaluation of the performance with user satisfaction to gain quantitative and qualitative data regarding user use.

7.2.1 Method

Participants

Twenty participants volunteered to take part in this study; twelve females and eight males, with a mean age of 29.55 years. The standard deviation of their age was 6.2 years and their age range was 20 to 50 years. Participants were selected from friends, family and colleagues of the researchers who conducted the study. The participants chose samples of at least 500 photos from different events taken over the course of a year. Moreover, those participants who had the intention to share their photos with a researcher were chosen. All participants had at least one kind of capture device. To this end, participants were from different countries but were asked to confirm that they had lived in the United Kingdom in the previous three years. All participants were either university graduates or undergraduates. All participants were familiar with the Windows operating system.

Initial setup

Each participant was asked to provide at least 500 photos taken in the year preceding the study. They also were asked to provide photos from at least three different events; the number of photos from each event was not an issue. The reason for this was to make the photo stream of each participant as diverse as possible over the timeline. Each participant was asked to provide their photo collection by copying them to a memory stick that was given to them. The sizes of the photos were decreased to 400*300 pixels to speed up the presentation while ensuring that the photo size did not affect the quality and looked pleasant on the slideshow windows on the screen. In the next step, the photo streams were checked for diversity over time and if they were not diverse enough, we removed them from the study. In addition, photos without a time stamp were removed from the photo stream. The participants' photo streams were copied to the shared folder alongside the researcher's photo stream. The system tagged each photo stream by its owner name at the time of copying onto the system.

Procedure

A user study was designed and conducted to investigate the effect of the first three transition modes and the proposed interface on user photo viewing behaviour and positive recollection. Each participant's photo stream was paired with that of the related researcher who conducted the study. Before pairing the participants, the photos were checked for consistency throughout the period.

This study investigated the following three conditions:

1. Logarithmic

2. Proportional

3. Fixed

Each condition had two phases. For each condition, Phase 1 was comprised of participants viewing 300 photos using the relevant transition mode. We showed 300 photos because there are enough to show the concurrency in two photo streams while also providing enough presentation time for users to adjust the speed for comfort to provide the experience of slow technology [172] for the user. In each condition, different photo sets were shown in ascending order according to the time of capture. The condition transitions were picked randomly from the three transition types investigated (logarithmic, proportional and fixed). During the study and the observations, the participants adjusted the transition speed using the vertical slider for comfort. They were able to change the speed of transitions whenever they wanted until the end of the slideshow presentation.

In Phase 2 of each condition, a random photo was picked from the participants' photo streams and the participants were asked the following questions:

1. Can they remember this photo from the slideshow?
2. Do they know what happened next in their stream?
3. What happened next in the other person's stream?

A visual clue of four photos was presented to the participants on request and they were asked which one of those photos came next. At the end, the participants were asked to verify their answer by searching and finding the photo shown to them using the system. For example as can be seen in Figure 7.1, we presented 25 photos out of 300 photos of the study of 2 streams of a participant and a researcher. A random photo from participants's photo stream was selected. Subsequently, a visual clue of photos from before and after the selected photo was chosen and then the participants were asked if they remembered what had happened shortly after that photo in the researcher's stream.

The same process was repeated in Phase 2 of this study by picking a random photo from the researcher's photo stream. Then, the participants were asked general open-ended questions for qualitative analysis. At the end of the experiment,

FIGURE 7.1: Summarised photo streams of two people and the visual clue.

the participants were asked to rank their favourite condition by choosing a score between 1 and 3. This study was conducted in the laboratory and the participants viewed photos on a laptop with a 17-inch display. The guidance form for this study can be seen in A.2 and A.4.

A detailed example of the visual clue we showed to the participants can be seen in A.4, where we showed a random photo from the participants' photo stream and asked them if they could remember what had happened next by showing them the four photos on the form, and what happened next in the researcher's parallel photo stream by showing them another four photos. The photos were selected manually by choosing the next closest photo to the selected random photo as the correct answer. The three 'wrong answer' photos were picked manually from long before or long after the randomly selected photo.

7.2.2 Results

The results presented in this section were analysed quantitatively and qualitatively from the interaction logs, a user task-based study, and a semi-structured interview conducted after each user carried out their tasks.

Total slideshow time

The average slideshow duration for viewing all 300 photos was: 181.19 seconds (standard deviation=145.26 seconds) for the proportional transition mode, 399.21 seconds (standard deviation=225.8 seconds) for the fixed transition mode and 262.23 seconds (standard deviation=132 seconds) for the logarithmic transition mode.

One-way ANOVA was conducted to assess if the use of logarithmic, proportional or fixed transitions affects the slideshow time duration. The ANOVA test result was F(2.57)=9.5, p=0.0002, which indicates that the results were statistically different. Furthermore, a t-test was performed between each result set; it showed that there is a significant difference between each pair of transition types (all p-values were less than 0.001). Therefore, it can be concluded that each of the transition types affected the length of the total slideshow time. Figure 7.2 shows the average total slideshow times for different transitions.

From the qualitative analysis, it can be observed that the use of the logarithmic transition mode was preferred for viewing multiple photo streams since this mode was faster and provided better positive recollection. The fixed transition mode was preferred by participants aiming to view the photos in more detail and for longer. One participant said:

> "I prefer to use fixed transition mode when I want to see photos in more detail in longer time... I use logarithmic transition mode for viewing photos faster with good comprehension."

The total slideshow duration for viewing all 300 photos by females was: 190.4 seconds (standard deviation=159 seconds) for the proportional transition mode, 433.76 seconds (standard deviation=226.6 seconds) for the fixed transition mode and 226.46 seconds (standard deviation=137.3 seconds) for the logarithmic transition mode.

The total slideshow duration for viewing all 300 photos by males was: 159.5 seconds (standard deviation=87.42 seconds) for the proportional transition mode, 251.9 seconds (standard deviation=203 seconds) for the fixed transition mode and 253.32 seconds (standard deviation=147.7 seconds) for the logarithmic transition mode.

The results were not significantly different in the proportional and logarithmic transitions but they were significantly different in the fixed mode. This shows that when they have the option to view multiple photo streams in detail using the fixed mode, women prefer to view photos in more detail than men.

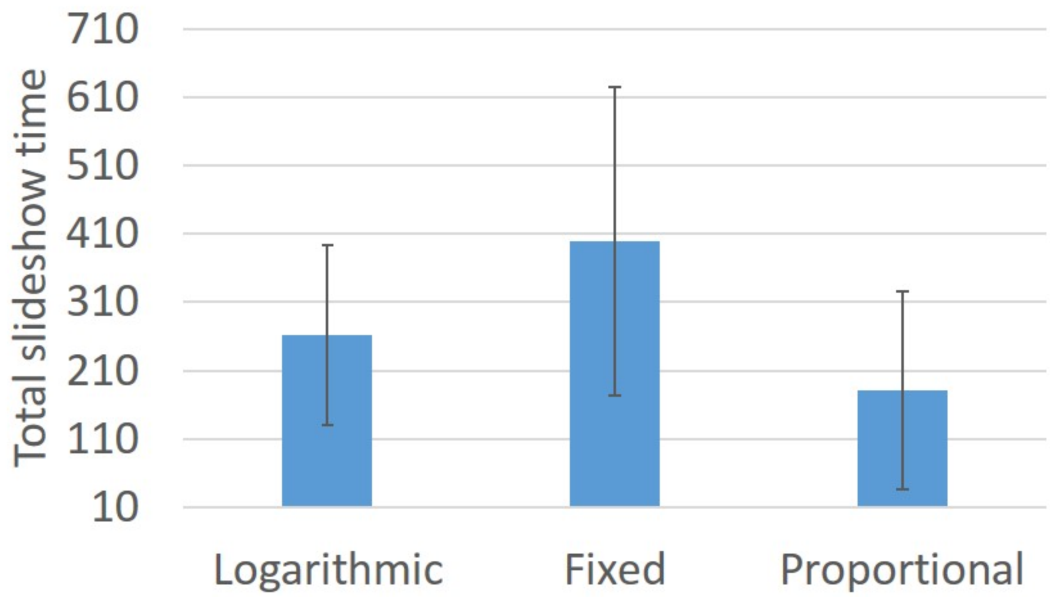

Figure 7.2: Average total slideshow time.

Preference of transition modes

During the interview we asked participants to rank their favourite transition modes; the ranking scores were between 1 and 3, with 3 given for the most preferred mode. The logarithmic transition mode was the most favourite transition mode with 51 points and the standard deviation of 0.6, next came the fixed transition mode with 39 points and the standard deviation of 0.7 and last was the proportional transition mode with 31 points and the standard deviation of 0.7.

Most of the participants believed that the logarithmic mode conveyed a notion of time and, although the speed of the slideshow was fast, they could follow the story in a more relaxed manner. In addition, event changes could be distinguished despite the speed of the slideshow. The participants also reported that photos that were taken in bursts were shown like a time-lapse video and that was visually very appealing. Nevertheless, the participants did not like the proportional transition mode as much as the other two modes because most of the transitions were either very fast or very slow. Figure 7.3 illustrates the participants' preferences for the manual transition modes.

Before starting the experiment, the participants were asked if they normally use a slideshow to view their photos; most of the answers were negative with 80% of the participants claiming that slideshows are "boring".

After observing the interface proposed in this study, the participants enjoyed viewing the photo streams with different transitions in a slideshow-like manner, admitting that these features made the slideshow more interesting. This reaction was due to the contextualisation of personal photos and the comparison of concurrent events from both streams. Secondly, the experience of viewing the photo streams was improved by factors such as the conveyed notion of time, the faster viewing of streams in the logarithmic transition mode and the freedom of selecting the transition intervals in the fixed transition mode. One of the problems in the first design of the system was the speed of the slideshow, which was solved by the temporal features.

Speed control

Throughout the experiment, the participants were able to change the speed of the transitions using the vertical slider. They selected a wide range of values for the base, coefficient and fixed intervals. The mod of each participant's selected values was calculated. The minimum value selected among the favourite base values was 7 and the maximum was 475.5. The average of the most preferred base was 203.5, with a standard deviation of 191.1. The minimum selected coefficient

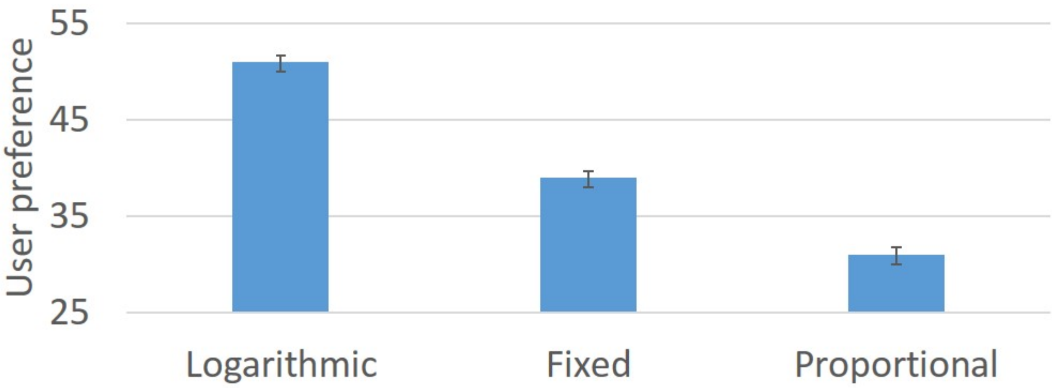

Figure 7.3: Participant preferences in the manual transition mode.

value was 2282.7, the maximum coefficient was 111660 and the average coefficient was 52868.55, with a standard deviation of 39065.16. In the fixed transition, the minimum selected transition time was 0.4 seconds per slide, while the maximum was 3 seconds and the average was 1.2 seconds, with a standard deviation of 0.83 seconds. These selected values show that, depending on the user personality and mood, different values are chosen for the speed of transitions. Therefore, no generic values can be defined for the transition speed in any mode. The range of the selected parameters for each transition can be seen in Figure 7.1.

Table 7.1: Range of selected parameters for each transition.

Transition	Min	Max	Average	STD
Logarithmic (Base)	7	475	203	191
Proportional (Coefficient)	2282	11660	52868	39065
Fixed (Transition)	0.4	3	1.2	0.84

Positive recollection

Three photos were chosen randomly from the participants' photo stream and another three were selected from the researcher's photo stream. We asked the participants if they remembered these photos from the slideshow. The mean average for remembering their photos was 3 out of 3 while the average for remembering the researcher's photos was 2.7 out of 3. After applying one-way ANOVA, we got values of F(1.38)=8.14 and p=0.006. After viewing the two photo streams using this application, it can be concluded that there is a significant difference between remembering the user's own photos and the researcher's photos. On average, the participants remembered 5 out of 6 photos (83.3%) of what happened next to them and the researcher when a photo from their stream was shown. On the other hand, they remembered 4.5 out of 6 photos (75%) of what happened next to them and the researcher when they saw a photo from the researcher's stream. One-way ANOVA resulted in $F(1.38)=1.7$ and $p=0.18$, showing that there is no significant difference between the means. The results show that, although the participants might sometimes forget what happened next in different conditions, mostly in the researcher's stream, they have a good recollection of the narrative in the multiple photo streams. Therefore, the side-by-side photo sharing application is an effective way for remembering the user's own photo stream and comparing it with a friend's photo stream. This application can be utilised as a storytelling tool, enabling relationships to be made between different events that have occurred in the life of two friends through their shared photos. Figure 7.4 demonstrates the positive recollection score of what happened next in the user's stream or the researcher's stream.

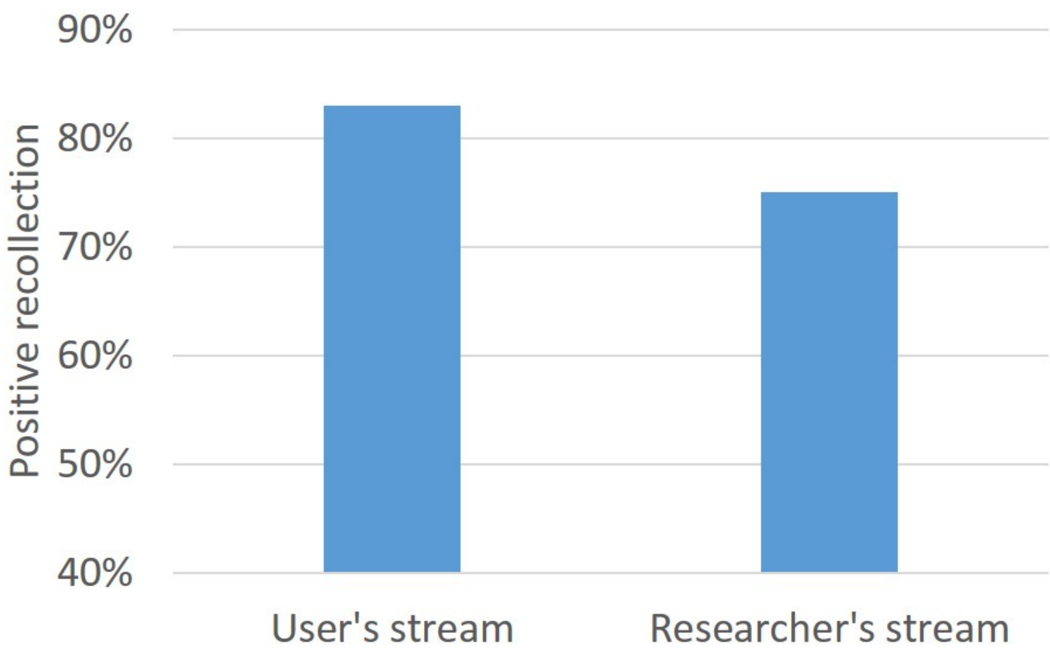

Figure 7.4: Positive recollection score of what happened next in the user's and the researcher's photo stream.

Positive recollection between females and males

Each participant was shown a photo first from their own stream and then the study organiser's streams, in three different conditions; the participants were then asked if they could remember that photo and whether they could remember what happened next. Therefore, there were 18 overall situations which means we asked participants in each of the three phases (Each contains 6 situations) if they remember their photo and their friend's photo (2 out of 18) and what happened next in their stream and friends stream after showing their friends photo and their own photo(4 out of 18).

When the participants saw a photo from their own stream, on average, females remembered 8.37 out of 9 with (93%, standard deviation=0.6) situations regarding the presented photo and what happened next, while, on average males remembered 7.21 out of 9 (80.1%, standard deviation=0.5) situations.

Moreover, when the participants saw a photo from the researcher's stream, on average, females remembered 7.80 out of 9 situations (86.6%, standard deviation=2.1) while males remembered 6.40 out of 9 situations (71.1%, standard deviation=2).

The results (Figure 7.5) showed that females are better at remembering photos and the ANOVA test showed that females remember photos significantly better than males for both self-streams and other's streams.

Positive recollection in different transitions

In order to investigate whether the transition modes affect the memory of what happened next in both photo streams, the average of remembering the participant's and researcher's streams for each transition mode was calculated. The participants remembered 5.1 out of 6 photos (85%) in the fixed transition mode, while they remembered 4.9 out of 6 (81.6%) in the proportional transition mode. Logarithmic was the best mode with 5.2 out of 6 photos (86.6%) remembered. One-way ANOVA resulted in F(2.57)=0.3, p=0.6, showing that there is no significant

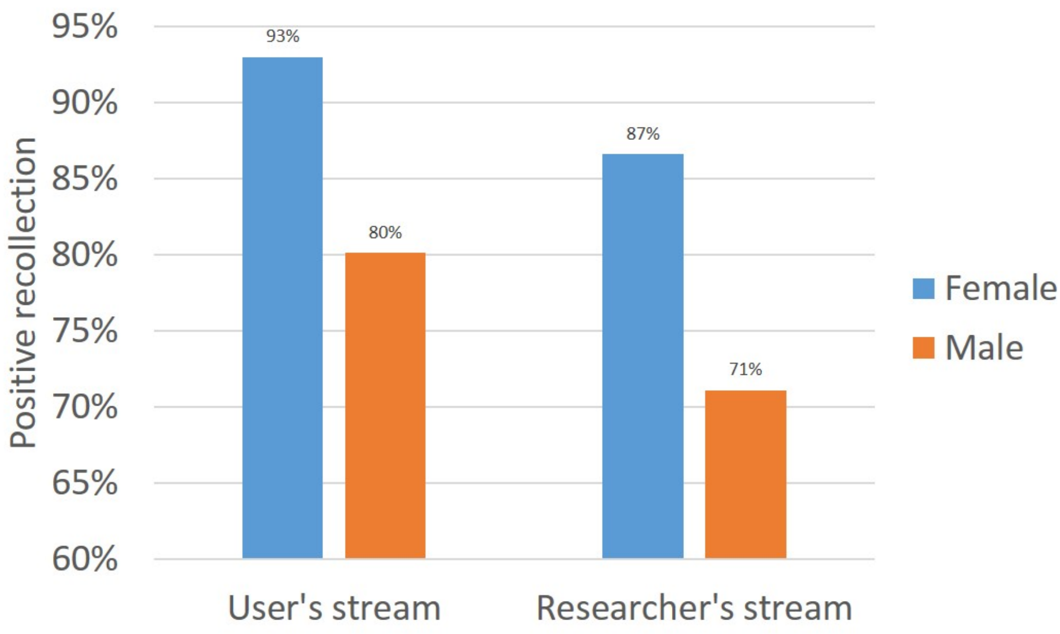

FIGURE 7.5: Positive recollection score comparison of what happened next in the user's and the researcher's photo stream between males and females.

difference between the three transition modes for remembering what happened next. The results of the positive recollection of remembering what happened next in different transitions is illustrated in Figure 7.6.

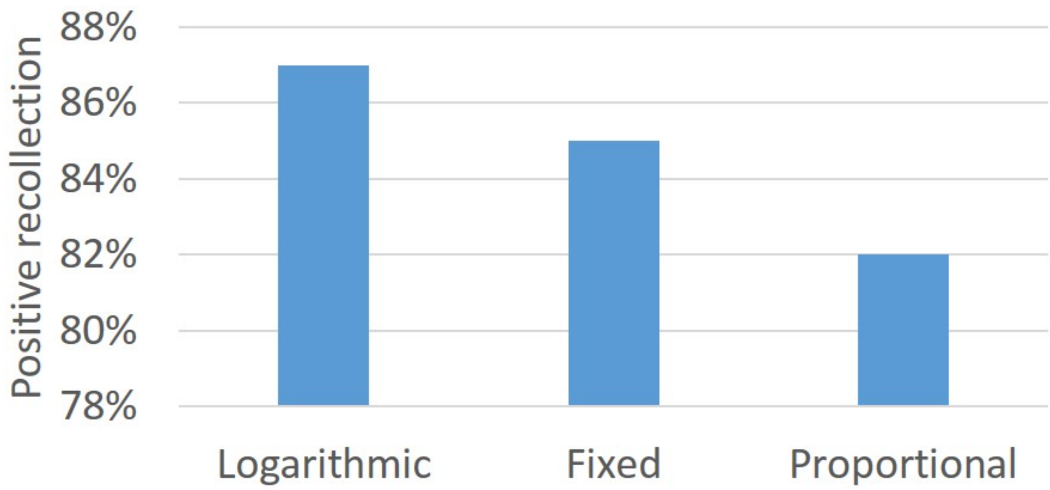

FIGURE 7.6: Results of the positive recollection of the photo and what happened next in different transitions.

Alternation between windows

In the proposed interface, one of the two presented photos would change after each transition interval. In case the transition happens in a window that did not change in the last transition, we have an alternation. The number of alternations between slideshow windows was calculated for each set of 300 photos. We found that, on average, there were 14.86 alternations in each data set. Out of the twenty participants, twelve used a camera phone and eight used a point-and-shoot camera. In the study conducted in Phase 1 (Chapter 5), it was found that more alternations between photo streams bring a better experience in the visualisation of multiple photo streams. This study showed that the average number of alternations in photo streams generated by a camera phone (18.22) was larger than that for a point-and-shoot camera (9.91). One-way ANOVA resulted in $F(1.58)=19.38$ and $p<0.0005$, and proved that there is a significant difference between the means of the number of alternations. Hence, it can be concluded that the current practice of photography with a camera phone in comparison to a point-and-shoot camera provides more evenly distributed photo streams and, consequently, more alternations between photo streams. Figure 7.2 shows the average number of alternations between slideshow windows for camera phones, point-and-shoot cameras and overall. The reason for this analysis was that in the previous study, most of the photo collections were generated by point-and-shoot cameras. By enhancing the application in this phase, however, people tended to take more photos using their camera phones because of the accessibility and good quality photo creation. Therefore, in this section, we analysed the differences between new photographic trends, specifically, between photos taken with camera phones and photos taken by point-and-shoot cameras. The result showed that camera phone photos result in a better experience compared to point-and-shoot camera photo collections.

Search

After viewing the photo streams, each participant was asked to find their own photo and the researcher's photo, which were picked randomly from the streams

TABLE 7.2: Average alternation between slideshow windows

	Average alternation between slideshow windows
Camera phone	18.22
Point-and-shoot camera	9.91
Overall	14.86

within the timeline, via controller buttons such as the play and pause buttons. On average, it took 49.66 seconds to find the photo from the user's own stream and 43.83 seconds to find the photo from the researcher's stream. Users searched both streams to find the chosen photos. No significant differences between the two data sets were found using one-way ANOVA: $F(1.118)=0.64$, $p=0.4$. On average, it took 46.75 seconds for each participant to find the photo after viewing both streams. The participants used mainly two techniques to find a photo. In the first technique, they used the timeline to find the event to which the photo belonged; they then located the photo by going through that event's photos using a one-by-one search. In the second technique, in cases where the participants were not sure which event the photo belonged to, they used a combination of timeline scanning and playing the photo streams in fast mode, until the required event was found. One of the participants said:

> "This reminds me of the VHS style, it is nice to search like this and see other photos until finding the one I want."

7.3 Evaluation of continuity detection

The fourth transition mode for the synchronous visualisation interface, which was introduced in the previous chapter, is continuity. In this mode, if two consecutive photos are continuous, the transition is set to be significantly faster than the speed set by the user. In this section, three different continuity algorithms applied for continuity transition were evaluated to select the most appropriate algorithm for continuity transition.

7.3.1 Method

The first step was to determine the decision thresholds for each of the three proposed continuity algorithms. Thus, an interface was designed to let the user decide if there is a continuity between two adjacent photos. In this interface, two consecutive photos are displayed forwards and backwards in time with a delay of 0.4 seconds in slideshow mode until the user decides if these two photos are continuous or not. After the user makes a decision, another pair of new photos is shown on the screen. In this experiment we presented 779 photos of a ski trip to the participants. The dataset was comprised of photos often taken in bursts, resulting in a good proportion of continuous photos. The participants decided which consecutive photos were continuous using the proposed interface. The manual decisions were logged and used to determine the optimal threshold of continuity for each of the proposed algorithms. Using the optimal thresholds, a comparison was conducted to determine which algorithm was the best for detecting continuity in photo streams.

7.3.2 Accuracy of algorithms

In order to detect which photo pairs were "continuous", three algorithms were applied, namely SIFT flow, SIFT and optical flow, which were described in the previous chapter and will be evaluated in this chapter. The process of the comparison of these techniques is depicted in Figure 7.7.

As described in the previous section, to find the accuracy of continuity detection for each algorithm, the users labelled continuous photo pairs using three different resolutions: small (60*40), medium (400*300) and large (640*480). The accuracy was calculated using Equation 7.1.

$$Accuracy = \frac{T_p + T_n}{T_p + T_n + F_p + F_n} \tag{7.1}$$

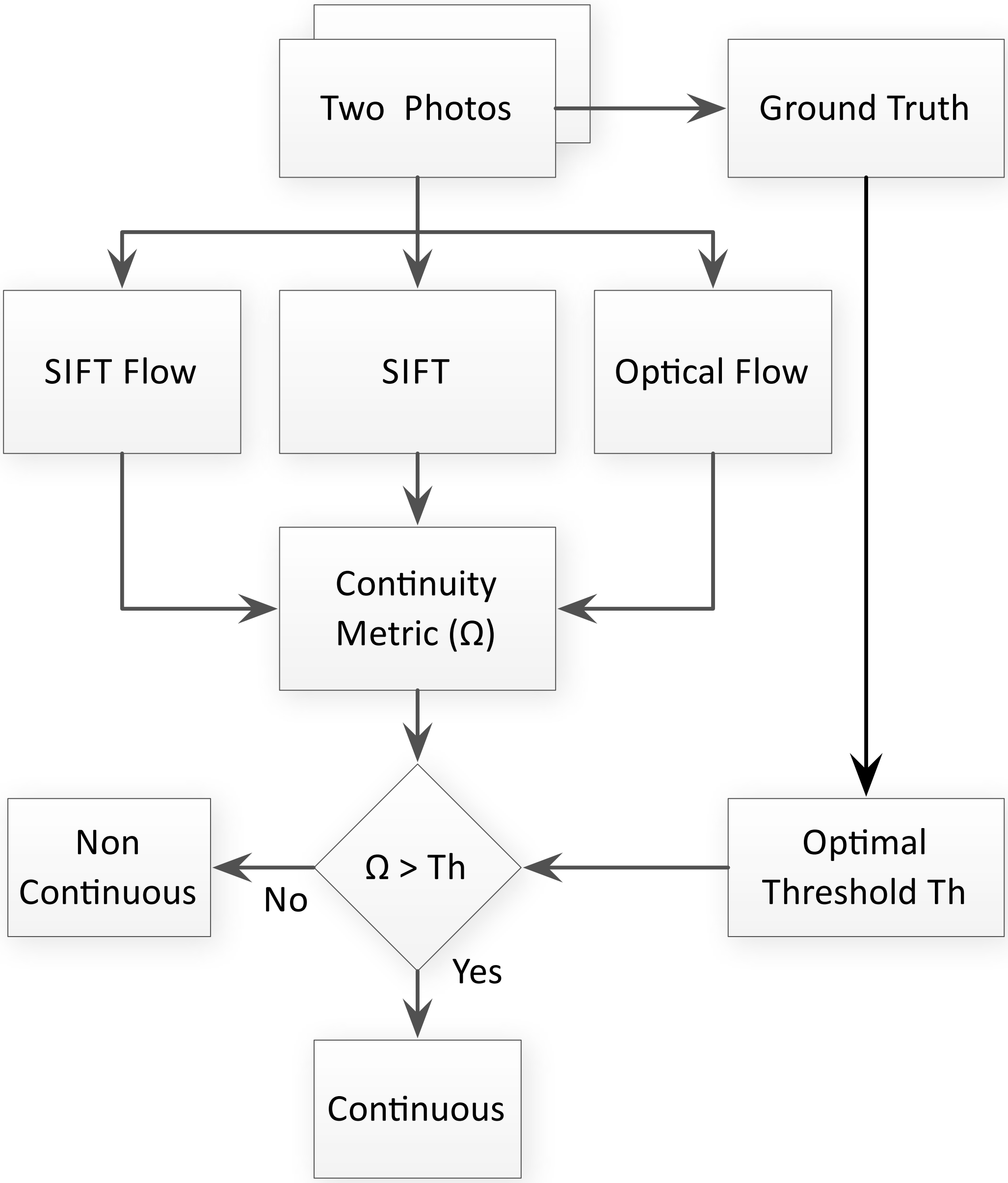

FIGURE 7.7: The process of the estimation of the continuity between two photos.

Here, the terms true positives (T_p), true negatives (T_n), false positives (F_p) and false negatives (F_n) compare the results of the detector with the manually labelled ground truth. This was done by comparing the optimal threshold and the continuity metric. In SIFT the continuity metric was the displacement of matched SIFT features in their proximity. Based on Equation 7.1 the optimal displacement was found by comparing it to the ground truth, which the accuracy of the algorithm was calculated. In SIFT flow, the optimal flow for dense sift was calculated using the same equation by comparing it to the ground truth. The same was done for optical flow by calculating the optimal flow.

The results of the accuracy of each algorithm are illustrated in Table 7.3. The accuracy of SIFT flow was 81% for small, 79% for medium and 79% for large size photos. The accuracy of SIFT for small, medium and large size photos was 91%. The accuracy of optical flow for small size photos was 69%, 71% for medium size photos and 75% for large size photos. The results showed that the proposed algorithm with SIFT had the closest performance to human decision making in determining continuity.

Table 7.3: Accuracy of the proposed algorithms for different photo sizes compared to the ground truth

Algorithm/Size	Small	Medium	Large
SIFT Flow	81%	79%	79%
SIFT	91%	91%	91%
Optical Flow	69%	71%	75%

After selecting the SIFT-based continuity detector as being the closest algorithm to human labelling, the number of continuous photos in the photo set of the experiment for manual transitions was calculated. There were three sets of 300 photos for each participant and, in total, there were twenty participants. The results showed that 85 out of 300 photos in each dataset were detected to be "continuous". This shows that there was a significant number of continuous photos in the user's personal photo collections and, thus, a great potential for exploiting continuity in visualising photo streams.

7.3.3 Continuity transition mode use

The users felt that the continuity transition mode appeared as a cross-over between the logarithmic transition mode and the fixed transition mode. By switching to the continuity transition mode, the participants were able to view discrete (non-continuous) photos in detail, just linked by the fixed transition mode. Furthermore, photos of continuous events were shown like a time-lapse video, just like in the logarithmic transition mode for photos captured in bursts. The logarithmic transition mode did not, however, present photos as continuous if they had been taken over a longer period of time (i.e., a time-lapse of a flower blooming).

7.4 Evaluation of desired time transitions

In the previous chapter, we designed two desired time transitions from the lessons learned in Phase 1 of our study: logarithmic and summarisation desired time transitions. In this section, the logarithmic desired time and summarisation desired time are compared.

7.4.1 Comparison of logarithmic and summarisation desired time

Method

In this section, the logarithmic and summarisation desired times are evaluated with different desired times to determine which method is more suitable for different total slideshow times. Twenty participants were recruited with an age range of 20 to 35 years; all participants were research students. We provided a photo set which contained 300 photos taken at various events by two photographers. The reason to provide 300 photos was that they were available from the previous study which was evaluation of temporal aspects and supporting the experience of slow technology [172] for users.

The desired time was set different in six iterations. In the first iteration, the desired time was 30 seconds and then 50, 75, 150, 225 and 300 seconds in the following iterations, respectively. In each iteration, we showed multiple photo streams to participants using both the summarisation and logarithmic desired time techniques. We selected up to 300 seconds since there was a time limit for the duration of the study. Moreover, the results showed that the ratio of 300 seconds for 300 photos was boring for participants which indicates that 300 seconds was enough limit for the maximum presentation. The participants were then asked to score how much they liked the presentation, giving a score from 1 to 10. The users were able to select the summarisation transition time between slides manually; by default it was set to 1.2 seconds, which was the average selected parameter for the fixed transition in the previous study.

Results

We compared the user preference in different total slideshow times to conclude if the length of the slideshow affects the selection of the desired time type by the user. The result illustrates that the summary desired time was the most suitable method for presenting all multiple photo streams in 30 seconds. The preference average score for 30 seconds in the summary desired time was 5.55 (standard deviation=1.8), while the logarithmic average score was 1 (standard deviation=0) as the presentation was very fast. The t-test showed that there is a significant difference between the means ($p<0.05$).

For a 50-second desired time, the logarithmic average score was low with 4.7 (standard deviation=1.4), while the summary desired time technique preference score increased to 6.7 (standard deviation=1). The t-test showed that the averages were significantly different ($p<0.05$).

When the desired time increased to 75 seconds, the average score for the summarisation desired time was 7.7 (standard deviation=1.1), while the average score for the logarithmic desired time was 7.05 (standard deviation=1.5). The t-test showed that the averages were not significantly different ($p>0.05$).

In 150 seconds of presentation, the average score for the logarithmic desired time was 8.7 (standard deviation=1.1), while the average score for the summarisation desired time was 7.45 (standard deviation=0.9). The t-test showed that the averages were significantly different ($p<0.05$).

When the total slideshow time was set to 225 seconds, the summary desired time preference score decreased to 7.05 (standard deviation=1.1) and most of the participants believed that the slideshow was a little long. However, the logarithmic desired time score was 8.2 (standard deviation=1.1) and the participants believed that the notion of time of the event change by the slideshow speed, as well as the faster presentation of photos taken in bursts, made the presentation more interesting. The t-test showed that the average scores were significantly different ($p<0.05$).

Lastly, when we increased the desired time to 300 seconds, the average score in the summarisation desired time was 5.6 (standard deviation=1.2) while the average score in the logarithmic desired time was 8.05 (standard deviation=1.3). The t-test showed that the results were significantly different ($p <0.05$). 90% of the participants believed that 300 seconds for the presentation of 300 photos in the slideshow mode is too long and boring. However, the notion of time in the logarithmic desired time transition made it more interesting.

It can be concluded from the information above that an increase in the total slideshow time results in enhanced interest in the logarithmic desired time compared to the summarisation desired time. However, the summarisation desired time held more interest for shorter slideshow times. Figure 7.8 illustrates the preference score of the summarisation and logarithmic desired time transitions for different slideshow lengths.

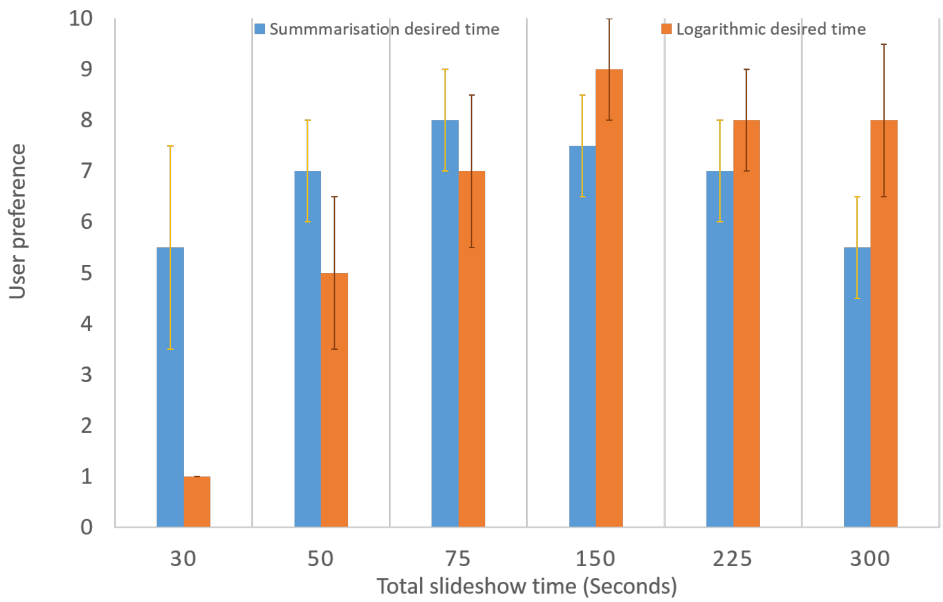

Figure 7.8: Presentation preference for different desired times.

7.4.2 User experience of summarisation and logarithmic desired time

At the end of the laboratory-based user study, we asked the participants about their feeling regarding these two transitions: when do they prefer to use either of these two transitions and how do they compare them with a normal slideshow?

The most positive answer was that the summarisation desired time is suitable when they want to view photos in more detail and they do not have time to view them all. As a result, the summarisation desired time was suitable when the participants wanted to review multiple photo streams with an emphasis on collocated and remote experiences, and to see the detail of each photo. On the other hand, the logarithmic desired time was suitable when the participants wanted to see the multiple photo streams faster and to just follow the photo stream storyline; although they could not see the photos in detail, they could follow the storylines of the photos in more detail.

7.5 Summary and discussion

In this chapter, the temporal aspects of the visualisation of multiple streams were evaluated in the laboratory environment. In the first section of this chapter, the visualisation of multiple photo streams, alongside the manual transitions (logarithmic, proportional and fixed), were evaluated. The results showed that the logarithmic transition was the favorite transition among the participants, who liked to use the logarithmic transition when they wanted to review multiple photo streams rapidly. The reason for this is that the logarithmic transition affects the total slideshow time and brings the notion of time to the user. The fixed transition was preferred when the participants wanted to view their photo streams in more detail with a slower transition speed. The users did not like the proportional transition compared to the other two transitions as they stated that it was sometimes too fast or too slow. Moreover, the values that participants selected for the presentation speed in each transition were different. Therefore, no generic values can be defined for the transition speed in any mode.

It was claimed in [173] that the gist of a single scene photo can be perceived in 100 msec. Moreover, Greene and Oliva [174] claimed that the gist of characteristics such as a natural or urban scene can be perceived in as little as 30 msec. Potter [175] also claimed that people can identify the presence of a particular scene in a photo stream presented at a rate of one scene every 125 msec. Therefore, the time interval of the slideshow in this application was never less that 30 msec. However, there is no previous research on remembering the order of multiple photo streams and the visual stories told by those streams. Our findings show that, although the participants might forget what happened next in different conditions (mostly in the researcher's stream) when we showed them a photo from the presentation of multiple photo streams, they have a good recollection of the narrative from multiple photo streams by remembering both the photos and what happened next in 79.15% of the cases. Hence, this application was a good platform for remembering photo collection stories of friends and comparing past events through the photographic medium.

Overall, it can be concluded that our application is suitable for release as a story telling tool between multiple photographers. In addition, the results showed that the positive recollection of stories between friends did not affect the transition types and the average rate of remembering what happened during the presentation was not significantly different.

The results from this section also illustrate that camera phone photo streams have more alternation between slideshow windows, which results in a better experience of viewing multiple photo streams compared to point-and-shoot camera photo streams. We found that searching through a timeline is pleasant for participants since the average time for finding a photo in multiple photo streams is reasonable. Moreover, using fast play alongside the timeline features enabled the participants not only to find a specific photo they were looking for, but also to enjoy viewing other photos.

The second section of this chapter described the evaluation of continuity transition to show continuous photos faster like a time-lapse video. Three algorithms (SIFT, SIFT flow and optical flow) were used to create the continuity transition; SIFT was found to be the best of the algorithms upon evaluation. The logarithmic transition enabled the participants to view photos taken in bursts faster. In addition to showing continuous photos taken in bursts faster, the continuity transition also showed photos taken over a longer period of time in time-lapse mode (such as the time-lapse of a flower blooming).

The third section of this chapter described the evaluation of the summarisation and the logarithmic desired time transitions, which enabled the user to choose the total slideshow time and then, either to present photos using the logarithmic desired time transition or to eliminate the redundant photos using the summarisation desired time. Therefore, the summarisation desired time and the logarithmic desired time techniques were compared. The results showed that, for short presentation times, the summarisation desired time is better than the logarithmic desired time. However, when the total slideshow length increased, the participants preferred the logarithmic desired time. The summarisation desired time was preferred when the participants wanted to review each photo in detail. The logarithmic desired time was suitable when the participants wanted to view photo streams rapidly and just follow the storylines of the photo streams.

A potential future work adding to this system can be designing and evaluating the the system using face recognition, the tag label of the person who was on the photo or the location that photos were taken rather than focusing on temporal aspects and only the people who uploaded their photo streams.

The next chapter will describe the design and building of an extended version for sharing and visualisation of multiple photo streams as an ambient display, using the lessons learned in Phase 1; a user experience study is also carried out. In this new design, the users will be able to see the latest shared photos (visual statuses) via Facebook in their slideshow windows. Moreover, the logarithmic transition, which was the favourite manual transition, will be applied to this system.

Chapter 8

4Streams: An ambient photo sharing application

8.1 Introduction

In Phase 3 of the project, we designed a system from the lessons learned in the initial user study from Phase 1, addressing the user requirements of sharing and visualising multiple photo streams.

The initial system in Phase 1 was designed for users to upload their past photos and share them with a small group of friends and/or family. The system enabled the users to view multiple photo streams concurrently and compare their past photos. We found that, most of the time, the users could remember their own photo streams and other users' photo streams while viewing them concurrently (Phase 2). However, in Phase 1 of the system design, the only place where the users could see the latest uploaded photos was the upload page in a grid visualisation style.

In the user study we found that the participants wanted to see the latest visual status of the small groups of friends in the multiple-window slideshow interface, rather than on the upload page, they also wanted to be notified immediately about everybody's most recent activities. Our first design upload page did not show each participant's photo streams separately and the multiple-window slideshow page had filter sliders to let the user choose the date. Therefore, in Phase 1 the system was not showing the latest 'status' photos of each participant in the single/multiple windows and it mostly emphasised showing the historical photos concurrently in a slideshow mode.

The other finding from the initial user study was that the participants liked the idea of viewing photo streams on a digital photo frame screen and leave it somewhere as an ambient display. For example, there was a participant who used an iPad 2. He really liked the idea of interacting with our system and viewing photos on a screen that size. He also added that it could be a very good idea to leave the iPad as a digital photo frame at home and see the photo streams on the digital ambient display. In addition, in Phase 2, we found that the logarithmic transition was the favourite transition in presenting multiple photo streams.

Therefore, from the initial user study that conveyed an observed lack of presenting live visual statuses of multiple photo streams between multiple users, and emphasising the value of the digital ambient display, we designed '4Streams' to allow the user to upload photos from their smartphone using Facebook and to see the latest statuses of members in a small group. Moreover, we kept the feature that allowed the user to view their past photos so that they could go back over time and compare past visual statuses in the slideshow mode using the logarithmic transition. In this application the users can review their latest visual statuses alongside their past visual statuses, rather than only historical photos. The system was implemented and installed on a Microsoft Surface Pro tablet that was equipped with a stand to be left as a decoration tool, rendering the application into a digital ambient display.

8.2 Design

The design of this system comprised two elements. Element 1 was the upload time when participants were able to share and send their photos to our application

(4Streams) using Facebook. Element 2 was the display, which included different interaction options and live updates of the latest participant photos as an ambient display. These two elements will now be described in detail.

8.2.1 Upload

Unlike the previous versions of the application, 4Streams claimed to be 'integrated with Facebook' and did not have a separate upload page; the upload engine of this version was Facebook. Therefore, the user was able to select the photos they had taken and use Facebook to upload them into any album they wanted. Moreover, the user was able to upload a photo straight after taking it using the Facebook integrated application, as found on current smart phones. Regardless of where in their Facebook photo collection the users saved the photo, the photo was saved into our system if the system was turned on and connected to the Internet. Due to privacy concerns and photo ownership, user-tagged photos in Facebook were not used in 4Streams in the current design.

The requirement to visualise the shared photos via Facebook on 4Streams was to add 4Streams to the user's Facebook friends. Then, if the user shared a photo with 4Streams or with a circle of friends with 4Streams, the photo was presented on our application. Basically, privacy settings are one of the features Facebook provides for sharing photos; this privacy setting lets the user choose the people with whom they want to share a photo.

One advantage of changing the privacy settings before sharing a photo via Facebook is that it gives the opportunity to the users to choose whether they want to present their shared photos on 4Streams (or not) by including (or excluding) a particular 4Streams user in their privacy settings. This means that when a user shares a photo, if they only choose 4Streams, the shared photo will appear only on the display of our application and only those users who use our application will be able to see the photo on the 4Stream display. The other option is to share the photo with 4Streams and other people whom the user intends to share their photos with on Facebook. Therefore, with this option, the photo will appear on the 4Streams display and other users will also be notified from the Facebook application. The user is also able to share their photo with all their friends. In this case, the shared photo will again appear on the 4Streams display and all the user's Facebook friends will be notified on Facebook.

In the upload phase, the system saves the photo and information such as the person who uploaded the photo and the date and time that the photo was uploaded onto Facebook. Figure 8.1 shows the upload action using a smartphone.

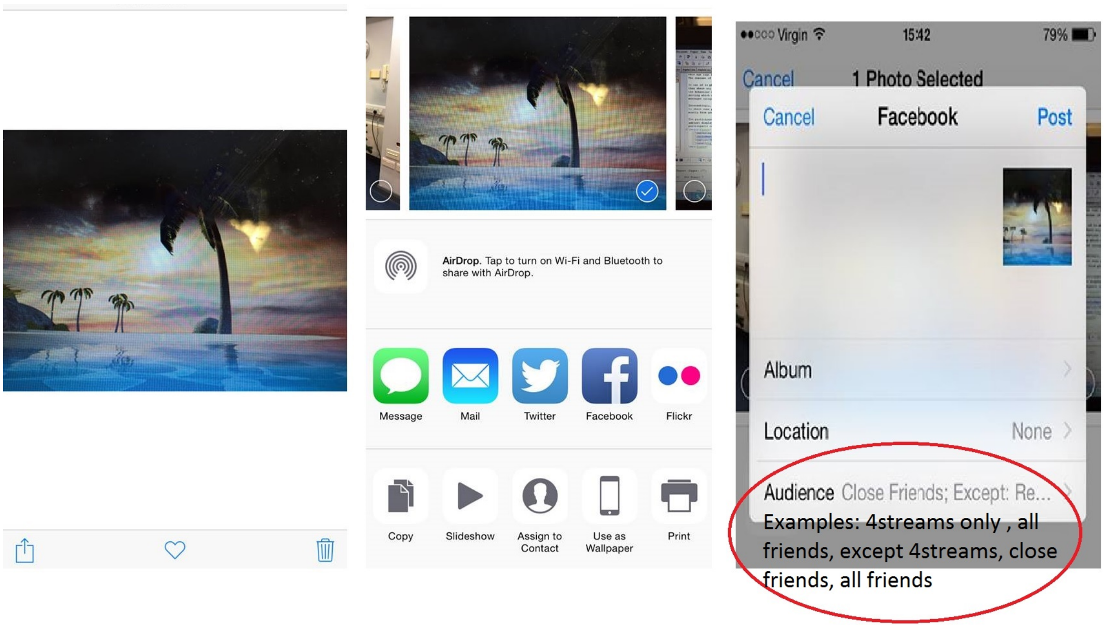

FIGURE 8.1: Sample screenshots of uploading photos using Facebook.

8.2.2 Display

After uploading photos from multiple users, the system saves them and their associated information. In the next step, the photos are shown on 4Streams and, following that, the system beeps to notify the user of the arrival of the new photo. Like the two previous interfaces, 4Streams contains four slideshow windows, which show multiple photo streams from different users concurrently. In addition, this version shows the latest photos that were uploaded by multiple users in the slideshow window. Therefore, the users are able to see the latest visual status of the members of their small groups such as family members or friends, and to compare them with their own photo stream. Figure 8.2 illustrates the 4Streams interface on a Microsoft Surface Pro tablet. The application was able to run on any Windows machine.

FIGURE 8.2: 4Streams interface on a Microsoft Surface Pro tablet.

Full screen mode

When the application launches in the full screen mode, four slideshow windows, each containing the photo streams from different users, appear on the screen. Each slideshow window shows the latest uploaded photo by each user. The optimum size, which we set experimentally for each slideshow window in this mode, was a rectangle with dimensions 500*350 pixels. One problem we came across was the change in the aspect ratio of the photos in the slideshow window; we could either select the centre of the photo while keeping the original aspect ratio or change the aspect ratio of the photo on the screen and show all the contents in the slideshow window. To decide between these two approaches we asked 25 people, showing them the results of these two options; 80% of them suggested that keeping the content of the photo was more important than keeping the original aspect ratio, since the aspect ratio change was not so significant on the screen. It took only two seconds for a photo to appear on 4Streams after the user uploaded the photo on Facebook. The full screen mode of 4Streams can be seen in Figure 8.3.

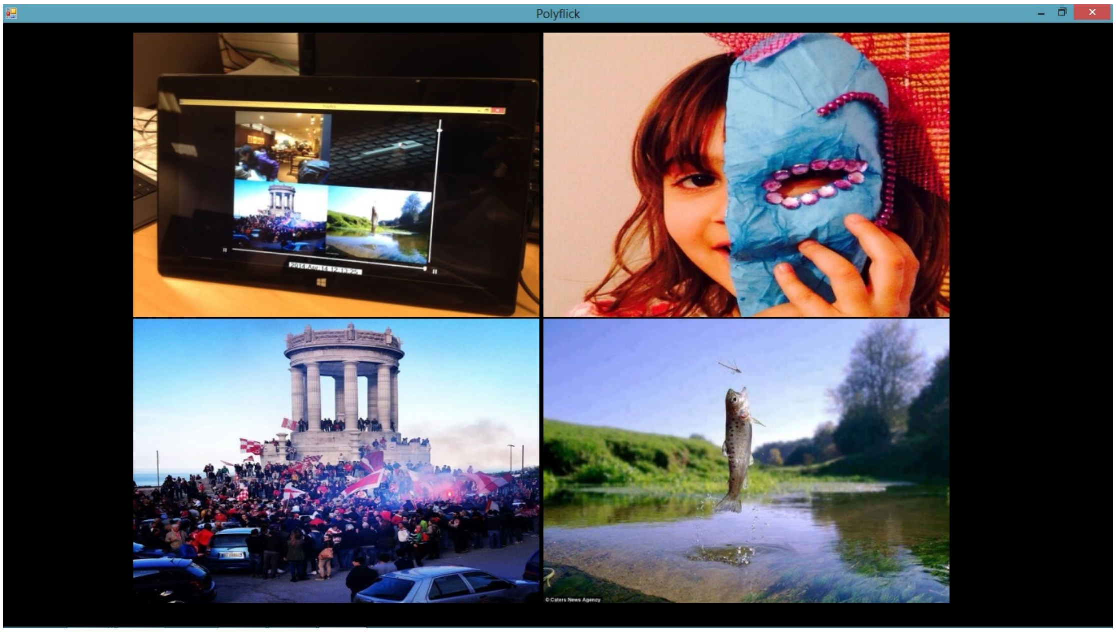

FIGURE 8.3: 4Streams full screen mode. Each slideshow window is dedicated to a user and the users can follow their latest visual status.

Setting mode

The setting mode appears when a user touches or clicks on any of the four photos in the full screen mode. Clicking on the setting mode photos toggles the display mode back to the multi-window slideshow. In the setting mode, the slideshow windows become smaller with dimension 400*300 pixels, where the change in the aspect ratio is not significant.

Changing the image dimensions results in having more space on the screen. Therefore, we placed a horizontal timeline under the four photos to allow users to view previous photos and see what happened earlier. By changing the slider, the closest photos to the chosen date appear. Unlike the first prototype in Phase 1 of the study, the default date for the slider is the date the most recent photo was taken; the date and time of the photo appears under the slider to support the narrative of the photo stream.

There is a vertical slider on the right side of the screen that enables the user to control the speed of the slideshow. The transition type chosen for 4Streams was the logarithmic transition because it was the preferred transition in the previous study (Phase 2).

On the left side of the slider there is a play-backward button and on the right side of the slider there is a play button. These buttons allow the user to start and control the slideshow for multiple photo streams. After touching or clicking play or play-backward, the buttons change to a pause button and vice versa. When the slideshow reaches the end, the pause button changes to play and play-backward buttons.

By clicking on any of the photos on the screen in the setting mode, the system returns to the full screen mode. Therefore, the user is also able to view a slideshow of multiple photo streams in the full screen mode. Moreover, by swiping any of the photos on the screen, the system goes into the single-window slideshow mode. Figure 8.4 shows the setting mode interface of the system.

Single-window slideshow mode

By swiping a photo in the setting mode, the system goes to the single-window slideshow mode, which enables the user to see the photo stream that belongs to the owner of the swapped photo. The controlling elements in the single-window slideshow mode are the same as those in the setting mode; the only difference is the stream of one user instead of multiple photo streams. The original size and dimension of the image is kept during the presentation in this mode. There is a back button on the top left side of the window to put the system goes to the setting mode. The screenshot of the single-window slideshow can be seen in Figure 8.5.

FIGURE 8.4: 4Streams setting mode.

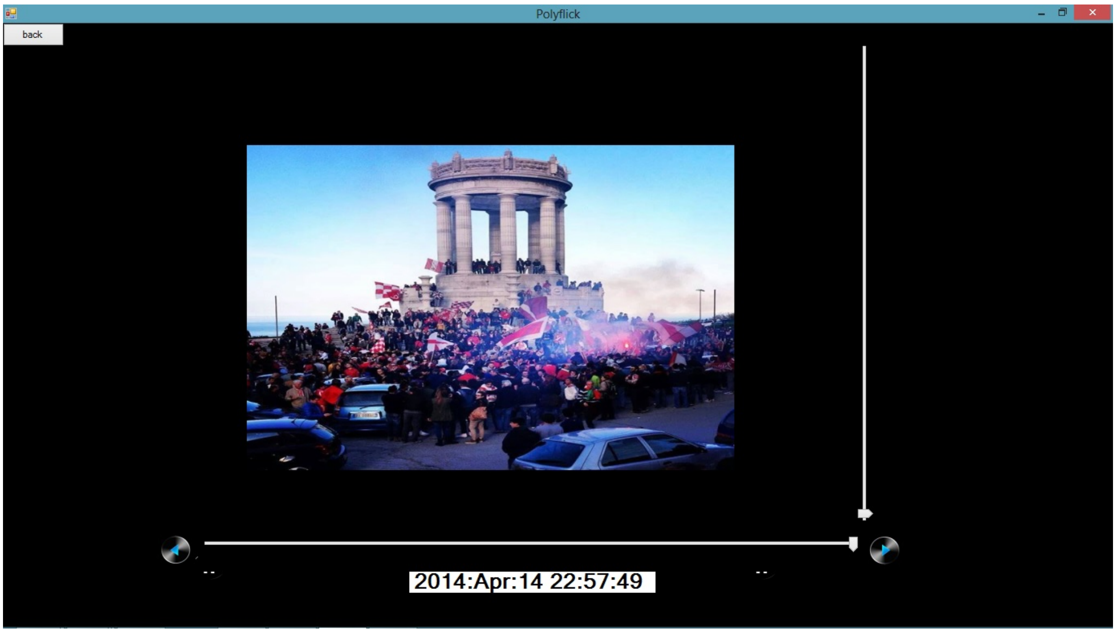

FIGURE 8.5: 4Streams single-window slideshow mode.

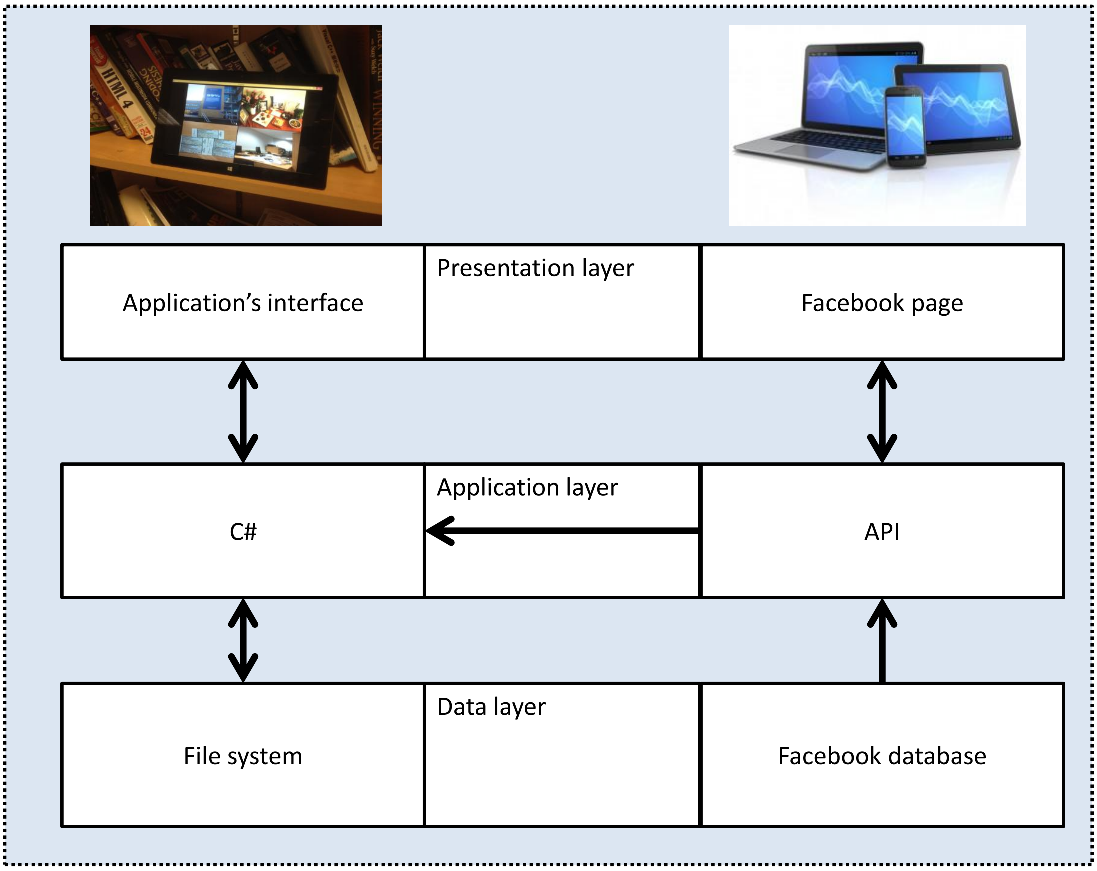

Figure 8.6: 4Streams architecture.

8.3 Implementation

8.3.1 System architecture

The system architecture in this application is comprised of four layers, which can be seen in Figure 8.6: client layer, user interface layer, application layer and data layer.

The client layer has two parts. The first part is a Windows machine, which enables the user to run the application. The second part is a smartphone or any computer that can be connected to Facebook in order to upload photos.

The second layer is the user interface and it has two parts. The 4Streams user interface is the first part included in the design contents of our system. All the elements explained in the design section are present in this layer. The other part of this layer is the Facebook user interface, which was developed by Facebook. The 4Streams user interface is connected to the first part of the application layer, which is a Windows machine, and the Facebook user interface is connected to the source where the photos are uploaded.

The third layer is the application layer and it has two parts. The first part is a C# developing tool, which forms the engine and controller of the 4Streams user interface. The other part of this layer is the application program interface (API) part, which sends Facebook information to the C# developing tool and the Facebook user interface.

The fourth layer is the data layer. In this layer, the first part is a file system. The other part is the Facebook database, which is connected to the Facebook API for transferring the information through the Facebook interface and the C# developing tool.

8.3.2 Facebook API and authentication with C#

The API is a set of routines, protocols and tools for building software applications. The API specifies how software components should interact and it is used when programming GUI components. A good API makes it easier to develop a program by providing all the building blocks the programmer then puts together.

There are many different types of APIs for operating systems, applications and websites. Windows, for example, has many API sets that are used by system hardware and applications; when you copy and paste text from one application to another, it is an API that allows that to work.

Most operating environments, such as Windows, provide an API so that programmers can write applications consistent with the operating environment. Today, APIs are also specified by websites; for example, Amazon, eBay, Google Maps and Facebook use APIs to allow developers to use the existing retail infrastructure to create specialised web stores. Third-party software developers also use Web APIs to create software solutions for end users. We now describe the Facebook API in detail.

Facebook is a rich and complex software platform, which exposes developers to a sophisticated and multifaceted development framework [176]. The meaning of Facebook programming might not be clear at first. There are essentially two types of applications related to Facebook.

One type comprises applications that live and thrive within the Facebook environment. These applications are essentially rich web pages loaded onto Facebook canvas pages and hosted on the main site. To use the applications, the users need to navigate to the Facebook site and log in to their own account. These applications can implement their own logic with whatever you can express from within a web page using web programming technologies and can gain access to Facebook friends, news feeds, media, photos and more.

Another approach to Facebook programming involves integrating some core Facebook functionalities into existing applications, such as websites, mobile applications, iOS, Android, Windows and desktop applications. We used a Facebook API through the second approach, which means we designed and implemented 4Streams to have access to the Facebook database.

In this approach, after registering as a developer, Facebook provides the developer with three codes: a client ID, client secret and a token string. We used them for authentication of the application by the Facebook API. The client ID and 'secret' enable a developer to reference the application during programming, while the 'token' provides the password key for the user of the application.

After the 4Streams application had been recognised, the Facebook API and C# were connected. There are two methods to access the Facebook database; the first method is Graph API [177] and the second method is Facebook Query Language (FQL) [178].

The Graph API is the primary way to get data in and out of Facebook's social graph. It is a low-level HTTP-based API that can be used to query data, post new stories, upload photos and perform a variety of other tasks an application might need to perform. The Graph API is named after the idea of a social graph. Representation of the Facebook information on Facebook is represented in Graph by: nodes (things such as a user, a photo, a page or a comment), edges (the connections between things, such as a page's photos or a photo's comments) and fields (such as the birthday of a user or the name of a page).

FQL enables the programmer to use an SQL-style interface to query the data exposed by the Graph API; it provides advanced features not available in the Graph API. FQL can handle simple maths, basic Boolean operators, AND or NOT logical operators, and ORDER BY and LIMIT clauses. It also provides information conveniently about the photos such as the owner of the photo, caption, date and time of the upload, name of the album and comments.

In the implementation of 4Streams, these two methods (Graph API and FQL) were combined. For basic information such as user information and identification, Graph API was used, while for deeper information such as downloading a photo, FQL was used for accessing information specific to that photo.

The data gathered by both techniques were formatted in to a Json array [179], which was accessed by a Json library [180] installed in C#. The result of the Json array was interpreted and presented meaningfully on the user interface layer using the C# engine.

8.3.3 Developing tool

The developing tool applied to code the core program of 4Streams was C#. C# is a multi-paradigm programming language encompassing strong typing, imperative, declarative, functional, generic, object-oriented (class-based) and component-oriented programming disciplines. It was developed by Microsoft within its .NET initiative and later approved as a standard by Ecma and ISO. C# is one of the programming languages designed for the Common Language Infrastructure [129].

In C#, we were able to design the interface using a GUI tool designed for interface programming. The items and the interaction elements could be placed on the application's interface using this feature of C#. The connectivity between the GUI section and the API was made using the C# main programming engine. In this part, the latest photos taken in Facebook by any of the participants were checked every two seconds and, if a new photo arrived from Facebook, the Facebook API passed that photo with its information from the Facebook database to the C# engine. After that, the C# engine sent that photo to the GUI page and, subsequently, the photo appeared on the 4Streams interface. All received photos and their information were saved to a file on the hard disk of the machine running 4Streams.

8.3.4 Interaction logs

4Streams was capable of saving the interaction logs of the system user on each device separately. The elements saved onto the system for further data analysis are now listed:

- Photo.
- Date and time the photo was uploaded.
- Date and time the photo was captured (if available).
- Photographer's Facebook ID and name.
- Time the application ran.
- Time the application closed.
- Time the application went to full screen mode.
- Time the application went to setting mode.
- Time the application went to single-window slideshow mode.

- Speed of the slideshow.
- Time a photo was downloaded to the system and name of the user who did it.
- Name of and time a control button was clicked.
- Duration of each slideshow's play or play-backward command.
- Photo's privacy setting.

8.4 Pilot study

8.4.1 Procedure

After designing and implementing 4Streams, a pilot study was conducted to evaluate the application's performance before conducting a real user study to see whether there is any interest in using 4Streams. It also allowed for finding and fixing the initial bugs of the application. In order to start the pilot study we operated 4Streams between four people. The participants were two lecturers and two PhD students at the University of Surrey, and they all had a desk at work. The application was installed on four Microsoft Surface Pro tablets. The tablets had stands and could be placed in a fixed location as a digital ambient display; all tablets were placed on the work desk. 4Streams was tested and used for a week. We did not perform any interviews or obtain any quantitative information in this phase and just analysed from the contents of the photos and the way participants used 4Streams by asking them informally about their experience.

8.4.2 Results

Interestingly, 85 photos were shared over a week-long period. The numbers of shared photos from each participant were: 25, 29, 17 and 14 (average of 21.25 and standard deviation of 6.9). All photos conveyed a sense of visual communication and news telling between the users. The way 4Streams was used and interpreted is discussed below. A sample of photos taken during the pilot study can be seen in Figure 8.7.

FIGURE 8.7: Pilot study photo samples.

News telling One way to use 4Streams was to tell the latest news of the participants by uploading the most recent visual status. Most of the time the users updated their photos to say what they were doing at the time of the pilot study. For example, one lecturer uploaded a movie he wanted to view or a photo of himself with other colleagues while showing them 4Streams. Another lecturer shared a photo of his children. One PhD student uploaded a photo of his dog, while the other shared a photo of their office and a new coffee machine they had bought.

Response to the news The participants in this study did not just tell their news; they also responded to the latest news of other participants by uploading a new photo. Therefore, the visual statuses from users in this study sometimes had a response. After uploading a photo which conveyed interest in opening a discussion, other users tried to answer the initial visual message with another one. For example, the first lecturer shared a photo, which was a message on a whiteboard that said “It is 7:10, and leaving now after a hard work”. The other lecturer responded by leaving another message on the whiteboard which said “It is 7:15 and leaving after a long day too”. Another scenario for message sending and responding was when one of the lecturers wrote a note on paper saying “It is Friday and nice to cycle” and one of the students replied with a photo from his office when he was working hard.

Wish messages During the pilot study some participants sent wish messages to others, sometimes targeting a single person. For example, there were some photos of a birthday cake to say happy birthday to one of the users. Moreover, there was a moment when a user shared a note on paper with the message of good luck to another user. Therefore, our pilot study shows 4Streams was a good platform to send visual wish messages.

Competition on creating the lifelog The obvious behaviour in the practice of sharing photos using 4Streams during the pilot study was that users were very keen to create a meaningful three-dimensional lifelog of photos in order to review them later. All shared photos contained a visual message and sometimes opened a discussion and, therefore, the flow of the photo stories was meaningful but, of course, the stories were discrete in time. After playing the 85 photos and viewing what happened between the users, 4Streams visualised a concurrent photographic lifelog of the four users in a very emotional way; it was a very good platform to remind them of all the moments and joy during the pilot study. The joy of creating the lifelog was one of the biggest impacts of 4Streams.

A platform to mention the system's bugs 4Streams also helped us to get information from the users regarding the system bugs. During the pilot study, the users took a screenshot of the errors they found on the system and, interestingly, 4Streams became a communication tool to let the developers know about the problems of the system. Sometimes during the bug discovery phase, some funny moments were noted; for example, one of the users posted a photo saying "damn bugs" when he found bugs. One of the lecturer's students in a supervisory meeting answered this in a funny way by writing a note saying "my mom used to call me a bug".

Colleagues and socialisation In this pilot study, it has been found that there is value using a photo sharing ambient display between colleagues in a remote environment. The results showed that all participants were keen on sharing their photos with each other, from everyday life to work moments. For example, they all shared photos from their travels or relaxation time as well as their current workplace statuses.

From the findings of the pilot study, it can be concluded that 4Streams is suitable as a photographic communication tool between colleagues in remote environments.

8.5 Summary

In this chapter, we described the design and implementation of a photo sharing application called 4Streams. In 4Streams, up to four users are able to share their photos using Facebook and see the latest visual status of each other on the screen. Moreover, they are able to see the photos taken concurrently in slideshow mode.

In order to implement 4Streams, firstly, we firstly took advantage of the Facebook API to connect the display to the user's Facebook account. Therefore, when a user took a photo, they were capable of sharing it with the 4Streams display by sharing the photo with alltheir friends, or only the 4Streams display.

4Streams contained three modes: full screen, setup and single-window slideshow mode. In the full screen mode, the system was ambient whereby the latest photo uploaded by each user was shown on the screen. In the setting mode, the user was able to play or play back the multiple photo streams they had taken as a slideshow. Moreover, there was a timeline where the user could go forward and backward over the multiple photo streams. In the single-window slideshow mode, the user could chose just a user's photo stream and review their photos.

In order to implement 4Streams, the design and the core logic of the system in the presentation and application layers was implemented by a C# developing tool. Following that, FQL and Graph API were applied to query the photos and their information from Facebook.

The system was deployed on four users as a pilot study to find out the value of using 4Streams. The pilot study showed that 4Streams was a good platform for telling news via photographs, sending wish messages, creating photo diaries and visual communication between the users. Moreover, this pilot study revealed the value of photo sharing in the workplace between colleagues. The next chapter will describe how 4Streams was applied to three different groups (close friends, family and colleagues) to investigate the user experience of the system in three different trials.

Chapter 9

Field study of 4Streams

9.1 Introduction

In the previous chapter, a novel photo sharing application, 4Streams, was designed and built as an ambient photo display, following design guidelines from the Phase 1 and Phase 2 requirements studies. 4Streams enables users to share their photos via the Facebook platform and display them synchronously in real time. Therefore, users are able to share their photos immediately after taking them using their smartphones. Moreover, 4Streams was designed to let the users review their historical photos shared on the system concurrently. In the previous chapter, the 4Streams application was deployed on four users in a pilot study and the results showed that the system needs to be evaluated by different types of small user groups in situated user trials. Three different user groups were chosen: extended family, close friends and work colleagues.

In the first study, we installed 4Streams on two Microsoft Surface Pro tablets and gave the display to an extended family to observe utilisation of the system. This group had four participants. The main reason to choose an extended family context was the closeness of the group members and the frequent exchange of photos between family members; there are often digital photo frames in family houses, displaying close and extended family members. In addition, it has been anticipated that the remote connection between family members (extended notion of family members) might increase the value of our application.

In the second study, 4Streams was deployed on four Microsoft Surface Pro tablets and given to four teenage friends to explore the user experience in a group of close friends. As in Phase 1 of our study, the reason for selecting *close* friends as a group was that they are ready to share their personal photos with fewer privacy concerns. Moreover, for a group of close friends, there is an explicit need for applications to enable easy sharing of their photos with each other [39].

In the third study, 4Streams was installed on an office computer and connected to a big display and situated in a workplace in a collocated environment to see how an ambient photo sharing display affects the workplace group dynamics. There were two reasons to select this workplace group. Firstly, in the pilot study of Phase 3, the participants were workplace colleagues and the study showed that this participant type showed strong interest for photo sharing using our approach. Secondly, we wanted to evaluate the collocated nature of our display and, therefore, we decided to select this group. The third study included five participants.

For data collection and analysis, a semi-structured group interview was first conducted for each group separately and the data were analysed using a thematic analysis approach. Secondly, the system logs were collected and analysed by quantitative analysis. Each trial is described separately in the following sections.

9.2 Trial 1: Extended family group

9.2.1 Participants

The family group was an extended family of four. An extended family group was recruited because in Phase 1 of the study we found that family members were interested in knowing what happened between them via their old photos. Moreover, family is a valid example of a small group of people with low privacy concerns whose members intend to share their photos with each other [19]. In addition, there is a digital photo frame in the house of most families, which can provide good motivation for placing our ambient photo sharing and visualisation tool in a family house. It is anticipated that the remote connection between family members (extended notion of family members) might increase the value in using our application.

Two members of the family, the father and mother, lived in the United Kingdom (Country 1), the grandmother lived in continental Europe (Country 2) and the niece lived in the USA (Country 3). Hence, this study aimed to evaluate the impact of the system in a live photo sharing scenario. The ambient display was observed by both collocated family members living together and remote members who lived in other countries. There were three female participants and one male participant. Their ages were in the range 38 to 68 years. The average age was 41 years and the standard deviation of their age was 21 years. Part of this group also participated in the first study. After the participants agreed to participate in this study, they read and signed the consent form. Information regarding family group participants is detailed in Table 9.1. The names are not the real participant names. To appreciate their participation, each member of the group was given a small gift.

Table 9.1: Family group participants

No.	Name	Age	Gender
F1	John	39	M
F2	Helen	40	F
F3	Elizabeth	68	F
F4	Diana	17	F

9.2.2 Initial setup

To conduct this study, two Microsoft Surface Pro tablets (D1 and D2) were provided. The 4Streams application (described in Chapter 8) was installed on both devices and then they were given to the participants. The tablets had Microsoft Windows 8 operating system installed. The tablets were touchscreens with an external keyboard. Figure 9.1 illustrates the Microsoft tablet used in this study. The tablets were kindly provided by Microsoft Research Centre in Cambridge in support of the study.

FIGURE 9.1: Microsoft Surface Pro tablet.

One of the tablets was used in F1 and F2's house in Country 1 and the other tablet was used in F3's house in Country 2. F4 was a passive user who just took photos and notified others.

F1, F2 and F4 had a Facebook account so they only needed to add our system account (4Streams) to their Facebook friends. F1, the father of the family, created a Facebook account for F3 and added 4Streams, alongside the other members of the family, to his friends list. The reason to add the 4Streams account to their Facebook friends was to be able to share and present their Facebook photos on the 4Streams display.

The participants were advised to share their photos on Facebook choosing from three privacy options in order to share the photos on the 4Streams display. The first privacy option was to share the photos with all their friends, resulting in the appearance of the photos on both the screen and the timelines of all their Facebook friends, regardless of whether they had access to the 4Streams display. The second option was to share the photos with just the family members of the study (F1, F2, F3 and F4) and 4Streams. In this case, the family members could see the photos on the 4Streams display as well as get notifications on Facebook. The third option was to share the photos solely with 4Streams, thus being only able to see the photos on the 4Streams display but not on the Facebook timeline.

The participants were advised on the different options of sharing their photos via Facebook. They could use their point-and-shoot digital camera to take photos and later upload the photos via their personal computers or tablet devices. In addition, three participants had smartphones with the ability to connect to the Internet via Wi-Fi or 3G; therefore, they had the option of taking photos with their camera phones and uploading them directly. All their smartphones had the Facebook application for which they could set the privacy setting before uploading their photos.

The participants were asked to run the application on their Microsoft Windows operating system whenever they turned on their tablet and to use the tablet as their preferred device. They were asked to use the Surface tablet as a digital photo frame. They were also asked to keep the device on as much as possible because the system did not have the capability of accessing photos retroactively.

In the test phase, all participants uploaded some photos on Facebook and the photos were visualised on the Surface tablet screen successfully. The participants were asked to use the timeline and control buttons to refer to photos taken earlier. The interactions with the system were explained to the participants in detail, and a demo from the pilot study was shown to them. The family group used the system and participated in the study for seven consecutive weeks.

9.3 Data collection and analysis

To collect qualitative data from the group, a semi-structured interview technique was used alongside the collection of interaction logs as quantitative data. The method for analysing the qualitative data from the interviews was adopted from [20] and was undertaken in several stages in the present study. The guidance form of the interview can be seen in A.7.

The first stage of the analysis was to listen to the recorded interviews. The next step was to transcribe the interviews; transcripts were read once and, then, were read again carefully. Once the reading was complete, several passes were made through the data to code them and define themes and categories using Nvivo software.

The other method of data analysis was to use quantitative data. Each device in the study stored the interaction logs. Information such as the time of the upload, the content of the uploaded photos, the person who shared the photos and the buttons and settings used, was stored in the logs of the system and analysed quantitatively later using Microsoft Excel. This technique was also applied for Trials 2 and 3.

9.3.1 Results

This section deals with the results of the qualitative and quantitative analyses. Firstly, the results from the interviews on the participants' current photographic practices are presented. This is followed by an analysis of quantitative data extracted from the interaction logs. Finally, the user experience of the participants using 4Streams is described.

Current photographic practice

Capturing Camera phones were the dominant capture device among the participants of this group. In the previous study, which took place two years previously, both camera phones and point-and-shoot cameras were used equally. The camera phone was used in situations where the participants did not have swift access to their point-and-shoot cameras. On the other hand, point-and-shoot cameras were used only on special occasions where the quality of the photos was of importance to the participants. However, this study showed that the quality of the photos taken by camera phones was as satisfactory as common point-and-shoot cameras, explaining why the participants predominantly used camera phones as their main capture device.

For example, F1 and F2 both said they used an Apple iPhone device but not any point-and-shoot cameras any more. F1 said:

> "We used to have a simple camera, like the old-school snappy simple camera. We would take it on holidays or on trips, take photos, come back home, offload them onto the computer. But we don't use the camera anymore; we both have smartphones and we've completely lost contact with cameras."

F2 added:

> "We both have iPhones so they produce pictures of good enough quality. Yes, so I think I only use that for taking photos."

The grandmother of the family (F3) had a point-and-shoot camera, but due to broken battery, she was using an old camera phone to take photographs. Also, she took photos quite rarely.

Storing In the family group F1 was the manager of their photo collections. F2 said that she does not manage any photos and she just passes them to F1. F1 said that he has two main repositories for the family photos. Firstly, he frequently uploads their phone photos to an external hard drive. He has set up a Google+ account where he uploads photos from the camera phones automatically. Therefore, he has all the photos in the Google+ photo cloud and on physical memory.

He also added that after each update to physical memory, he deletes the photos from their camera phones. This pointed out that cloud computing, such as social networks or third-party servers, is emerging as a new means of photo storing.

Sharing The family group did not share their photos on Facebook because of privacy issues. However, Google+ was very common among them and F1 uploaded his photos via Google+ when he was away from home due to the stronger privacy setting provided by Google+. F2 said:

> "Like last year when John was in America for two weeks, we were checking every day on Google+ where he's been and what he's done."

They claimed that their main sharing platform is email and not current social networks and instant message applications. They were also using other applications, such as Whatsapp and Viber, for sharing photos between each other, but not very regularly. Regarding the use of instant message application services for photo sharing, F2 said:

> "You remember you installed WhatsApp for me because you were going to the market and you were supposed to send me a photo."

The grandmother of the family was not able to share photos using cloud technologies. However, other members of this group were using current technologies to share photos but still not as their main photo sharing platform.

Structure of the family members

The study was taken during summertime and, therefore, some family members were travelling, which provided a good opportunity for this study to investigate the impact of the system when family members were remote. In this study, the structure of the family members was classified into the following five phases:

1. Start of study in Country 1
2. Reunion of F1 and F3 in Country 2
3. Return of F1 to Country 1
4. Reunion of F2 and F3 in Country 2
5. Return of F2 to Country 1

The participants used the system for seven weeks. Phase 1 of the study started and finished in two days (10/07 to 12/07) when F1 and F2 were in Country 1 and had one of the Microsoft Surface tablets devices (D1). F3, the grandmother of the family, just had a Facebook account and could only upload photos but she was not provided with a device at that stage (D2); therefore, she was only sharing photos during that period. F4, the passive user, only acted as a photographer and was living in Country 3 during this period.

In Phase 2, which started from the third day of Week 1 and continued until the end of Week 3 (13/07 to 2/08), the father of the family travelled to Country 2 with one of his daughters to stay with F3 for two weeks. Meanwhile, F2 and the other daughter were in Country 1, and F4 was in Country 3. In this phase, F1 carried D2 from Country 1 to Country 2 to place the device there; therefore, F3 was able to use the display from this phase.

In Phase 3, which started in Week 4 and ended in the middle of that week (3/08 to 6/08), F1 came back to Country 1 and joined F1. F4 was in Country 3 in her hometown and F3 was in Country 2 using device D2.

In Phase 4, which started from the middle of Week 4 and ended in the middle of Week 6 (7/08 to 22/08), F2 went to Country 2 to join F3 and F1 stayed in Country 1. D1 was in Country 1 and D2 was still in Country 2. F4 was still in Country 3.

In Phase 5, which started from the middle of Week 6 and continued until the end of Week 7 (23/08 to 2/08), F2 came back to Country 1 to join F1 using D1. F3 was in Country 2 using D2 and F4 travelled to another city in Country 3. Table 9.2 illustrates the structure of the family members and the devices used during the study.

TABLE 9.2: The structure of the family members and the devices used during the study

	Country 2	Country 3	Country 1
Phase 1 (10/07 to 12/07)	F3	F4	F1, F2, D1
Phase 2 (13/07 to 2/08)	F1, F3, D2	F4	F2, D1
Phase 3 (3/08 to 6/08)	F3, D2	F4	F1, F2, D1
Phase 4 (7/08 to 22/08)	F2, F3, D2	F4	F1, D1
Phase 5 (23/08 to 2/08)	F3, D2	F4	F1, F2, D1

The photos sent

The number of photos taken and sent by each participant were counted. In total, 71 photos were uploaded and shared on Facebook. F2 shared and sent 31 photos, the most of all; F1 uploaded 25 photos; F4, a teenager, uploaded 11 photos; F3, an elderly person, uploaded 4 photos. Figure 9.2 illustrates the number of photos sent by each person.

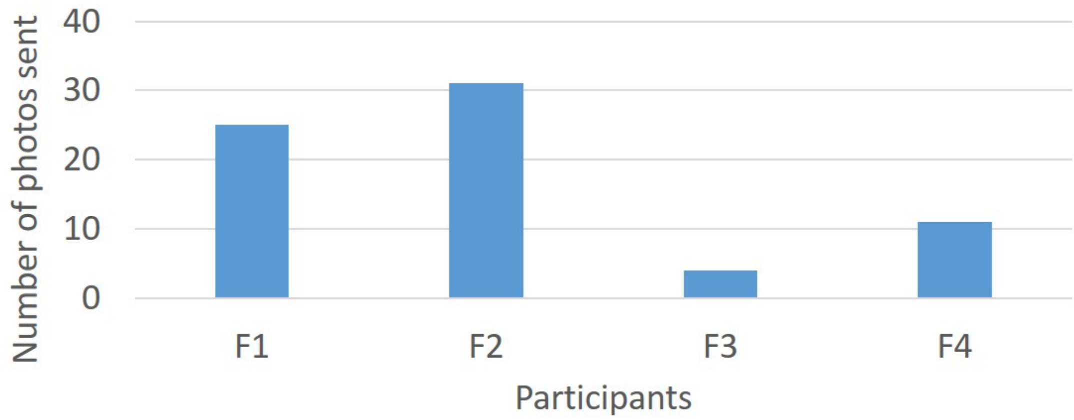

FIGURE 9.2: Total number of photos sent by each participant.

Most of the uploaded photos were taken during the nine days of Phase 5, twenty-two photos in total. In this phase, F1 and F2 were in Country 1 and F3 was in Country 2. F4 was taking photos of her trip to another city of Country 3.

During the twenty-day period of Phase 2, twenty-one photos were taken and shared. During this phase, F1 was in Country 2 while F3 and F2 were in Country 1. In Phase 4, which was four days long, seventeen photos were taken and shared while F2 and F3 were in Country 2 and F1 was in Country 1. In Phase 3, which lasted three days, eight photos were shared while F1 and F2 were in Country 1 and F3 was in Country 2. Finally, in Phase 1, which was only two days long, three photos were shared in the period during which F3 had not yet received D2.

We calculated the average number of photos shared per day in each phase; the results show that Phase 3 had the highest number of photos uploaded per day, with 2.6 photos shared per day. The second highest number of photos uploaded and shared was that of Phase 5, which had 2.4 photos shared per day. In Phase 1, 1.5 photos were taken and shared per day. The average number of photos uploaded and shared in Phase 4 was 1.13 photos per day. Finally, in Phase 2, 1.05 photos were shared per day.

From the average daily photo sharing rate for each phase, it can be concluded that, in phases when F3, the grandmother of the family, was alone in Country 2, the number of photos taken per day increased and the system, therefore, had the highest rate of usage. This illustrates the fact that the family members were inclined to communicate via photos with the oldest member of the family when she was alone. The average number of photos uploaded per day in each phase can be seen in Figure 9.3.

The number of photos taken by, and sent from, each participant during each phase was counted, as seen in Figure 9.4. F2 took the majority of photos across different phases. Therefore, at first glance, it can be concluded that the different phases did not affect the behaviour of the dominant photographer during the study. However, during the interview, F1 mentioned the problem of the Internet connection while he was in Country 2 and, therefore, he could not upload all the photos he took; he had also hoped to share many more photos than he was able to. To sum up, between F1 and F2 who were the most frequent photo takers, the one who was in Country 2 and away from home was more keen on sharing photos.

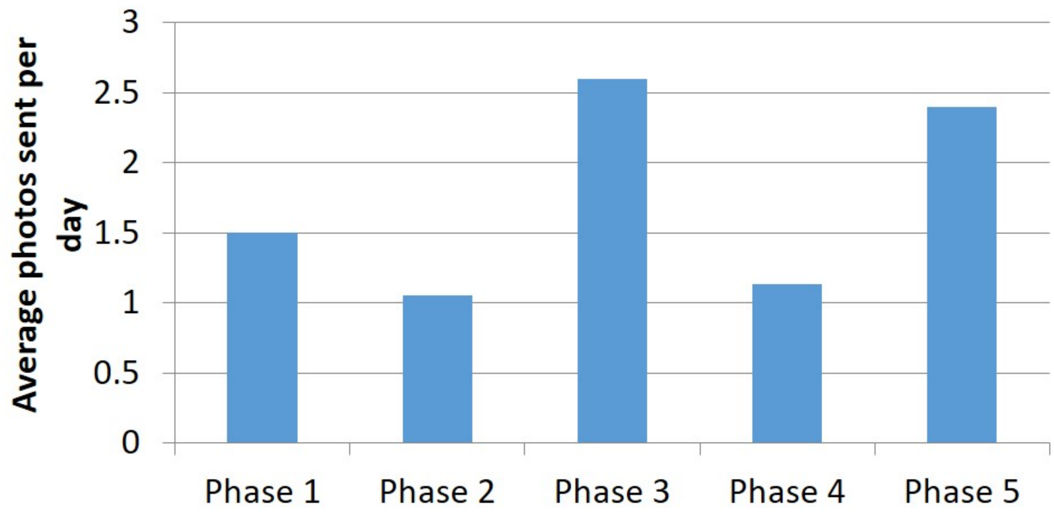

FIGURE 9.3: Average number of photos uploaded per day in each phase.

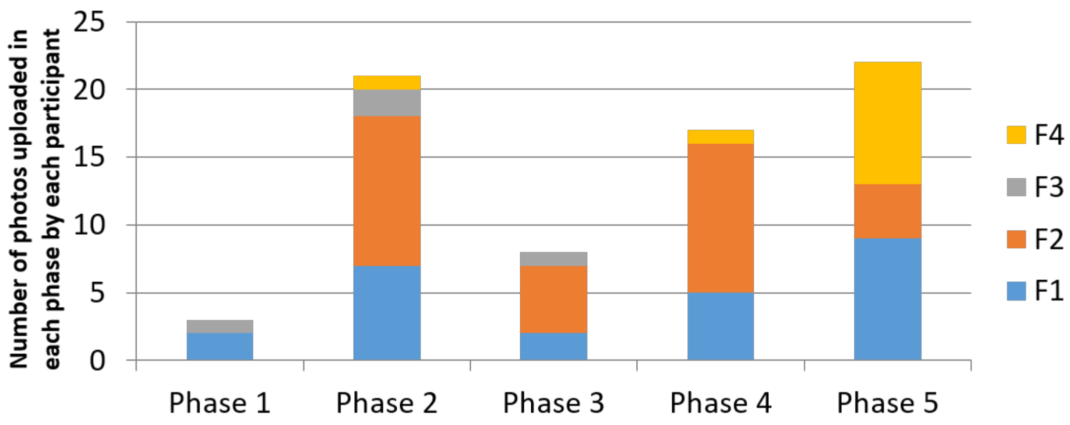

FIGURE 9.4: The number of photos uploaded by each participant in each phase.

Content analysis of photos

To analyse the content of the sent photos, a categorisation technique adopted from [19] was used to classify the photos in a meaningful way for social connectedness, using the categories that are now described.

1. Messages. This category contains photos that tell or show something new. For example, new things in a house.

2. Greetings. This category comprises the photos that convey a greeting. For example, a photo that conveys a sense of thinking about the photo viewer or wishing good luck for the viewer.

3. Everyday life. This category contains photos to present the everyday life of the photographer, such as photos of kids and corners of the house.

4. Special events. This category updates the photo viewer that the photographer involved in special moment such as a birthday.

5. Something funny or aesthetic. This category presents photos that are funny or aesthetically pleasing. A photo of a flower or a funny selfie can be considered as fitting into this category.

The categorisation explained above was used to analyse photos sent between the four members of the family. Figure 9.5 shows the number of shared photos among family members in each category.

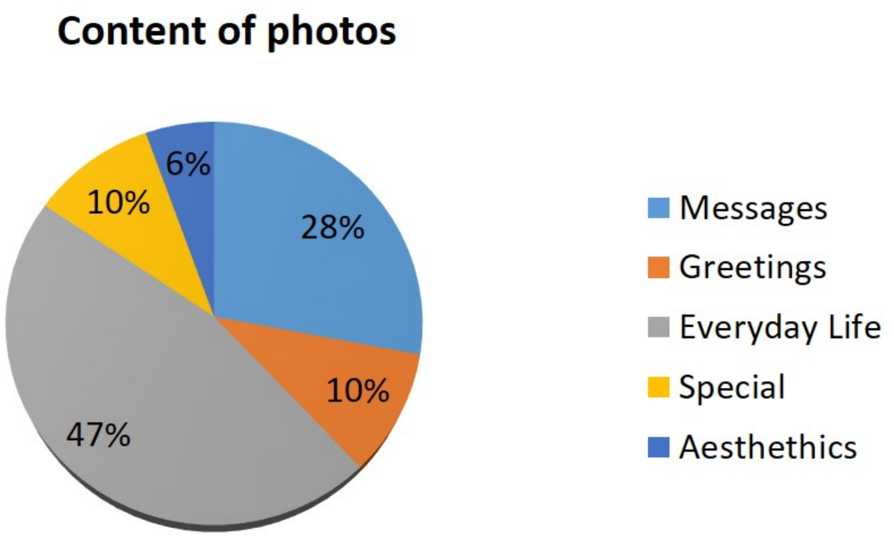

FIGURE 9.5: The number of shared photos in each category.

Messages This category contained 28% of the photos and was the second highest category. Typical examples were photos of the baggage before travelling, screenshots of the application and photos of food.

The niece (F4) sent photos of her boyfriend. F1 and F2 shared photos that show they packed their luggage before travelling. They also sent photos of a meal they cooked and prepared. F1 took photos of his coffee preparation time and his mug.

F1 shared a photo of a whiteboard in his office. The same as F1, F4 shared a whiteboard message which said:“Days until Nina leaves”. Another example was when F2 shared a photo of a Lego kit a child was playing with.

F1 took a photo of a train station with the message “Mind the gap” to show that she had arrived to her destination. Also, F2 took a photo of a noticeboard that detailed the opening times of a local supermarket and shared it with F1 using the application. F1 took photos of his grandmother’s garden in Country 2 to show the new honey harvest tools.

F1 and F2 shared a photo of a fox from their garden and F3 called them from Country 2 instantly after seeing the photo on the screen to tell them that she was impressed by seeing a fox in their son’s garden. F1, F2 and F4 shared photos that can be categorised as messages. Figure 9.20 illustrates sample photos from the messages category.

Figure 9.6: Examples of shared photos in the messages category.

Greetings The percentage of photos that fell in this category was 10%. It typically contained photos of people posing for other family members. F1 took photos of a dog in Country 2. F1 and F2 both took some selfies; overall, there were four photos which could be considered as selfies.

F1 shared a photo of his childhood, which enabled the family to reminisce about the past. F4 shared a photo with her parents showing that they were waving their hands for other members of the family. F1, F2 and F3 shared photos in the greetings category. Samples of photos in the greetings category can be seen in Figure 9.7.

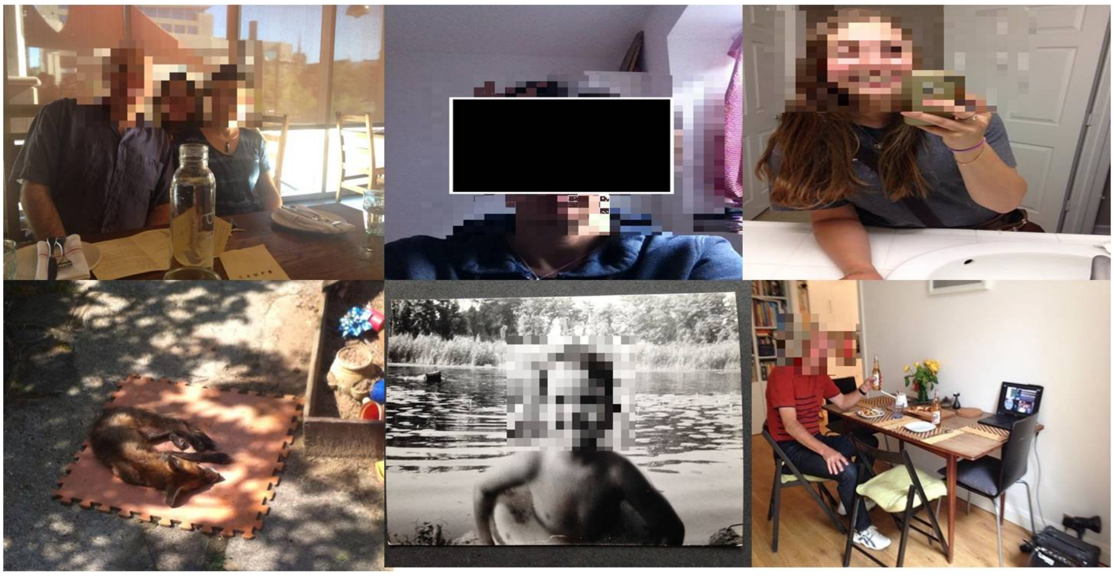

FIGURE 9.7: Examples of shared photos in the greetings category.

Everyday life The largest category, which comprised 47% of the photos, weres photos taken of the everyday life of the participants. Examples include photos of the home environment and young children playing.

For example, F1 uploaded photos of one child playing in Country 2 and F2 uploaded a photo of another child playing in Country 1. There were photos of home furniture, which F2 and F1 uploaded when they were in Country 1. F1 uploaded photos of streets while he was driving. Most of the photos in this category were shared among the family members when they were separated. The grandmother of the family was keen on seeing photos of her grandchildren and the father and the mother liked to see the everyday lives of their children when they were not with them. F1, F2 and F4 shared photos in the everyday life category. Figure 9.8 shows some photo examples in this category.

FIGURE 9.8: Examples of shared photos in the everyday life category.

Special events The special events category had the same proportion of photos as the greetings category, with 10% of the photos. This category included photos of special events such as a birthday party and a concert that some of the participants had taken part in.

F4 shared photos of a concert. She also shared photos of her first trip to another city in Country 3. F1 shared photos of a horse riding event when he was with his daughter in Country 1. F3 and F4 did not share any photos of special events. However, when there was a special event, the number of shared photos was larger compared to the number of photos in other categories. Figure 9.9 presents the shared photos in the special events category.

Funny or aesthetic photos This was the smallest category, with 6% of the photos. The people who shared this kind of photos were the grandmother (F3), F1 and F2. F3 shared a photo of a flower and a lake. F1 shared a selfie photo but

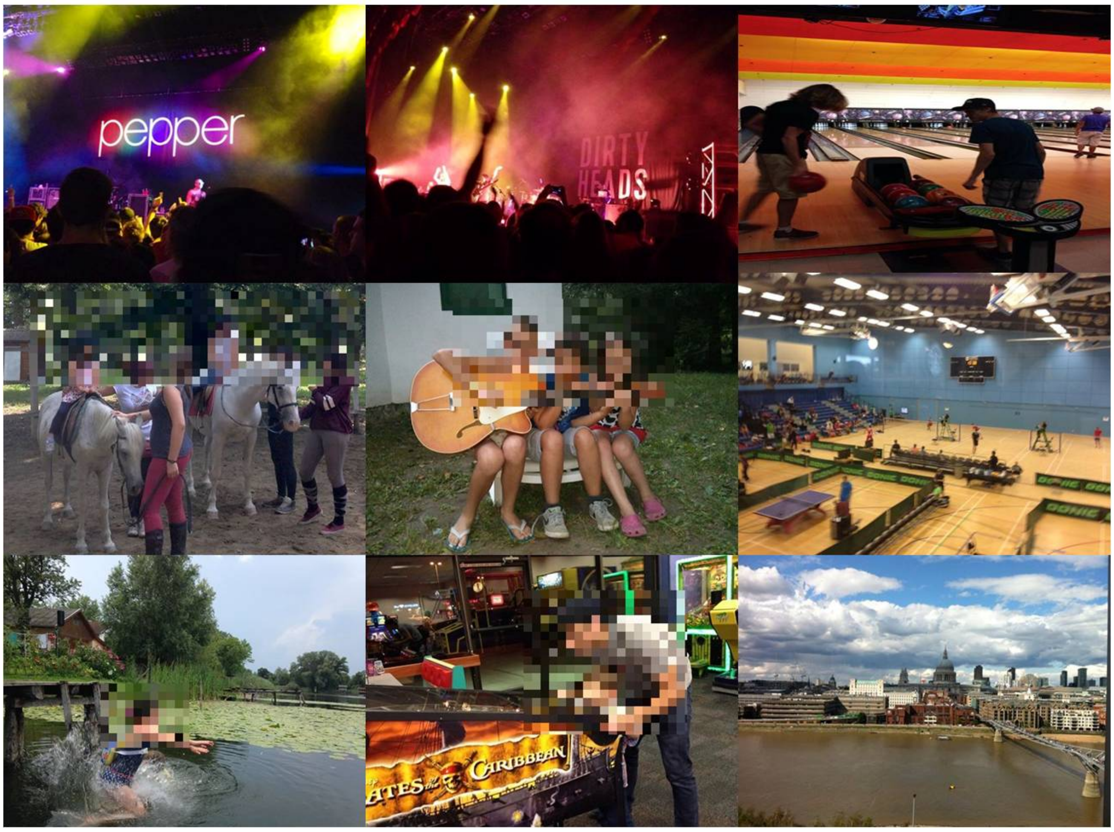

Figure 9.9: Examples of shared photos in the special events category.

since he posed funnily to make others laugh, we placed the photo in this category. Examples of photos from this category can be seen in Figure 9.10.

Privacy settings

The participants had three options to choose in the privacy settings. The first option was to upload photos and share them just with 4Streams, which showed the photos on the screen of the application. The second option was to share the photos with all their friends. The third option was to share the photos with the family members who participated in this study as well as 4Streams.

F1 shared 76% of his photos just with 4Streams, 24% of the photos with family members and no photos with Facebook friends. He said that he does not like to share personal photos in Facebook and that he has lots of friends in Facebook with whom he does not want to share his personal photos. He shared some photos with

Figure 9.10: Examples of shared photos in the funny or aesthetic photos category.

the family group because he wanted them to have those photos in their Facebook accounts. He said sharing with 4Streams is the easiest way to share photos as he did not need to create a group to share the photos with. Another reason for sharing the photos only with 4Streams was that other participants could only see the photos via the device and would not get any notification from Facebook.

F2 shared 97% of their photos with 4Streams only, and just 3% with all her friends. She said that she made a mistake in the privacy settings when she uploaded one photo and she shared it with all her friends when she just wanted to share it with 4Streams. The reason she preferred to share the photos with 4Streams was the same as that given by F1; namely that it has easier privacy settings as well as she was not getting any notification from Facebook.

F3 shared all her photos with all her Facebook friends, who were actually her close family, six in total. As it was not easy for this participant to work with the privacy settings, she decided to share all her photos with all her Facebook friends.

F4 shared all her photos only with 4Streams because all the other participants had agreed to view her photos only via the display and not via Facebook. Nobody in this group shared their photos publicly. The privacy settings for different participants can be seen in Figure 9.11.

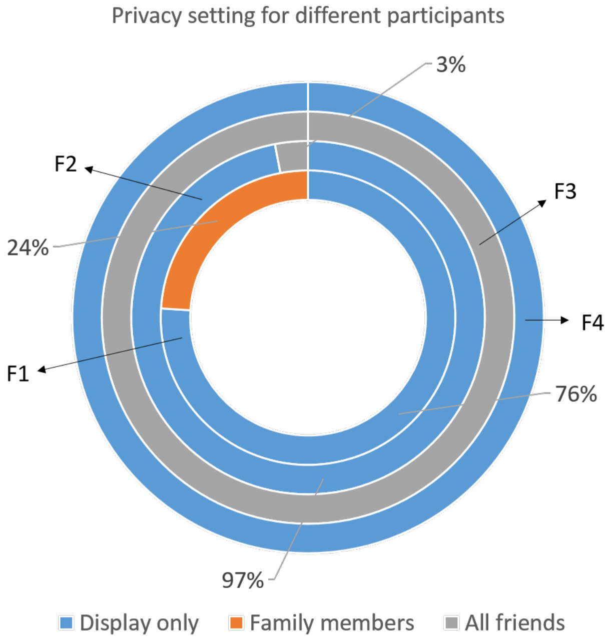

FIGURE 9.11: Privacy settings at the time of upload in the family group.

Received photos

D1 was situated in Country 1, where F1 and F2 were living, and operated from Phase 1 to Phase 5. D2 was sent to Country 2 in Phase 2 until the end of Phase 5. In total, 68 out of 71 photos were received by D1, which shows that the device was operating and connected to the Internet most of the time. D2 received only forty-four photos out of 71. The reason was that in Country 2, the Internet was not connected all the time and it was expensive for the participants to always leave the device on.

During Phase 1, all three photos were retrieved by D1, while no photos were received by D2 as the device was not operating. In Phase 2, twenty photos were received by D1 and nine out of twenty-one photos were received by D2, showing that participants in Country 2 missed many photos. During Phase 3, all eight photos were received by both devices. In Phase 4, sixteen photos were received by D1 and ten photos out of seventeen were received by D2. During Phase 5, twenty-one photos were received by D1 and seventeen out of twenty-one photos were received by D2. F1 said the following about this problem:

> "In Country 2, I could not leave the device on all the time. Therefore, my mother and I missed lots of photos there. I suggest to change the design of the device in a way not to miss the photos."

Figure 9.12 shows the number of photos received by D1 and D2 in each phase.

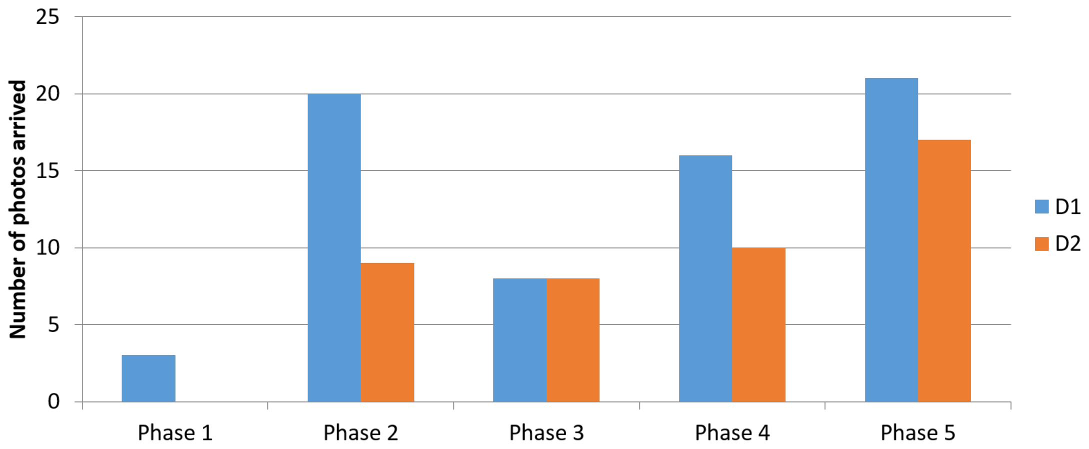

FIGURE 9.12: The number of photos received by D1 and D2 in each phase.

Device use

Overall, D1 operated for 858 hours out of a possible 1176 hours and D2 operated for 406 hours. In Phase 1, which was two days long, D1 operated for 26 hours and D2 did not work at all. In Phase 2, which was twenty days long, D1 operated for 400 hours and D2 operated for 156 hours. In Phase 3, D1 operated for 62 hours and D2 operated for 50 hours. D1 operated for 260 hours and D2 operated for 105 hours in Phase 4. In Phase 5, the D1 operating time was 110 hours and D2 was 95 hours.

On average, D1 worked for 16.44 hours per day and D2 worked for 8.4 hours per day. In Phase 1, D1 operated for 13 hours per day on average and D2 did not operate at all. In Phase 2, D1 operated for 20 hours per day and D2 operated for 7.8 hours. D1 and D2 operated for 20.66 and 15.66 hours per day in Phase 3, respectively. In Phase 4, D1 operated for 17.33 hours per day and D2 operated for 7 hours. In Phase 5, D1 and D2 operated for 12.22 and 10.55 hours per day, respectively.

According to the average usage of D1 per day, D1 was used more frequently until the end of Phase 3, when it reached its peak and, thereafter, the average usage declined as the interest in using the system declined. In D2, the average usage of the system per day rose until the end of Phase 3. In Phase 4, the interest decreased but suddenly in Phase 5, after F3 became alone and F2 left Country 2 for Country 1, the use of the device increased.

Interaction with the system

The users were able to interact with the system. Whenever a user run the application, four slideshow windows appeared. The photos taken and shared by each participant appeared in their designated slideshow windows. The setup mode appeared on the screen when touching any of those slideshow windows. In the setup mode, the user was able to use the timeline to browse photo streams. In addition, the user was able to play or play back the slideshow to view the photos from multiple users in time order. There was a vertical slider which enabled the user to choose the speed of the slideshow.

Full screen and setup mode In total, D1 was in full screen mode for 857.3 hours, while D2 was in full screen mode for 405.87 hours. In Phase 1, D1 was in full screen mode for 25.96 hours, while D2 did not operate. In Phase 2, D1 and D2 were in full screen mode for 399.9 and 155.98 hours, respectively. In Phase 3, D1 and D2 were in full screen mode for 61.87 and 50 hours, respectively. In the next phase (Phase 4), D1 and D2 were in this mode for 259.84 and 104.98 hours, respectively, and in the last phase (Phase 5), D1 was in full screen while D2 was in this mode for 405.87 hours.

D1 and D2 were in setup mode for 42 and 7.8 minutes, respectively. In Phase 1, D1 was in setup mode for 0.04 minutes, while D2 was deactivated. D1 and D2 were in this mode in Phase 2 for 6 and 1.2 minutes, respectively. In Phase 3, the system was in setup mode in D1 for 7.8 minutes and D2 did not go to setup mode and stayed in full screen mode all the time. In the next phase (Phase 4), D1 was in setup mode for 9.6 minutes while D2 was in setup mode for 6.6 minutes. In Phase 5, D2 did not go to setup mode while D1 was in this mode for 16.2 minutes.

These data show that the system was in full screen mode most of the time. However, F1 and F2 sometimes used the setup mode to review older photos. In addition, F3 was not interested in using the setup mode when she was alone. F1 said:

> "Everyday I would go back by timeline and play the old photos...most of the times it was on full screen."

Single-window slideshow The single-window slideshow was designed to enable the participants to view a single person's photo stream; however, the participants did not used the single-window slideshow to review a single person's photo stream. Instead, they used it to see each photo in a bigger size. F1 said:

> "I have just to open one picture to see it better - like a bigger picture - but not for following somebody for some period of time or playing like that, whatever, his pictures or her pictures again. It's just for having a full-screen picture."

Speed of the slideshow The speed of the slideshow for the family group, while they were reviewing their multiple photo streams, was fixed to the default value most of the time; the default value was 5 as the base of the logarithm in the logarithmic transition. They mentioned that if they had more photos in their collections, they would change the speed of slideshow, but the presentation length was not that lengthy so they preferred the default setting. However, in D1 they changed the base value between 2 and 900 in three trials, and in D2 they changed the base value between 2 and 1000 in one trial.

Impact on solitary interaction between the user and the system

In the family group, all three members who had access to the system (F1, F2 and F3) used the system. During the interview, all of them claimed that they looked at the screen alone and mentioned that when the system was in full screen mode, they could see the latest status of the other members of the family. Furthermore, when they were reviewing the photos, they could see what was happening between them concurrently; they enjoyed both these experiences. F2 mentioned that when she was in Country 1 and the other family members were in Country 2, a close friend was staying with her for a week and the device was on the dinner table in the dining room. She added that her friend was impressed by the application and the way they could get the latest news from F2's family members. During the interview, F2 added that her children were impressed when they were viewing their own photos on the screen. Based on this feedback, the solitary interaction of the participants with the system can be categorised into three scenarios.

The first scenario was when one of the photographers (F1, F2, F3) was viewing the photos alone. The second scenario was when an audience member other than the photographer was viewing the photos on the system, namely F2's best friend. The third scenario was when subjects of the photos, such as kids, were viewing the photos on the screen.

Frohlich [2] proposed the following framework for the solitary interactions between a user and photos during the time of viewing the photos: interpretation, recognition, recollection and self-recognition. The main elements in this framework were photographer, subject, audience and their relation with the photo.

Recognition is when a photographer views their own photo. Interpretation is when an audience member views a photo taken by another person. Recollection and self-reflection are when the subject of a photo views that photo.

Based on the information gained during the user experience and the proposed framework by Frohlich, it can be concluded that participants experienced interpretation, recognition, recollection and self-recognition during this study. The only difference with the Frohlich framework is that the combination of these experiences happened simultaneously in the current experience. In this section, the impact on solitary interaction in different scenarios based on our user experience using 4Streams is described.

Interpretation and recognition At first glance, in the first scenario, when a participant looks at the screen, they see four photos of which one belongs to them as the photographer. There are three other photos the other participants captured. Therefore, each participant is simultaneously a photographer and an audience member. As a result, it can be claimed that a participant using our system has the experience of interpretation while looking at the three other windows and recognition while looking at the photo they took themselves at the same time. F2 said:

> "I found it really nice seeing the activity of others while seeing my own activity and it was really interesting sometimes to see all photos at the same time."

She also added:

> "I think I would use this application more if I have it because it would be interesting to see how we spent our days."

From these two quotes it can be concluded that this participant liked to see her photos and others at the same time. Moreover, she enjoyed seeing what happened among the group using the application. This brought a sense of interpretation and recognition at the same time.

Interpretation The second scenario was when an audience member who was neither the photographer nor the subject of any photo viewed the photos; in this case the viewer just interprets the four photos. As F2 mentioned, one of her friends spent a week with her while she was the only participant in Country 1. F2 said:

> "I had a friend of mine staying with us and she was like "what is this?". We explained and she was like "Wow!". She really liked the idea and she was sometimes viewing our photos."

Interpretation, recollection and self-recognition The third scenario was when a subject viewed themselves in the display. A good example was children, when their parents took many photos of them. The parents said that the kids were very interested when they viewed themselves on the screen. In this scenario the children experienced recollection and self-recognition by viewing the photos in which they were subjects alongside the experience of interpretation by viewing photos of others.

Interpretation, recognition, recollection and self-recognition During this study, there was an interesting scenario where F1 experienced all the mentioned solitary interactions proposed by Frohlich within the application at the same time. There was a photo of F1 in the system taken by F2. Hence, F1 was interpreting two photos taken by F3 and F4; he had a sense of recognition by looking at his shared photo on the screen and, finally, he experienced recollection and self-recognition by looking at his photo on the screen as a subject.

Impacts on social interaction between the users and the system

In this section, the social interaction between the people exposed to our system is analysed. There were moments when more than one person viewed the screen. For example, F1 and F2 reviewed and viewed the screen together. In addition, they once reviewed the whole photo stream using our system before we conducted the interview. The parents and their children also viewed photos collectively. While F1 and F2 were in Country 2, they viewed the photo streams or the latest statuses of the photo streams with F3. F2 also viewed the photos with her friend. Moreover, the grandfather of the family viewed the photo streams with F3.

Frohlich [2] also proposed the following framework for the social interactions between the user and the photos during the time of viewing the photos: storytelling and reminiscing. The main elements of this framework are, again, the photographer, the subject, the audience and their relationship with the photo.

Frohlich defined storytelling as when a photographer is talking about their taken photos with an audience member. There is another scenario for storytelling, namely when a subject is talking about their photo with an audience member. In reminiscing, a subject and a photographer talk about photos. However, in this application, we found two additional scenarios to this framework, bi-directional storytelling and social interpretation. Social interpretation is when the audience talks about a photo they did not take or for which they are not the subject. Bi-directional storytelling is when two photographers talk about their photos. A combination of these social interactions occurred during our system experience in the family group. Different social interactions between the users and the system are now described.

Bi-directional storytelling and social interpretation There was a moment when two photographers (F1 and F2) were reviewing and viewing their photos on our device. During viewing the four photo streams, we observed their behaviour. We saw that they were explaining what was happening to them individually in each photo to each other, in detail. For instance, F1 was talking about a photo he took of his new haircut in Country 2 and F2 was talking about the food she cooked.

During the time they were viewing their photos in slideshow mode, they suddenly saw a photo of a man in F4's photo stream, and they discussed whether he was

F4's boyfriend or not; this is considered to be social interpretation between them. Social interpretation means that they were interpreting a photo they did not take.

From the above-mentioned stories, the experience of two photographers during viewing their photos using 4Streams can be claimed as the two experiences of bi-directional storytelling and social interaction.

For example, F1 and F2 were viewing and discussing the photos in Country 2 F2 took. F1 said something about his interest in social interpretation of photo streams:

> "For me it was very interesting to see what's happening somewhere else with my family including what Helen was doing with Katy (daughter of the family) and me and my mom talked about that photo... We were also talking about the photos we took."

F1 also experienced the sense of social interaction, as he said:

> "My mother mostly was looking at Katy's photo with me and we were talking about that."

Storytelling and social interpretation Another scenario of social interaction between users and the system is when a photographer and an audience member view the screen; this happened twice during this study. The first occurrence was when F1 was with her friend and the second occurrence was when F3 and her husband were viewing the photos.

F3 said that when she was viewing the photo streams, she saw a photo of a fox in the garden in Country 1 and she told her husband about it; they then viewed that photo together and discussed whether or not there are any foxes in Country 1. She was also telling the stories of the photos taken by F1 and she uploaded them on the system.

Reminiscing and social interpretation During the revision or live update there is another scenario when the photographer and the subject of the photo are viewing the photos together. For example, parents viewed photos with their children. The children liked to see their own photos alongside their parents and remembered what was happening to them. During the observation one of the kids mentioned a photo of when she was in a horse riding event and talked about it with her father, and F1 continued the conversation with her. She also talked about a photo of F4, who was her cousin, taken in Country 3 and told her parents and us "This is Diana, I like her"; this opened a new conversation topic.

Communication tool

Family members were enthusiastic about using photos as a way of keeping in contact, especially because F3 was living in Country 2, F4 was living in Country 3 and F1 and F2 were leaving Country 1 for different periods to visit F3. Therefore, our system was used as a communication tool to connect the family members using photos. F1 and F2 used the system in Phases 3 and 5 to update the older member of the family, and they were in touch with the family members while they were away from Country 1. Therefore, this tool could be a new medium for communication between family members.

F3's manner of photo sharing was slightly different from that of F1 and F2. The oldest participant was very pleased about the photos she could see from the other three family members. Hence, she was mostly expecting the other members to provide new photos to the system. However, she was not keen on informing others about her current visual status. Thus, she only shared her old photos and photos of her garden flowers.

> "I was sharing what I believed was interesting for them. I was not mostly sharing new photos."

F1 and F2 shared photos that conveyed live communication to show their latest statuses mostly to F3 or to each other when they were away from Country 1. F1 said:

> "I liked it because we were in different parts of the world at the time when the experiment was done. I thought that it was so exciting to see new pictures every day. I found it really nice seeing the current activity of others so I could understand where F2 was and was it rainy there?"

Regarding this topic, F2 said:

> "I think it's an interesting way of looking at other people's lives. I'm not necessarily interested in what everybody I know is doing in their life because I can't cope with that amount of information. But with the people around me, I think I would like to see a photo of F1 during the day."

A trigger for other communication tools

Participants said that during this study, they used our system, phone and Skype as communication tools among family members. They said that they used Skype to talk to F3 in Country 2, while the phone was the internal communication tool. However, our system provided a new platform for communication. We did not provide any option for comments and captions as we wished to evaluate how plain photo sharing affected communication within an extended family.

Family members believed that using a photo sharing application as an ambient display let them know the latest statuses of other members. However, in some cases it was a trigger for other communication tools. For example, in Phase 5 when F1 and F2 were in Country 1 and F3 was in Country 2, they shared a photo of a fox in their garden; as a result, F3 and her husband called them instantly after seeing that photo. F1 said:

> "About the fox; it was a whole thing about the fox. The biggest thing about the fox is basically that there was a little bit of a story in our family. We often have foxes in our garden and my father is from the mountains and he is very familiar with foxes. Whenever he was in England here visiting us he would never see a fox in the garden. Granny saw millions of foxes and we have foxes every morning. He said 'No way, you're lying; no foxes are in your garden ever'. Then I managed to take a photo. This is the first photo when my dad finally saw a photo of a fox in our garden. It's an interesting story that triggered this family conversation about foxes in our garden. That was proof and it was visual proof and it triggered a lot of communication in different channels over it. He called me straight after seeing that photo. "

Viewing old visual statuses

One feature that was very appealing for the participants was viewing their old visual statuses concurrently over time in slideshow mode. After using this feature, they mentioned that they remembered many events that had happened during the study. The photos were ordered chronologically so that they could follow what had happened. Regarding the experience he had, F1 said:

> "Helen made a new salad and she took a picture of Katy eating it and so on, and we were so excited about that salad when we were there. I don't know why, but I forgot about it and I saw it today, and there were more photos than I saw then of the salad and of the preparation. It just completely got me back about there's a new salad. I remember now, at the time when I got back and then, Helen made me the same salad and I had it for the first time and everything just comes back and that rain, I remember the rain. That car that we saw at the end, I remember me taking my time driving and taking the photo because I was very much shocked by the appearance of that car. I forgot about

> it completely, which was not a big deal; I do forget things a lot. But now, it all came back; that drive to Stansted to pick them up was a nightmare. It was Friday afternoon; I think it took me three hours to get to Stansted that afternoon. I was trying all the roads and in the end, I ended up taking a photo on the M25 of this funny car."

System understanding

Different participants understood the system differently. F1 and F2 understood the system as a visual communication tool between family members; therefore, they were constantly trying to update their latest news and share what they were doing with others. Moreover, they saw the system as a small-group photo sharing application with the capability of awareness and comparison. F2 said about her understanding about the system:

> "I think it's so interesting seeing photos that were taken at the same time in different places, because it's like a 3D life between friends. You have one life that is recorded in photography as two dimensional. But I think adding somebody else's experience that is parallel to yours, it's almost like another dimension added to what you were doing at the time for communication."

F1 added that he sees the system as a platform for sharing artistic photos and making a competition between family members who can take better photographs. However, F2 said that she does not follow artistic photography and she just likes to take photo snaps. F3, interpreted the system as a platform to review younger family members and, then, she added some photos that she liked. She said that she likes sharing photos of flowers because it makes her photo streams prettier and, then, she can follow other streams' stories.

Children and socialisation

The four members of the family were not the only persons who used the system; the children of F1 and F2 were fans of the application and commented on the photos. Therefore, the application made the children socialise with other members of the family. Also, the children liked to interact with the system; F2 said that her daughter interacted with the system more than she did.

F1 said, regarding the children's reaction:

> "Janet would get very emotional. Especially the first two weeks, Janet and I were alone and Helen and Katy were here and this was basically the first time for a long time to be separate from Mum. I was there of course and Granny is there, and she knows Granny and Grandpa very well, and she has got all the confidence in them. But when she saw Katy and Mum doing something there, she would be like, 'I want to go home'. She would become very emotional when she saw the pictures, so Janet was reacting as well."

Decoration tool

The digital ambient display was placed in the participants' homes as a decoration tool. In Country 1, the participants said that they placed the tablet on the dining table and that it operated most of the time. In Country 2, the device was in two places, the dining table and the the garden table where most family members gathered.

F1 and F2 both liked to have the system as a digital photo frame at home. F1 liked the idea of having this system at home or even a bigger wall-mounted LCD to view their photo streams. However, F2 was concerned about privacy issues. She said that she does not like people other than family see their photos. Therefore, she did not agree with a big screen. However, she said that she could hide the tablet or digital photo frame whenever she wanted. F3 liked to have the system at home and look at it frequently. She said:

> "I can spend the rest of my life just viewing these photos of my family, so this is interesting and that is exactly what I want to have at home, like a photo frame and see what children do."

Facebook versus our system

In the family group, the participants used Facebook to share their photos. Therefore, they were able to see what they shared via Facebook or our application. The main platform for viewing photos in this group was our system. They rarely used Facebook as the main platform for viewing their photos as most of the photo privacy settings were set to be shared with 4Streams.

F2 said about sharing photos with Facebook:

> "It was easy to upload photos through Facebook and send them to the application."

F1 said that this application can be used as an additional tool to Facebook. Therefore, using Facebook and its privacy settings for sharing photos was a convenient technique for F1 and F2. However, regarding the oldest member of the family, F1 said that using Facebook to share photos was not as easy as viewing photos via the application. Hence, she did not share many photos. For the oldest member of the family, the same as for other members, the intention was to view photos on our system and not on Facebook.

The main reason that F1 and F2 decided to see their photos on our application was that in our application they just could see the people they like and not other bulky news from people they did not want to follow. Regarding this, F1 said:

> "You see on Facebook what people are sharing, but on one page you see a video clip of the new pop singer, some fun stuff and then friends' pictures. Even that friend is a remote friend and it's a friend of a friend and… In this application I see only photos...It's so much stronger because it's people you do care about."

Improvements

Family members suggested two areas of improvement for the system. The first one was the problem of the Internet connection. During the study, F1 and F2 were in Country 2, and they did not have access to the Internet all the time. Therefore, D2 did not receive all the photos uploaded by the other participants. The suggestion was to design the system in a way to enable the retrieval of shared photos even when the device is not operating.

The second improvement was to install the application on a smartphone so that participants can be notifid about the latest visual status of each other wherever they are. F2 said:

> "(Install) for the mobile phone because I think this is how people like. How much time do you spend at home during the day? I arrived when you arrived (8 PM), if you think about that; what is my display during the day? The phone."

9.4 Trial 2: Friends group

9.4.1 Participants

In this trial, the participant group contained four close friends who were first year Arts students at the University of Surrey. The reason to select close friends was that in Phase 1 of the study we found that close friends are very keen in sharing their personal photos with small privacy concerns. Moreover, close friends are a small group of people with a need for applications to enable them to share their photos with each other [39]. The user ages ranged from 17 to 18 years with a mean of 17.25 years and a standard deviation of 0.5 years. All participants were female. The participants were living in University of Surrey accommodation. This group's participants were recruited via an email message asking for volunteers who would like to share their photos with their close friends using an ambient display. Once they agreed to take part, the participants were asked to read and sign a consent form to participate in this study. Each participant was given a Microsoft Surface Pro tablet to use for four weeks upon completing the last interview. The information about Group 2 participants is given in Table 9.3. The names are not the real participants' names.

TABLE 9.3: Close-friends group participants

No.	Name	Age	Gender
P1	Amy	17	F
P2	Tiffany	18	F
P3	Jordan	17	F
P4	Abi	17	F

9.4.2 Initial setup

This group consisted of four close friends who were living in the University of Surrey accommodation. We gave them one Microsoft Surface Pro tablet, each with the same specifications as those given to the family group participants. Our system was installed on the tablet and tested by adding the participant's Facebook account to the 4Streams account. All participants took photos and shared them using Facebook, and the shared photos appeared on the screen of the application before the study started. The demo of the pilot study was also shown to them.

The participants were asked to share their photos and set their privacy settings using the same techniques described for the family group in Section 9.2.2. The study lasted for four weeks.

In this trial, the same data collection and analysis methodology used in Trial 1 was used, and the results are shown in the next section.

9.4.3 Results

This section deals with the results of the qualitative and quantitative analysis. First, we start with the current practice of the participants' photography. Then, we analyse and present the quantitative data extracted from the interaction logs. Finally, the user experience of the participants within 4Streams is described.

Current practice of photography

Capturing For this group, who took a lot of photos, the camera phone was their main or only capture device. We asked them, on average, how much and how often they take a photo. P4 said:

> "Quite a lot. If there is a reason we will. Last night we went to an event and I personally took around 50 pictures of that event."

The participants in this group just used their camera phones as well as features such as photo filtering to capture and edit their photos. P3 said:

> "We take our photos on our phones and then upload them...We use filter options too."

Storing The main repositories of photo collections for members of the friends group were their camera phones. They said that whenever they need space on their phones, or when they buy a new phone, they add their photos to a physical memory. They also saved photos they received from other people via Viber and Whatsapp on their phones. They considered their Facebook tagged photos as their own photos and Facebook was a cloud base of the photos others took of them. However, they never used cloud services such as Google+, Dropbox or Flickr to store and keep their photos.

Sharing In the close friends group the scenario for photo sharing was very different compared to the family group; they used social networks, mainly Facebook and Instagram, for photo sharing to communicate with their friends and for self-presentation; they mentioned that Viber and Whatsapp applications are used for sharing their private photos or funny photos from other sources.

Interestingly, the privacy issues for photo sharing between the friends group and the family group were significantly different. Family members did not like to share private photos via Facebook, so that nobody, apart from family members, could see their photos. In the friends group, however, the main concern was that they did not want their family members, such as their grandmother, to see their photos; they did not mind sharing some photos of partying and going out in public. P1 said:

> "All the photos that I uploaded I do not mind if people see them."

P2 said:

> "Sometimes Facebook is so public. If you have family members there, like your grandmother, to see your photos and you can't specify who can see your photos."

Structure of the friends group

Unlike the family group, the friends group's structure did not vary during the four weeks of the study. P2 was away for a weekend to visit her hometown for a wedding. The wedding was in the third week of the study (Day 20). The other members did not participate in any special event. All participants were living in the University of Surrey accommodation and they had a lecture together three times a week; there was no guarantee that they were together for the rest of the week.

The photos sent

For each participant, the photos sent in different weeks were counted. In total, forty-four photos were uploaded and shared on Facebook. Most of the shared photos belonged to P1 and P2, who uploaded thirteen photos each. P3 uploaded ten photos and P4 uploaded eight photos.

Most of the photos were uploaded in Week 3, when P2 went to the wedding event. In Week 3, P1 uploaded eight photos, P2 uploaded eight photos, P3 uploaded seven photos and P4 uploaded five photos. The results show that 63.3% of the shared photos were in this week, when the participants were most active. After Week 1, Week 2 had the highest number of photos with nine photos in total. In the last week, five photos were shared in total and in the first week only two photos were shared.

From this information, it can be concluded that the wedding trip was a good motivation for P2 to increase the rate of photo sharing between the members of this small group. Figure 9.13 illustrates the number of photos sent by each person in each week.

Content analysis of photos

The content of the close friends group was categorised using the same technique and categories used for the family group. Figure 9.14 illustrates the number of shared photos between the close friends in each category. Unfortunately, not all the uploaded photos were received by the application; this is discussed in the

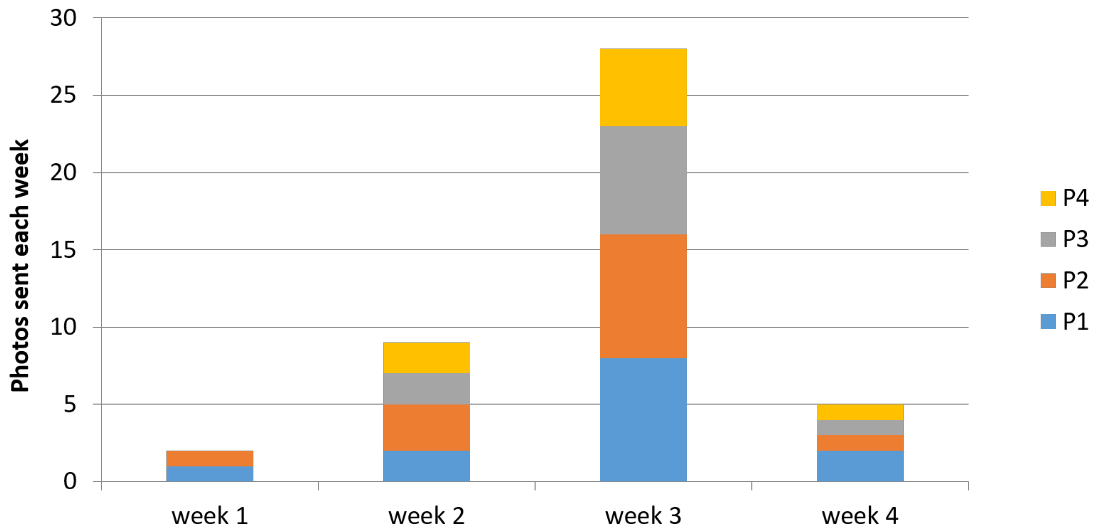

FIGURE 9.13: The number of photos sent in each week by each participant.

following sections. Examples of friends photos received by the application can be seen on Figure 9.16.

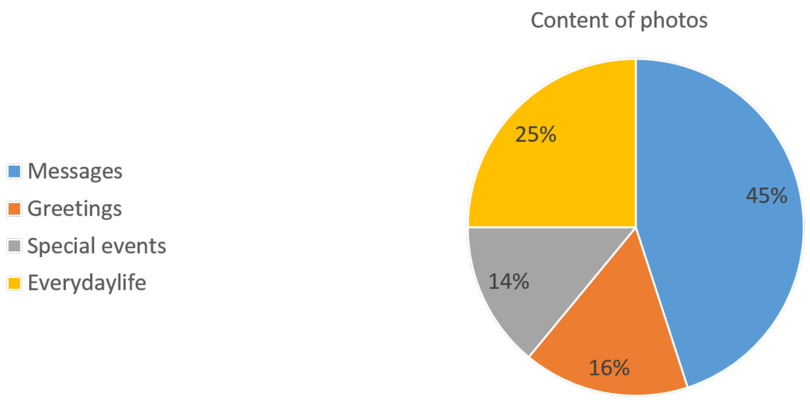

FIGURE 9.14: The proportion of shared photos in the close friends group in each category.

Messages This category contained 45% of the photos, making it the largest category. Typical examples were photos of baggage before travelling, homework papers and food.

P4 shared photos of different cakes she prepared and a pizza. P3 shared a photo of new clothes she bought as well as a new beauty product. P2 was also a pizza lover and she shared a photo of a pizza she cooked. However, P1 shared a photo of a landscape with a written message describing her current status, using other photo capturing applications.

Greetings The proportion of photos in this category was 16%. It typically contained photos of people posing for their friends; for example, P1 took photos of their mutual friends. All participants, except P4, took a selfie, which can be placed in this category. P3 shared a photo with her mother and P2 shared a photo with her hometown friends.

Everyday life The second largest category was that of photos taken from the everyday life of the participants and comprised 25% of the photos. Examples are photos of the home environment of the participants. For example, P2 shared a photo when she went out with friends and P1 shared a photo when she was with other friends in university. Most of the photos in this category were taken when the participants were with their friends in university communal areas and lectures.

Special events Special events was the smallest category, with 14% of the photos. This category included photos of special events such as a wedding event for P2 and parties other participants went to. P1 also shared a photo of a visit to London.

Privacy settings for photo sharing

The same choices of privacy settings, similar to those of the family group, were available to this group. However, the participants in this group added another privacy setting to the study, which we did not predict. They shared some of their photos publicly.

The participants shared twenty-one out of forty-four photos (48%) with all their Facebook friends, which shows that most of the time people in this age range had Facebook on their mind and they wanted to notify all their Facebook friends about their activities. The contents of the photos they shared with this privacy setting were from all categories.

They shared fifteen out of forty-four photos (34%) with close friends. Before we started the study, we asked the participants whether they share any photos with smaller groups of friends; their answer was no. This shows that the concept of our system changed the behaviour of the participants regarding photo sharing. P2 said that it is a good idea to share private photos on Facebook with privacy settings; she did not use this feature previously and said that they usually use Whatsapp and Viber applications for that reason.

Interestingly, eight out of forty-four photos (18%) were shared publicly. This indicates that people in this age range do not mind sharing some photos with people they do not know. The photos they shared with this privacy setting were mostly in the greetings and special events categories.

The participants in this group did not share any photos with only 4Streams, which shows that the application and the ambient display were not their first priority and that Facebook was more important for them. The results of the privacy settings for different participants can be seen in Figure 9.15.

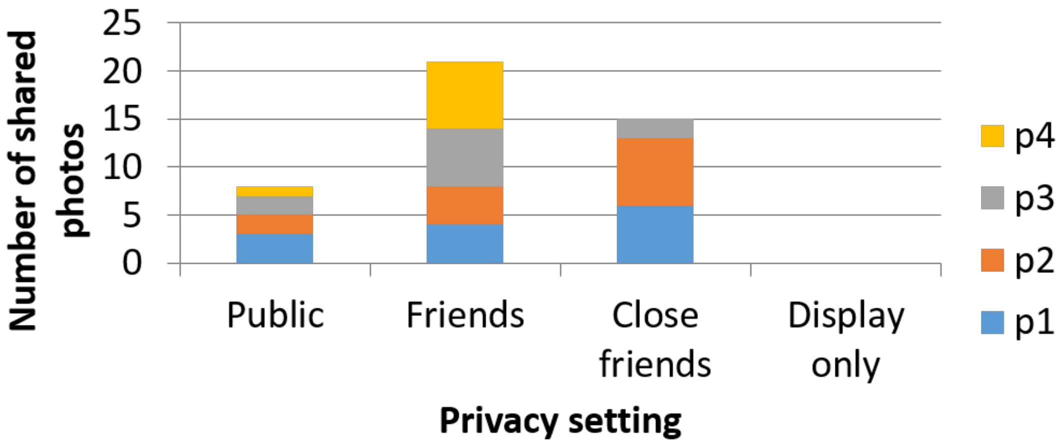

FIGURE 9.15: The privacy settings for different participants in the close friends group.

Usability aspects of the system

During the trial, all participants in this group encountered problems using the ambient display. In this section the problems of usability of the system are addressed.

Photos received by the application The first problem was discovered during the analysis of the quantitative data, before the interview session. We found that the system did not receive most of the photos that had been shared via Facebook; D1 received eight photos, D2 received four photos, D3 received two photos and D4 received only one photo, which was sent by the participants in the test phase before the study started. From these data we can deduce that, although the participants were told to keep the device on as much as they could and leave it on a fix place as an ambient display, they did not use the ambient display most of the time. Figure 9.16 shows the photos received by our application from all the devices.

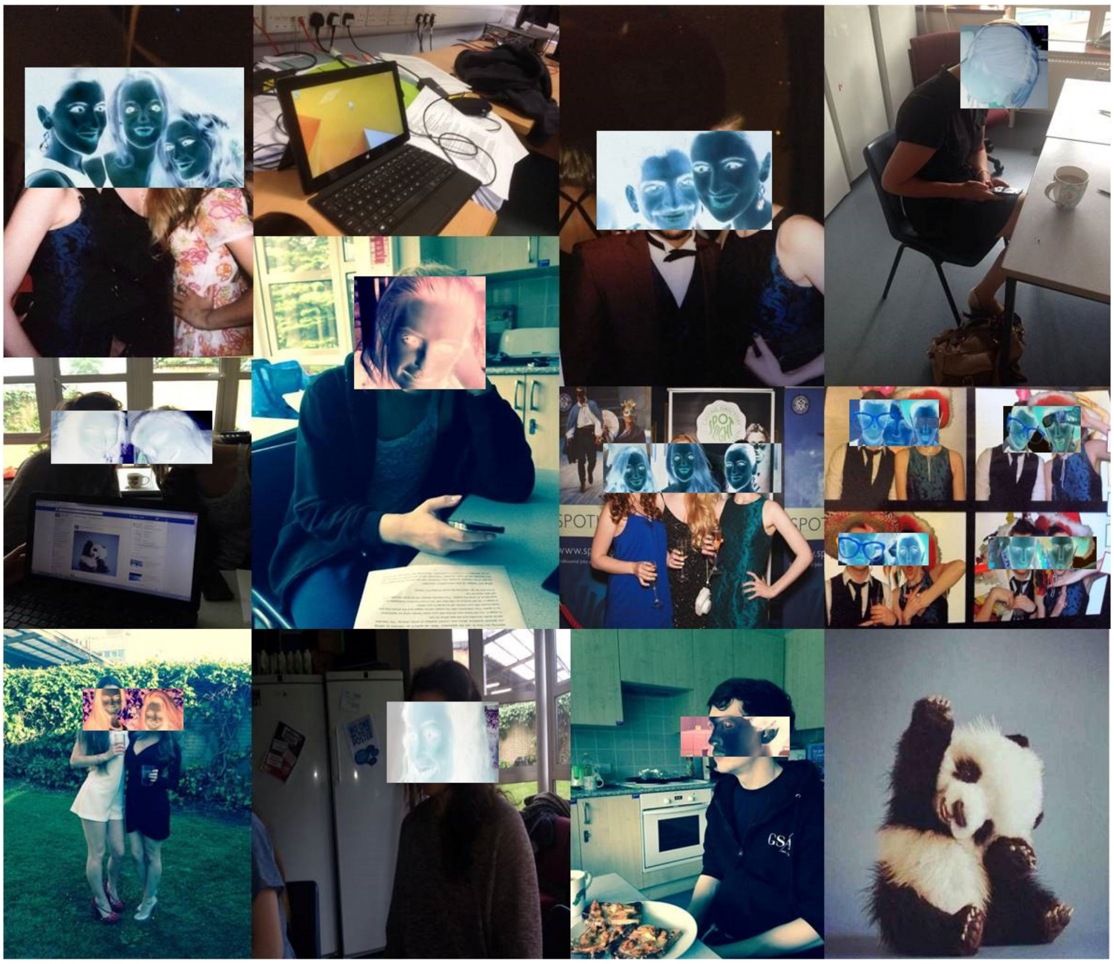

Figure 9.16: Photos received by our application.

Reasons participants did not use the system During the interview we asked the participants why they did not use the system and they gave different reasons. The first reason, on which all participants agreed, was that they were not at home all the time and, therefore, they could not leave the device on all the time at home; they also had fears about security and safety. P1 also said that the desk in the university accommodation is too small and she could not leave the display on all the time there.

One of the main reasons was that they did not share any photos with only 4Streams and they were getting notifications from Facebook before they used the ambient display. Hence, they were viewing photos from Facebook rather than our application. It can be concluded from this part that Facebook was the participants' main platform for photo sharing rather than our application.

The other complaint was that four weeks is a short period of time and P3 said:

> "I can't take photos for the sake of taking photos, I need better reasons"

P1 said:

> "We didn't do photo sharing so much when we were here because we are close friends and see each at least three times in a week."

During the study, however, they shared a reasonable number of photos, thus discarding this reason for not using the display.

All participants had unlimited Wi-Fi in their accommodation; however, they decided not to use the system as we described and, instead, they used Facebook for their photo sharing platform. P1 suggested that she liked to use our system with her family but not with close friends because she wanted to see her family photos in the frame when she was away from them and friends cannot be good users for this system. As a result, it can be said that 4Streams, as an ambient display, did not fit to the close friends group, in contrast to the family group.

Improvements The first improvement the participants suggested was to not leave the privacy issue to the participants and instead, to set it with the device because Facebook privacy settings are not user friendly. P4 said:

> "The worse thing was that we tended to see it on Facebook before we look at it on tablet. The privacy setting with only the display would push us to use the display more."

Another point to improve the system was to design the system in a way to be with the users all the time, such as implementing 4Streams on a mobile phone application. P3 said:

> "Possibly it was better to have it with us all the time, whereas the tablet was just in our room so in our Facebook we would see them quicker before we actually saw them in the tablet."

Another improvement they mentioned was to design the system in a way to retrieve old photos whenever they opened the device because they would not like to keep the system on all the time. P4 said:

> "I do not want to have the system on all the time, better to open it sometimes and see the photos."

The participants also suggested adding captions to describe more details about a photo, or to add a voice message as an attachment to a photo to describe it better. The other medium they were interested in was video. P2 said:

> "You could not text at the same time so you sort of made handwriting photos note on them...Adding audio to the photo is a very good idea and we would love that (voice message)... we also liked to send videos."

Finally, the participants suggested creating a different upload interface rather than Facebook, mostly because the Facebook privacy settings were not easy for them to use and they might also upload photos such as profile photos that they did not want to send to the display. P1 said:

> "Having profile picture of Facebook is like showing off to friends like I am so pretty. Not a good idea to have it there (on the display)....I would like an option to upload photos into the device rather than Facebook."

9.5 Trial 3: Workplace group

9.5.1 Participants

The third group was five colleagues who were working in the same office in the Department of Electronics at the University of Surrey. There were two reasons to select this workplace group. Firstly, in the pilot study of Phase 3, the structure of our participants were colleagues and the experiment showed a high level of interest between participants for photo sharing using our application. Secondly, we wanted to evaluate the collocated nature of our display. The participants had worked in the same office for six months; P1 and P2 were friends and they socialised out of the office but the rest of the participants did not socialise out of the workplace. P1 and P2 were PhD students while P3, P4 and P5 were research assistants. All participants were male and aged between 27 and 40 years old with a mean age of 32 years and a standard deviation of 5.2 years. All participants had been living in the United Kingdom in the preceding five years.

The participants of this group were recruited by email. The email, which was sent to people working in the Department of Electronics, asked for volunteers for the study; those who wanted to volunteer should work in the same office and should also be willing to share their photos on a display which placed in their office. Once they agreed, the participants read and signed a consent form to participate in the study. The participants were given a gift after the interview as an appreciation of their time and support. Information about the workplace group's participants is given in Table 9.4. The names are not the real participants' names.

Table 9.4: Workplace group participants

No.	Name	Age	Gender
P1	Alexandro	27	M
P2	Pepe	28	M
P3	Socrates	38	M
P4	Alan	39	M
P5	Harry	28	M

9.5.2 Initial setup

As mentioned earlier, the workplace group consisted of five colleagues working in the same office situated in the Electronics Department of the University of Surrey.

We provided a 42-inch touchscreen monitor and placed it in a free space on a desk in the office. We asked the participants where they would like to leave the screen and they decided to leave it close to the coffee machine to provide social interaction while they are drinking coffee. Moreover, the screen was close to the main door and, therefore, other people could see the photos from our participants.

The application was installed on a laptop and the laptop was connected to the LCD monitor via a USB port for touchscreen connectivity and an HDMI port for screen mirroring. The laptop was hidden under the monitor. The laptop had 2 GB of RAM, the processor was Intel GMA X3100, the operating system was Windows Vista and the physical memory capacity was 160 GB.

The participants were instructed in detail how to use the system, the same as the other groups. The application was tested before starting the trial for each participant and the privacy setting options were described for uploading and sharing the photos via Facebook. The participants were advised that if they did not want to share a photo with the device, they just needed to exclude our application during the sharing process. The difference in the setup of this group compared to the other groups was that they used a 42-inch screen in one place rather than the Microsoft Surface Pro tablets in different places. Moreover, the participants were colleagues and not friends or family members. The environment of the office and the application on the screen can be seen in Figure 9.17.

FIGURE 9.17: The office environment in this study and the application running on the LCD screen.

Structure of the workplace group

The same as for the friends group, the work group's structure did not vary during the four-week trial. P2 participated in the study for a week and after that P5 took his place. The reason for this change was that P5 was interested in participating and P2 was too busy during the trial. However, we used both of the participants' experiences during the interview. During the trial, P1 and P2 went to the same party, while P3 and P4 were at another event together. P3 and P5 had short trips and shared photos of those trips. Most of the time, the participants were in Guildford, United Kingdom.

In this trial, the same data collection and analysis was used as in Trial 1 and the results are shown in the next section.

9.5.3 Results

This section deals with the results of the qualitative and quantitative analysis. First, we start with the current practice of participants' photography. Next, we analyse and present the quantitative data extracted from the interaction logs. Finally, the user experience of the participants within 4Streams is described.

Current practice of photography

Capturing Similarly to other groups, in the workplace group the participants' dominant capture device was their camera phone. Just one of them (P3) used a point-and-shoot camera and mentioned that his camera phone was his main capture device. However, he complained about the quality of the camera phone photos, but his phone was three years older than the other participants' phones. He said:

> "So almost everything I share I take with my phone, but I do take other photos with my camera, which are better quality normally and less kind of instant."

Storing Participants in this group used several places to store their photos. P1 kept all his photos on his phone's physical memory, also backing up the photos using Dropbox Cloud. P3 used the Amazon server and the rest stored their photos on their physical memory.

Sharing The workplace group participants used common photo sharing applications such as email, Viber, Whatsapp, Dropbox and Facebook, but their main photo sharing application was Facebook; they mentioned that they share photos with their group and friends mostly using Facebook. P4 said:"'I would say Facebook is dominant.". However they added that for more private photos they use Dropbox. The participants in this group were not interested in instant messaging services such as Whatsapp or Viber and they did not use them very often. S3 said: "I'm not cool enough for anything (other applications for photo sharing) apart from Facebook."

The photos sent

In this trial, for each participant, the photos sent in during the four weeks were counted. In total, forty-five photos were uploaded and shared on Facebook. Most of them belonged to P3, who shared twenty-six out of forty-five photos. P4 shared nine photos, while P5 shared five photos. P1 and P2 shared four and two photos, respectively.

Most of the uploaded photos belonged to Week 3, when fourteen photos were shared. However, the number of shared photos in Week 1 and Week 2, namely twelve photos for each week, was not too different from the number of photos shared in Week 3. The fourth week had the fewest shared photos, seven photos. The number of shared photos in each week shows that, unlike the other groups, the participants in this trial were similarly active in the first three weeks and the last week of the trial, and in the first week the momentum for being active in photo sharing decreased (see Figure 9.18). The results also show that twenty-eight out of forty-five (62.2%) photos were shared during weekends. From this information it can be concluded that the weekend was the most convenient time for colleagues to share their photos. Regarding the weekend, P3 said:

> "It was like I come on Monday and see what they (other participants) did during the weekend and it was nice."

In this trial, the system ran all the time and, therefore, all photos were retrieved by the application and the display was on 24-hours a day for four weeks.

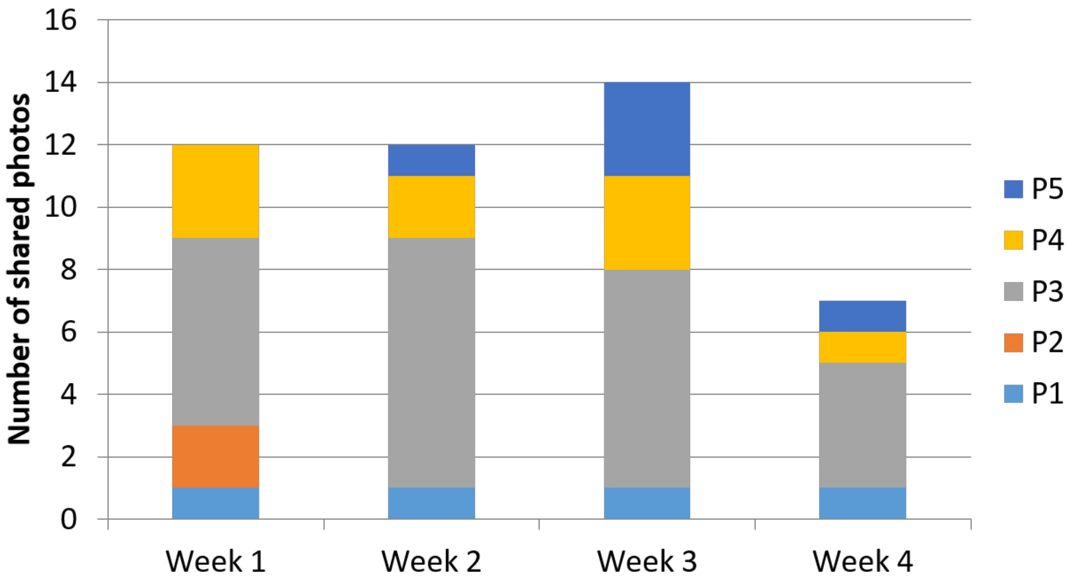

FIGURE 9.18: Number of photos sent each week by each participant.

Content analysis of photos

The same technique used to categorise the other groups' photo content was used for the workplace group photo contents. Figure 9.19 illustrates the number of shared photos in each category.

Messages This category contained only 14% of the photos. One reason for this was that the ambient display was situated in one place and the participants were not at that place all the time; therefore, they did not try to send many photo messages compared to the other two groups. For example, P4 shared a photo of his child to let the other members of the group know that he has a child and P3 shared a photo of him climbing. P1 and P2 both shared a photo of the results of their PhD projects. Another example was when P3 shared a photo of a ticket-selling machine to say that he was buying a ticket or that P4 shared a photo of the

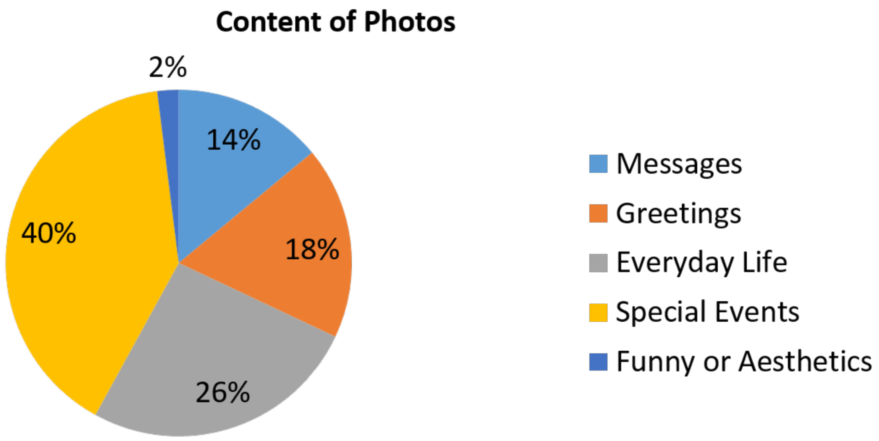

FIGURE 9.19: Number of shared photos in each category for the workplace group.

University of Salford when he had a meeting there. Figure 9.19 depicts example photos shared in the messages category in this trial.

FIGURE 9.20: Examples of shared photos in the messages category.

Greetings The percentage of photos in this category was 18%. It typically contained photos of people posing for the other members of the group or taking a photo of the people whom other members knew. For example, P4 took a photo of one member in a different office in the University of Surrey Electronics Department and P3 and P2 shared their own photos. The example greetings category photos from the workplace group can be seen in Figure 9.21.

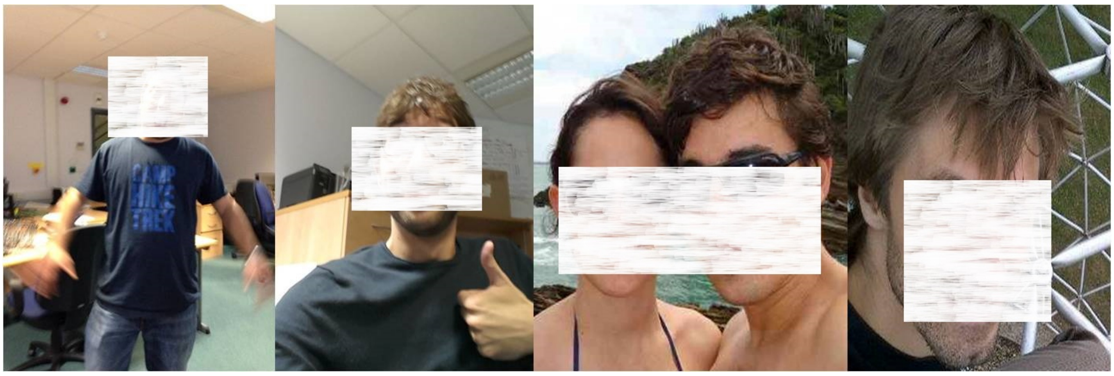

FIGURE 9.21: Example shared photos from the workplace group in the greetings category.

Everyday life The second biggest category belonged to the everyday life of the participants, with 26% of the photos. Examples were photos of P4 at home with a child and computer application results that members of this group were using for fun and daily experiments. Lunchtime in the university and the computer facilities on the desk of the participants were other examples. Figure 9.22 gives examples of everyday life workplace group photos.

Special events The special events in this trial was the biggest category, with 40% of the total photos. Participants of this group were mostly sharing photos of the special events they participated in during the weekend. For example, P5 and P3 shared multiple photos of an event they attended together and P3 shared a photo of a sample recording event. A concert was another example that P3 shared during the trial. Examples of special events photos from the workplace group can be seen in Figure 9.23.

Funny or aesthetic photos Funny or aesthetic was the smallest category, with just 2% of the photos, comprising a single photo of a leaves that was shared by P4. This photo can be seen in Figure 9.24.

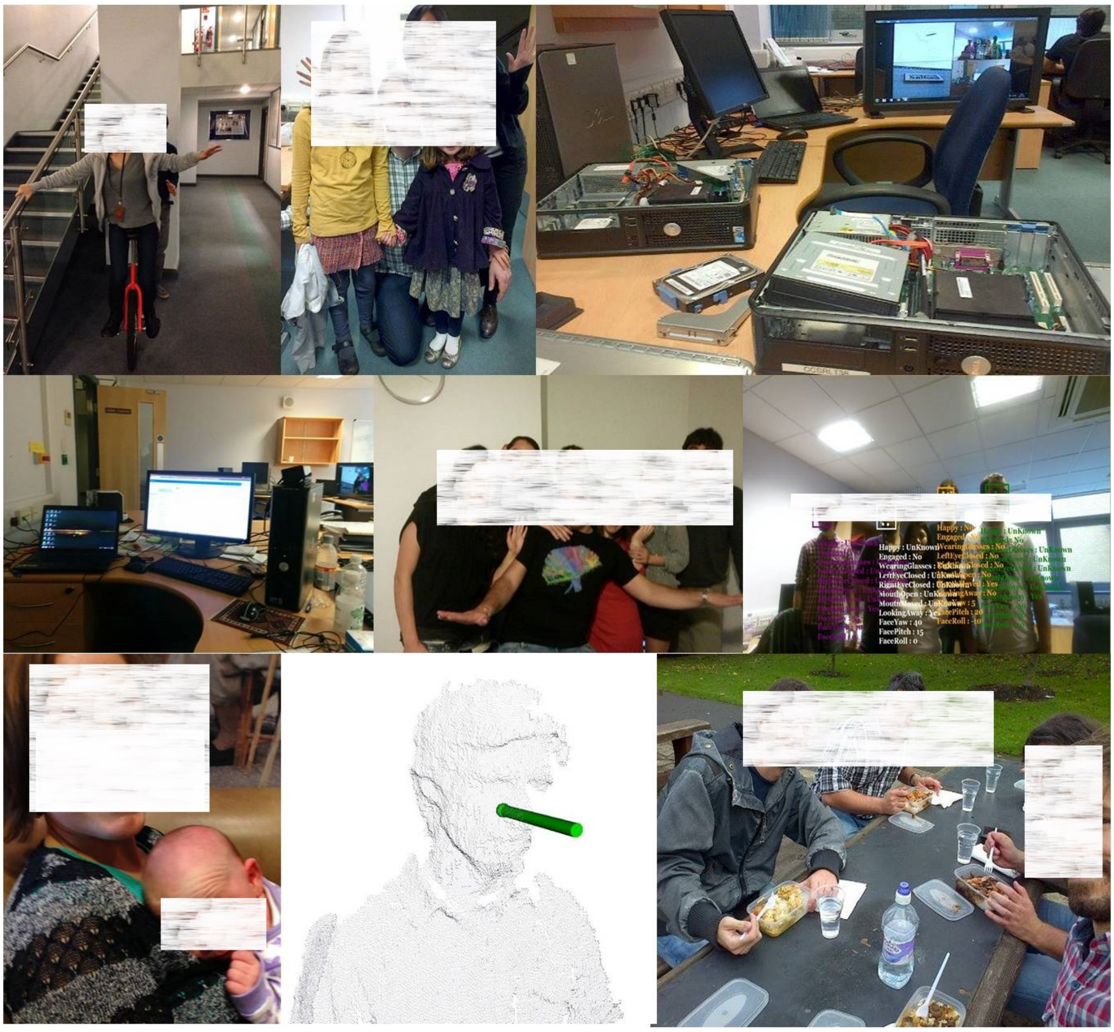

FIGURE 9.22: Example shared photos from the workplace group in the everyday life category.

Privacy setting

The participants had three options to choose from in the privacy settings. The first option was to upload a photo and share it just with 4Streams, which shows the photos only on the screen of the application. The second option was to share the photos with all their friends. The third option was to share the photos with colleagues participating in this study.

In this trial, in total of 75.5% of the photos were shared with Facebook friends, which shows that the participants intended to share most of their photos with their Facebook friends. Next, 15.5% of the photos were shared with colleagues. This shows that there were moments that participants wanted privacy between

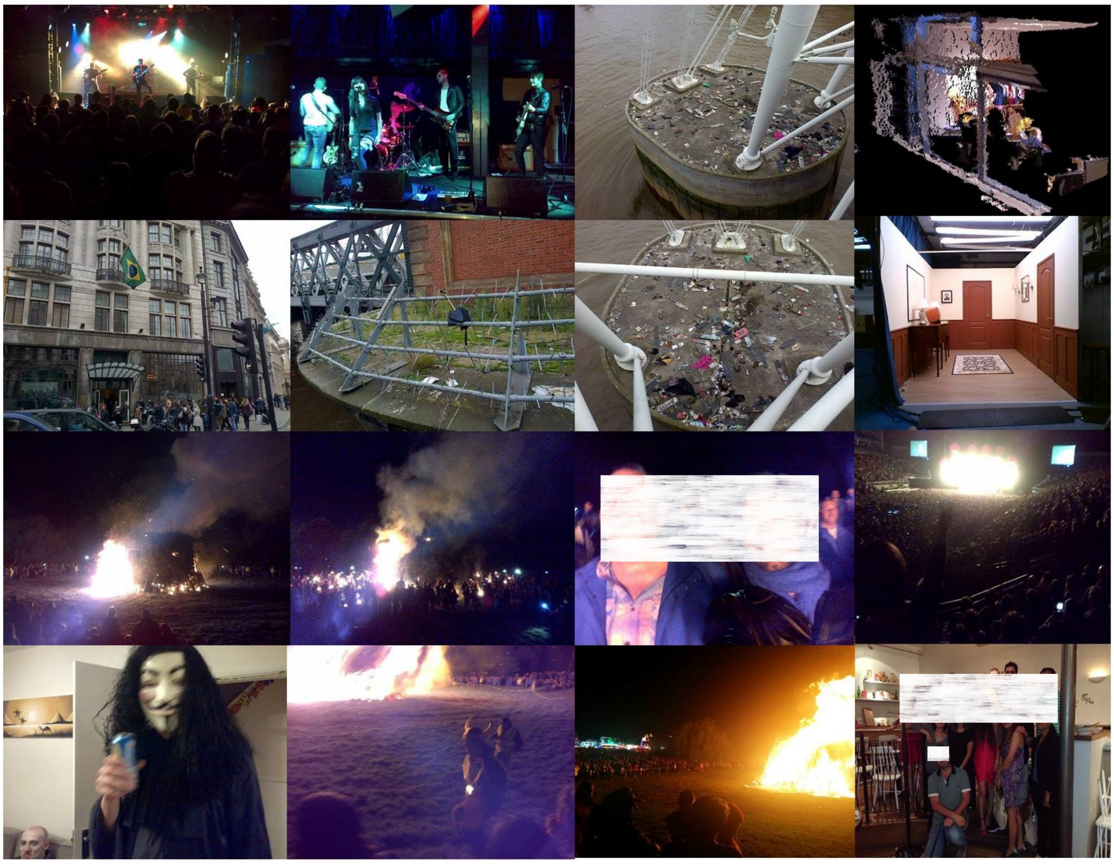

FIGURE 9.23: Example shared photos from the workplace group in the everyday life category.

FIGURE 9.24: The shared photo in the aesthetic photos category.

colleagues but still used Facebook as a platform to notify them. Finally, only 9% of the photos were shared with 4Streams only, which shows that most of the time the participants preferred to use our system alongside Facebook. P3 mentioned that the photos he shared on the computer were the photos he wanted to share with all his friends. Sometimes he wanted to share photos with 4Streams only but, due to the difficulty in using the Facebook privacy settings on his old smartphone, he decided to share photos with Facebook friends.

P1 shared three photos with 4Streams and only one photo with Facebook friends. Unlike P1, P3 shared twenty-four of his photos with Facebook friends and only one photo with 4Streams. P4's activity between sharing photos with Facebook friends (four photos) and colleagues (five photos) was almost the same, while P5 shared four photos with his Facebook friends and only one photo with colleagues. P2, shared two photos only and both of them were with colleagues, which shows that he was not interested in sharing photos on Facebook. Based on this information, it can be concluded that each participant, depending on his personality, had different behaviour for sharing photos in terms of privacy settings. However, as mentioned earlier, P3 said that he would share some photos with 4Streams only if the privacy settings were more user friendly on his phone. The results of the privacy settings for different participants can be seen in Figure 9.25.

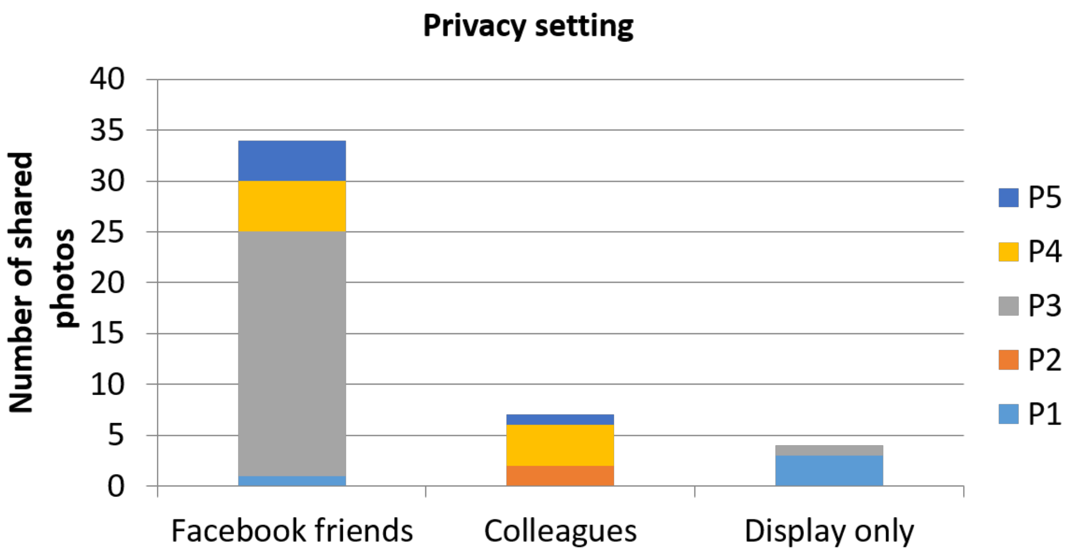

FIGURE 9.25: Privacy settings of photos uploaded by the workplace group.

Interaction with the system

The users were able to interact with the system. Whenever a user ran the application, four slideshow windows appeared. Photos taken and shared by each of the participants appear on their designated slideshow windows. Setup mode appears on the screen when touching any of those slideshow windows. In the setup mode, the user was able to use the timeline to browse the photo streams. In addition, the user was able to play or play back the slideshow to view the photos from multiple users in time order. There was a vertical slider that enabled the user to choose the speed of the slideshow. In this section, the user interactions with the system are presented.

Full screen and setup mode The display was in full screen mode for a total of 671.7 hours. In the first week, the display was in this mode for 167.95 hours. In Week 2, the time the display was on full screen mode decreased to 167.94 hours. In Week 3, the system was in full screen mode for 167.9 hours. In the last week, the full screen mode usage rose up to 167.92 hours.

The system was in setup mode for 17.4 minutes overall. In the first week, participants used the setup mode for 3 minutes and in Week 2 they used the setup mode for 3.6 minutes. In the third week, the setup mode was used for 6 minutes and in the last week the setup mode usage was 4.8 minutes.

Based on this data, it can be concluded that, in the first week the participants were mostly focussing on full screen mode and following that week, as the number of taken photos increased, the number of minutes the system was in setup mode increased. In the third week, the participants used the setup mode to review their uploaded photos and, after that, in Week 4, although the number of photos increased slightly, the participants used the setup mode less than in the third week. However, due to the number of uploaded photos, the setup mode usage in Week 4 was more than in the first two weeks.

Single-window slideshow The single-window slideshow was designed to enable the participants to view a single person's photo stream. Nevertheless, the participants did not use the single-window slideshow to review a single person's photo stream. The logs of the system showed that the system went to single-window slideshow just a few times. During the interviews, most of the participants mentioned that this happenned by mistake or curiosity of learning the system's features. In this group, they did not use the single-window slideshow to view the photos in bigger size, as the photos were big enough to be viewed on the screen.

Speed of the slideshow Interestingly, from the logs of the system it was found that the participants did not even try to change the speed of the slideshow and they used the default slideshow speed; the base of the logarithm for the logarithmic transition was 2. P4 said, and other participants also admitted, that:

> "It (speed of the slideshow) was fine just to play and it was going on...
> Just the default was OK."

Live visual status during the week

During the weekdays the participants shared 37.8% of the shared photos. Not all of the participants were in the office all the time; they had different uncoordinated break times. Therefore, the participants shared photos of new things happening in the office. For example, P4 and P5 took photos of an officemate who was riding a one-wheel cycle in the office environment in order to notify P1 and P2 later about what was happening in the office. P3 took a photo of P2's supervisor with his children in order to notify him later that he was there. The participants also shared many photos of their work software applications in order to update others of their latest research results. Another example was when P4 went to the University of Salford and updated his colleagues about it by sharing a photo showing the university main building. The participants were mostly using this tool during the week to update each other about work and they said that the photos they shared during the week were mostly for colleagues and they would not share those photos with other groups such as family. P4 said:

> "I think I shared some photos specifically knowing that they would be up on the screen in the office. So when I went to a project meeting in Salford I shared a picture of the University of Salford's logo, which, you know, I would have walked normally. But it was kind of different way of communicating with the people in the office....I would not sent the Salford logo to mama."

Weekend news-teller

During the weekends the participants went home and had their own leisure time. As we mentioned earlier, 62.2% of the photos were shared during the weekend. Meanwhile, the participants were taking photos and sharing them on Facebook. However, other participants were not at the office to see the photos live. Moreover, not all participants were checking their Facebook frequently to see all the shared photos. They confessed that they sometimes saw some photos on Facebook before seeing them on the display. The participants gathered on Monday and saw what had happened during the weekend. P1 said:

> "I liked to see what other colleagues are doing when I was not with them. So I can, for example, come on Monday and see what they did during the weekend or something like this and it was nice."

P3 also said:

> "Well, I was more interested in seeing the new picture rather than the old one as I told you before just on Monday to see what was happening in the weekend or something like this."

Getting to know others

In this trial for the workplace group, all the members were not well acquainted with the social context outside work. For example, P1 and P2 were friends and P3 and P5 sometimes went out with their other colleagues. P4 had joined the workplace recently, whereas others had worked there together for long time.

Visualising and sharing the multiple photo streams provided opportunities for the photographers to introduce information about themselves as well as an opportunity for social probing. P2 said during the interview:

> "I could know others better in the office. For instance, P4's daughter, I could see her and I did not know Alan has a daughter or he is married which lead to knowing Alan and his life better. Actually this made us know each other better."

P1 also said:

> "I did not know P4 well and we were talking rarely. With the display our conversations increased and we knew more about each other and we knew what was happening between us during the weekends. This was a good start to know new people more in depth in this office."

4Streams as a conversational tool

Situating the display in the office to let the colleagues share their photos in a semi-social environment provided a significant conversational environment in the office. The nature of this conversation varied depending on whether the photographers were gathering or other colleagues from other offices were entering the room or viewing the display out of the room.

There was a coffee machine in that office where the colleagues used to gather during the coffee break. Other office colleagues joined our participants during the coffee break to chat. The display raised the question of what it is and how it works. In addition, the participants were looking at their photo streams and talking about their latest status while they were taking a photo. P2 said:

> "When I was passing in front of there (office) or during the coffee time, it (the display) was there. So you just take a coffee and talk about the latest photos and sometimes old photos."

P1 supported P2 with an example:

> "There are some funny pictures there. I remember one that Louis made a drawing and we shared it, that was fun. It made us laugh so much."

Regarding the presence of other people from other offices, P5 added:

> "Other people outside were curious sometimes and asking about the display and making funny conversation about our photos."

P1 said about one of his friends who was working in another building:

> "Simon asked how he can be on the display and I told him this is a special tool for us."

Intrusiveness of the display in the workplace

The screen was situated in a place where most of the participants could look at it. When they entered the office, they could see the screen, which was exactly in front of P5. Undoubtedly, the conversations in the office were not only about the photos on the display, although it would turn into a conversation about it later on, as each photo ignited a conversation topic. It is very important to find whether the device was intrusive and whether conversations regarding the display interrupted the participants from working. During work, there were photos that ignited conversation between the participants during work time. However, there were moments that a new photo would arrive but the participants did not start to talk about it at that time. The participants mentioned that the conversations during the work time were not long. An example is when a photo from the University of Salford arrived and P5 updated the others that P4 was there. P5 said:

> "I could see when they changed. Like, if it changed I would look over and see what was new and back to work. Sometimes I talked about the new photo with others but not all the time as I was busy with work."

Regarding the idea of non-intrusiveness, P4 said:

> "I think having it so you could see it directly from the door as you came in. We walked past it several times a day, but for me it wasn't a distraction to have it there. You just thought of looking at it and thought 'ah that's nice'."

P5 complained that the screen kept switching off and P3 replied:

> "Yes, it's my fault. Nobody was in the office and I was working so I did not want to waste energy but most of the times it was a big window-style box over the corner with all the pictures and it was nice... No I did not turned it off for intrusiveness."

It can be concluded that the participants accepted the display as a tool in the office and that it created short conversations between them but it did not distract them from work and they accepted the display as a photo frame in the office.

New photography practice

According to the information gathered at the interviews, we noticed that 4Streams changed the participants' practice of photography. Before using this application, most of the participants' shared photos were about interesting occasions or scenes. However, they continued their past photo sharing practices. Therefore, they were sharing more photos than they were in their normal photo sharing practice. Another reason that they shared more photos was that the application was, by itself, a trigger and motivated them to share more photos. In conclusion, the context of the display changed their old practice of what and how many photos they were sending.

P2 said:

> "More attempted to share more (photos) with (the display) – especially things related to work because that's where the screen was."

P5 added:

> "The incentive was to take and share more photos of people who actually work in that lab."

4Streams and Facebook

In the opinion of the participants, this application could be a supportive add-in application for Facebook. P2 said:

> "It looks like a complement for Facebook because there is that big screen that you can see pictures that your friends posted."

P3 also added:

> "It feels like an extension of Facebook because everything that appears on that screen you've posted on Facebook anyway but with new vision of the workplace photos."

Although they mentioned that the privacy settings in Facebook are not easy and Google+ offers a better platform for choosing the private circle of friends to share photos with, they all admitted that 4Streams has the ability to make Facebook more personal for a small group of friends. They said that, nowadays, their main photo sharing platform is Facebook and not Google+. Therefore, this application can support Facebook rather than Google+.

Compared to Facebook, they were interested in viewing the latest photos of only their colleagues and the photos related to work in the office display. In Facebook, instead, they could see random photos of different people and did not have the chance of seeing photos of their colleagues; colleagues were not always those people whose their photos appeared on the newsfeed page of Facebook. P4 said:

> "Because Facebook gives you what you most want to see when you log in and it probably means that you miss a fair amount of what your friends actually show on Facebook, like people in this group; whereas in your system you always see the latest pictures from each person."

To support this sentence, P2 added:

> "It (Facebook) got this machine learning method that basically learned from your previous behaviour and comments which actually is bad because it tends to be biased towards places that you've seen recently. And there are some people that just get forgotten from the Facebook main page."

Improvements

The participants in this group addressed solutions to enhance application productivity. The improvements are now described.

The first improvement for the office display was that the participants wanted the ambient display to be more passive rather than interactive, which prevented them from any kind of interaction with the system. All of them said that they did not like the interaction section and that the photos on the display were static, making it difficult for them to review older photos. They wanted 4Streams to show old photo streams automatically and the display to be more dynamic rather than a fixed four-slideshow window until a new photo arrives. As a result, they wanted a full passive ambient display to view a slideshow of old photos automatically and to notify the arrival of a new photo when it just arrived. P1 said:

> "It was static and you could just see the last picture. So when I came, for example, on Monday morning, it was just the last picture that they took on the weekend, I would like to see all the pictures they took during the weekend without interacting with the system."

The second improvement the participants mentioned was to provide a place on the screen to show the photo captions; this could bring more information about the photos and they could understand the story of the photos better. However, it could provide fewer subsequent conversations about the displayed photos. P5 said:

> "Something else that just occurred to me was you don't see captions on the system, so you might write a witty caption or an amusing caption."

Furthermore, since not everyone in their office was active, the participants wanted to add more people to the group so that they could follow the active members. P4 said:

> "I like viewing four people and then adding another person you kind of like and then just switch off the user because he hasn't been sending anything...And then switch on whoever was active let's say."

9.6 Summary and discussion

In this chapter, the user experience within 4Streams was described. Three groups were recruited for the study. It was found in the literature review that there is a need for sharing photos within a small group of people [39] and what we we found in Phase 1 of our study was the need for a live photo sharing application as an ambient display and the importance of showing multiple photo streams concurrently. 4Streams was built in response to these needs. In this chapter, the results of a study comprising three groups of people (extended family, close friends and workplace friends) were presented.

The reason we decided to ask for extended family was that a family is a small group and they do not hesitate to share their personal photos. Moreover, older members of the family like to see what is happening to the other members of the family by photos [19]. In the pilot study, we found that 4Streams was a good platform for news telling via photos. Therefore, extended family members could benefit from this characteristic of the system.

The second group was a group of close friends. In our previous study in Phase 1, we found that friends like to share their photos with each other. Moreover, there are lots of photo sharing applications currently that close friends use to share their photos, such as Viber and Whatsapp. However, current photo sharing platforms do not provide well-organised photo collections between small groups of people. Therefore, we decided to examine how 4Streams fits with a small group of close friends.

The third group comprised four colleagues who shared an office. We did not have information about how a photo sharing application display fits into four workplace colleagues. The only thing we knew was that many people check their social media websites at work. We did not even know whether a display would distract them from work. Therefore, we decided to examine the impact of the photo display in a university office environment and see in what ways colleagues share their photos with each other when they have a display at work.

In the family group, the average number of photos uploaded per day was different in each phase. In the phases when the oldest member of the family was alone, the number of uploaded photos from other members increased; in total they shared seventy-one photos. In the close friends group, forty-four photos were shared in total and when one of the participants was at a wedding event and was away from the others, the number of uploaded photos increased. In the workplace group, forty-five photos were uploaded and in Week 3 of the study they uploaded most of the photos. Interestingly, the photos in the workplace group were mostly shared at the weekend.

The majority of the shared photos in the family group belonged to the everyday life category (46.4% of the photos). This type of photo is sent with the intention of keeping people connected to the everyday life of their family. This photo category contains photos about normal things in and around the house and typically contains photos of the home environment such as children, garden and animals.

The majority of the shared photos in the close friends group were for messages (45.4% of the photos), where participants were trying to inform each other via their latest statuses. Photos in this category are meant for notification or discussion; for example, to involve people in choices. Sending a message will probably be followed by communication when the time is right. Most of the shared photos in the workplace group were special events, constituting 40% of the photos; participants uploaded photos of special events during the weekend to let the other colleagues review them later in the office. The participants in each group used 4Streams for sharing different types of content depending on the type of group and participant.

In another study [71], the biggest category was special events (54.4%) where other family members shared their photos with older family members. In the family group, the participants' sharing rate increased in Phases 3 and 5 because the oldest member was alone, but the majority of photos belonged to the everyday life category. In another study [19] of sharing photos with older family members, most of the photos belonged to the everyday life category (27.3%), a result supported by the family group in our study.

As mentioned earlier, Frohlich [2] introduced the diamond framework for photo sharing and the main components of photo sharing were the subject, the photographer and the audience. Each of these components were experiencing a sense, one at a time, such as recognition, interpretation, reminiscing, storytelling or recollection and self-recognition. In this user experience study we found that using 4Streams combined the sense of interpretation, recognition, recollection and self-recognition in a single solitary interaction of a user within the system. Therefore, we designed a new framework for solitary interaction of a user with 4Streams, as seen in Figure 9.26. This diagram shows that a photographer, by viewing the 4Streams display, can be a photographer, an audience member and a subject simultaneously. Moreover, during the slideshow, when the time feature is added to this system, the transitions between being a photographer and a subject and/or an audience member can be varied.

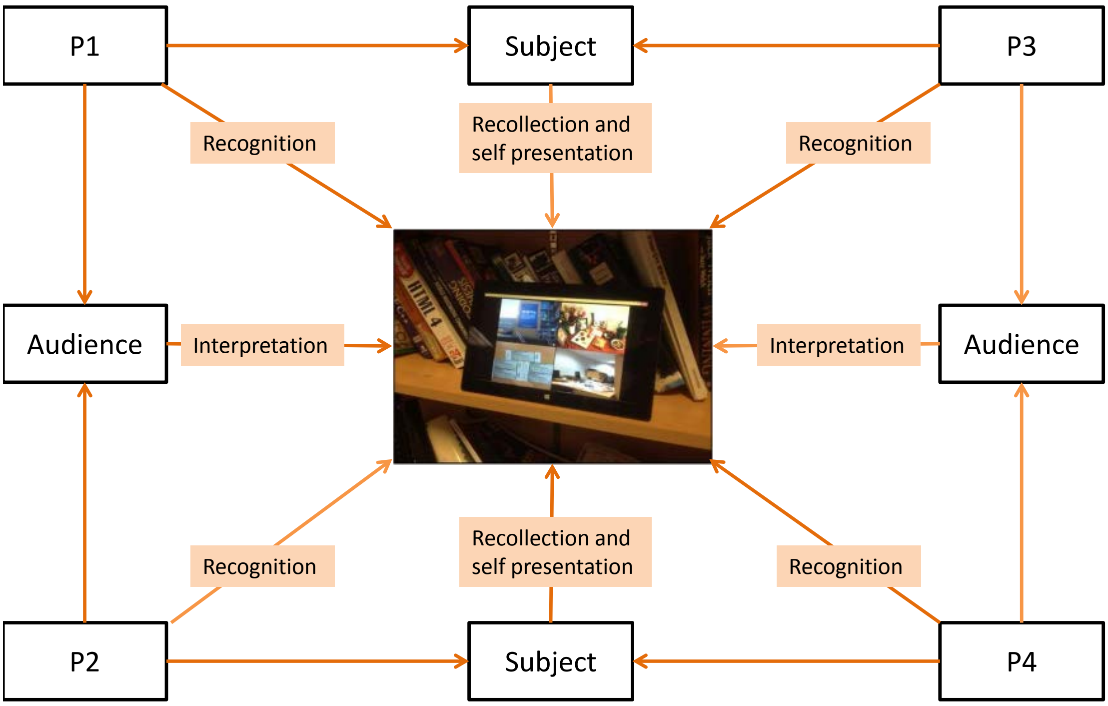

FIGURE 9.26: Solitary interaction of a user with 4Streams.

In the social interaction between a user and the system, 4Streams brought a new sense of social interpretation and bi-directional storytelling, which Frohlich did not define. In social interaction, two audience members talk about a photo they did not take or for which they are not subjects; bi-directional storytelling, two photographers, two subjects or a subject and a photographer who did not take a photo but were one of the photo sharers, tell a story about their photos to each other. 4Streams provided a new combined sense of social interaction between the user and the system, as defined by Frohlich. In Figure 9.27, the possible social interactions between a user and the system are presented.

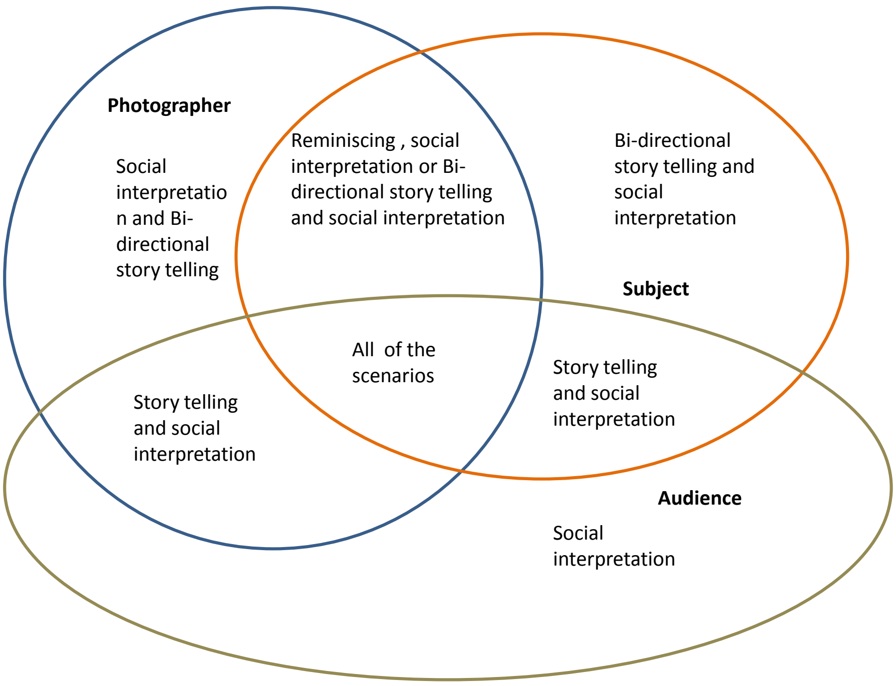

FIGURE 9.27: Social interaction of the user with 4Streams.

4Streams was also used as a decoration tool by the family and workplace groups. In the family group, it was placed on the dinner table or a shelf of the house. The workplace group accepted 4Streams as an ambient photo display in the office for decoration. However, the close friends group did not show any interest in using the system as a decoration tool and did not leave the displays on their desks.

4Streams was a trigger for other means of communication between the family group members; a good example is when the grandmother of the family sent an SMS message to other members of group after seeing a photo of a fox in their backyard. On the other hand, in the close friends group, Facebook was the main platform for photo sharing. In the workplace group, the participants used the Facebook comment boxes for talking about the photos. Moreover, the photos taken over the weekend were discussed during the week by the participants; this made the system useful as a conversational tool in the office.

4Streams brought other people who were not participating in the study into the experiment as an extended audience. For example, in the family group, the children and a friend of the mother of the family were interacting and talking about the display, and this provided a good platform for children and socialisation. In the workplace group, people from other offices were interested in the photos their colleagues took and talked about these photos with the participants. However, the close friends group did not mention other people interested in the photos on display as they did not place the display in their homes.

For the family group, the main sharing platform was the 4Streams display as they shared most of their photos with the display and they did not use Facebook as their main platform of photo sharing. The workplace group's main device for viewing the photos of others was 4Streams; however, they said that, on some occasions, they saw the photos on Facebook before viewing them on 4Streams. The close friends group's main platform of photo sharing was Facebook and they preferred using Facebook for viewing photos rather than 4Streams.

The results show that 4Streams was very useful to the family group and family members expressed their desire to own this type of device. Although we did not know what the effects of 4Streams might be on the workplace, 4Streams was an appropriate and non-distracting tool in an office environment. However, the main concern of the friends group was the mobility of the device; they did not like the idea of using 4Streams as an ambient display and they liked to have it on their mobile phones.

Finally, the system had a number of limitations. Participants suggested the system should be able to retrieve photos when it was not connected to the Internet. Moreover, participants suggested implementing this application on a mobile phone platform. Some participants believed that the system should have a different upload page than Facebook, while others believed that this application is well suited for Facebook users. The final suggested improvement was to make the display show old or new photos automatically based on subtle or implicit user interactions such as eye-gaze or movement.

Chapter 10

Conclusion

10.1 Introduction

This thesis presented a series of research work dedicated to providing an understanding of, and recommendations for, the design of visualisation and sharing of photo streams by small groups of people such as friends and family members. Section 10.2 of this chapter describes the achievements of the work presented in this thesis and contributions to the knowledge base via the research questions detailed in the Introduction chapter. Section 10.4 outlines possible future work that could be carried out as a result of the conclusions of this thesis.

10.2 Conclusions

The major contributions of this thesis allow the conclusions to be summarised as follows, answering the research questions. In addition, the design recommendations that are concluded from the results of this thesis are presented at the end of this section.

10.2.1 Values and requirements of sharing and visualisation of past photo streams by a small group of friends

Nowadays, people tend to share their photos. Not only are they keen on sharing their photos with others, but also they want to view other people's digital photos. The thorough literature review called for the design of a photo sharing application to enable people to share and see their photos taken in different places and times among small groups. In order to fill this gap, a web-based photo sharing and visualisation application was built and implemented that enabled people to view and share their old multiple photo streams concurrently and chronologically, thus enabling them to compare what happened to them in the past via their photos.

A user study was conducted by deploying the system to twenty people and the result showed that the system surprised the participants when the photos on the display were from the same time and same place (collocated) or the same time and different place (remote) in both our layouts, which were multiple- and single-window slideshow. For the collocated experience, multiple users took photos of the same event and, therefore, the event was shown more completely from the perspective of different photographers. For the remote experience, the users were able to see what happened to others while they were doing something else in the past. Unlike the single-window slideshow, which did not satisfy the users in this regard, the participants liked the multiple-window slideshow. There was another state: Asymmetric transition. In this state, one user had many more photos than other users; therefore, multiple photo streams were not shown concurrently all the time. The solution to this problem was to summarise multiple photo streams for consistency between slideshow windows during the presentation.

In our initial design, there were three transition types designed for the system in addition to the normal slideshow with a two-second fixed transition to see whether the user experience increased the joy of the slideshow. The transitions were proportional, event informer and user desired time. In the proportional transition, the slideshow transition between each slide was calculated based on the time difference between consecutive photos. In the user desired time, the total slideshow time was chosen by the user and the transitions were calculated based on the user desired time. Finally, in the event informer, multiple photo streams were clustered based on time features and at the end of each chronologically sorted cluster there was a message to say the event has changed.

The proportional transition time provided a sense of natural event change for the participants during the slideshow. However, the problem was that in some cases the slideshow was very fast or very slow. The event informer showed the event change message during the slideshow and, therefore, the participants could identify photos that did not belong to the same event. However, it was not as intuitive and natural as the proportional transition. The normal slideshow was boring and time consuming for the participants. In addition, the desired time introduced viewing photos in a desired time selected by the user for the presentation. However, it did not give a notion of time for event change or show photos taken in bursts faster. Another problem of the desired time was when the total slideshow time was short and the server was not able to load all photos during the slideshow.

The results showed that the proportional transition time was the favourite transition. However, the average interest in this transition was not significantly higher compared to the desired time and the event informer. All our proposed transitions had a significantly higher rank compared to the normal slideshow. However, our proposed transitions still had problems and the participants proposed combining these methods in order to solve the problem that some transitions are sometimes too long and sometimes too short.

In this study there were three groups: family, friends and close friends. In the family and friends groups, the participants experienced creating a photo diary and our application made viewing those photos from different angles fun and enjoyable. The close friends group uploaded their old photos and our application brought an awareness of their past and comparison between their old photos.

From this experiment it was identified that the requirements for the visualisation of multiple photo streams using our system are: photo summarisation across multiple photo streams, image re-targeting, adding a visual status to the system for communication via photos, making the system ambient, designing a single timeline for browsing multiple photo streams, combination of transitions and finding the optimal temporal parameters for the visualisation of photo streams.

10.2.2 Determination of optimal temporal parameters for the visualisation of multiple photo streams

From the study design and the study conducted in Chapters 4 and 5, we identified the following three temporal aspects for the visualisation of multiple photo streams: manual transitions, continuity transition and desired time transitions. The manual transitions contained the logarithmic, proportional and fixed transitions. In the logarithmic transition and the proportional transition, the slideshow transition was proportional to the time difference between consecutive photos. In the fixed transition, the user was able to change the transition manually by a fixed amount. In the continuity transition, if two consecutive photos were continuous, then the transition was faster than that for two discrete consecutive photos. The desired time transition contained a logarithmic desired time transition and a summarisation desired time. The former showed all the photos but the slideshow transitions increased based on the user desired time and, later, the redundant photos (Asymmetric transition state) were eliminated by clustering photo streams based on social metadata and temporal features alongside the selection of the most representative photo in the cluster by using a SIFT flow algorithm.

The first study was a task-based user experience study and the manual transitions alongside the system values in remembering the photos were evaluated. Our findings demonstrated that, although the participants might sometimes forget what happened next in different conditions (mostly in the researcher's stream), when we showed them a photo from the presentation of multiple photo streams, they had a good recollection of the narrative in the multiple photo streams by remembering the photos and what happened next for 79.15% of the time. Hence, this application was a good platform for recalling the photo collection stories of friends and comparing previous events via photos.

The findings showed that the logarithmic transition was the preferred transition, followed by the fixed and proportional transitions. The results also showed that the transition types affect the total slideshow time and the results of remembering between transition modes were not significantly different.

The photo streams from camera phones brought more transition between slideshow windows and, consequently, a better experience of viewing multiple photo streams. The results also showed that searching via a single timeline was a pleasant experience, where participants were able to find their own and their friends' photos using the timeline and control buttons.

The second study developed a better algorithm for detecting the continuity. Three algorithms were used to create the continuity transition; these three algorithms were evaluated and we found that SIFT was the best among them. The logarithmic transition enabled participants to view photos taken in bursts faster. However, the continuity transition presented continuous photos taken in bursts faster, thus enabling viewing of photos taken over a longer period of time in time-lapse mode (for example, a time-lapse of a flower blooming).

The last study was the comparison of the logarithmic desired time and the summarisation desired time. The results showed that, for short time presentation, the summarisation desired time is better than the logarithmic desired time. However, when the total slideshow length increased, the participants preferred the logarithmic transition time.

10.2.3 User experience of ambient visualisation of multiple photo streams within small groups of people

In order to investigate the user experience of the visualisation of multiple photo streams within small groups of friends, an application was designed and implemented. In this application, people were able to share their photos with our application via Facebook and follow the latest visual status of others. Moreover, they were able to review the past photo streams they took concurrently.

This system was deployed separately as a field study, between three groups: close friends, family and workplace colleagues. In the family group and close friends group, each participant had the application on a Microsoft Surface Pro tablet in their own place, while in the workplace group, a large display was situated in the office for the people working at the same place. After the experiments, the logs of the participants' interactions within the system were stored and analysed. Moreover, a focus group session was conducted and the results were analysed qualitatively.

The results showed that the system fitted the family group nicely, as they shared a reasonable number of photos; they viewed the photos from our application on Microsoft Surface Pro displays provided to them by sharing the photos with that display only. On the other hand, the close friends group preferred to review their photos from Facebook by sharing them with both the display and the Facebook friends rather than our display only. The close friends group participants said that they did not like having their friends' photos on the display on their desk while they could view their photos on Facebook. However, they said that they would like to share their photos with their family members with our application.

The study with the workplace group showed that the system was not intrusive in the office and the participants could consider it as a picture box in the office. In this group, the participants shared the photos of their weekend for discussion on weekdays; they also shared the photos related mostly to work during the week. The results showed that our application fitted the workplace group well.

Previously, Frohlich [2] introduced the diamond framework for photo sharing, with the main components of photo sharing being the subject, the photographer and the audience. Each of these components experiences one experience at a time, for example recognition, interpretation, reminiscing, storytelling or recollection and self-recognition. In this user experience study, we found that using our application results in having a combined sense of interpretation, recognition and recollection and self-recognition in the solitary interaction of the user with the system. Moreover, in the social interaction between the user and the system, our application brought a new sense of social interpretation that Frohlich did not define [2], whereby two audience members talked about a photo they did not take or they were not a subject of. Moreover, our application provided a new combined sense of bi-directional storytelling, social interpretation and reminiscing together in social interaction.

10.2.4 Design recommendations for photo sharing applications

As found by the user experience studies in this thesis, the sharing and visualisation of multiple photo streams within small groups of people, such as friends and family members, was an interesting experience for our participants. According to the major findings of this study, the design recommendations are listed as follows:

- The designed system for the visualisation and sharing of photo streams should take advantage of the network connectivity between the devices.
- Due to situations where the Internet connection speed is low or the Internet becomes disconnected during real-time photo visualisation and organisation, the photo sharing application should save the photos and keep the latest photos and their associated information on the hard drive after connecting to the Internet.
- The photo sharing application should be able to support different screen sizes such as large displays, mobile phones and digital photo frames.

- In order to have an efficient photo sharing application between multiple people within a small group, the application should enable the users to compare their past by the time of capture, whether or not they were together at the same time.

- It is necessary to have an option to summarise multiple photo streams when photos of different streams do not belong to the same time in order to provide a comparison between streams and decrease the presentation time, thus avoiding boring presentation.

- Manual transitions, such as the logarithmic and the fixed transition time, enhance the experience of the slideshow. The nature of the logarithmic transition time decreases the total slideshow time by improving the comprehension and the feeling of event changes; the fixed transition time lets the user view photos manually in more detail or faster.

- The results showed that 28% of photos in photo collections are continuous, which means there is a movement feeling between consecutive photos taken in bursts or as a time-lapse. Therefore, there is a need to design a feature to show those photos automatically using a video sequence to make the presentation more pleasant and decrease the presentation time.

- To search through multiple photo streams, a single timeline alongside control buttons, such as play back and play forward, using different transitions is beneficial.

- Future photo sharing and visualisation applications should support video and audio alongside still photos.

- Extended families would benefit from having a photo sharing display at home to update their visual status regularly with each other as a communication and decoration tool.

10.3 Limitations

Although the study provided answers to the research questions set out in Chapter 1 and revised in this chapter, a number of issues emerged that provide an opportunity for further research and which are listed below.

- This thesis was limited to photos shared by camera phones or point-and-shoot cameras. However, photos from wearable cameras were not used and the value of using our system with photos from wearable cameras has not been investigated.
- The final version of the system (4Streams) was not able to retrieve photos that arrived when the device was off and this issue should be solved in the future.
- None of our systems were able to support audio files alongside the photo or video although video and audio are media that provide information in more detail. Moreover, some participants mentioned during the user study that they would like the system to have video sharing alongside photo sharing.
- During the user study, we found that the participants wanted to enjoy a sense of awareness in remote experience, completeness in collocated experience and live communication via visual statuses using our application. This could be provided by designing 4Streams to be operated on mobile phones; the current 4Streams design is not suitable for mobile phones as the screen on mobile phones is too small.
- Another limitation of our system was that it changed the aspect ratio of the photos. This has been scarified by having all information of the photo rather than choosing the centre of the photo. Therefore, in some rare cases, the photos on the screen were not pleasant.
- Another limitation of the system was not designing a subtle or implicit interaction with the system, such as using hand gestures or eye gazing. Therefore,

the participants proposed designing a system in a way to be smarter by user movements rather than showing the latest visual statuses all the times or detailed interaction of the user within the system for reviewing past photos.

- Our system supported the presentation of multiple photo streams from up to only four people.

10.4 Future work

We are aware of the limitations of the current system and we suggest further work in the area of photo sharing within a small group of friends. Hence, this section presents extended research possibilities.

10.4.1 Investigation of passive photography values using our system

As described in the literature review, there is a new type of photography, passive photography [45–47]. In passive photography, users wear a camera and, then, the capture device takes photos automatically based on different sensors such as timer, light change and temperature change. The value of passive photography have been identified previously in [1, 27]. One research area to be considered is visualisation and sharing of photos taken in a passive manner. Our application has the potential to present multiple passive photo streams obtained by different users and, therefore, investigation of the passive photography values using our system during photography and during visualisation is a good future research driven by this work.

10.4.2 Combining passive and active photography

Passive photography might become a common type of photography if photo visualisation tools are developed to support this type of photography in the future.

However, undoubtedly, normal active photography with camera phone and point-and-shoot cameras will still have their own values. Therefore, creating a tool to enable the user to have an enjoyable experience when reviewing passive photo streams alongside active ones is another future research are driven by our research.

10.4.3 Designing and studying our application for smaller screens such as mobile phones

A third suggestion for future studies is to design a new application for concurrent visualisation of multiple photo streams on mobile phones. As the popularity of smartphones has increased, the development of natural user interfaces for mobile phones has drawn attention from both the research and commercial communities. For example, in current mobile applications, photos are shown in chronological order in grid view or as a single photo on a screen. Re-targeting [59, 76, 77] is another approach to fit the smaller size photos on mobile phone screens. Moreover, Karlsson et al. [9] proposed a solution by summarisation of photo collections on smartphone displays. Our system presented its own values for sharing and visualisation of multiple photo streams but the users claimed that they need to view photo streams on their mobile phones, which have small screens. Therefore, it is worth designing and studying a new application for sharing and visualisation of multiple photo streams on smaller devices such as mobile phones.

10.4.4 Adding implicit or subtle interaction for larger screens in home or workplace environments

In this research we found that using our photo sharing application in a fixed place with a larger display is suitable in the workplace. However, using still images as the latest visual status of users for a long time was not pleasant for the participants. Currently, there are many cheap devices to support gesture interaction, such as Microsoft Kinect [181]. Therefore, designing an implicit or subtle interaction for

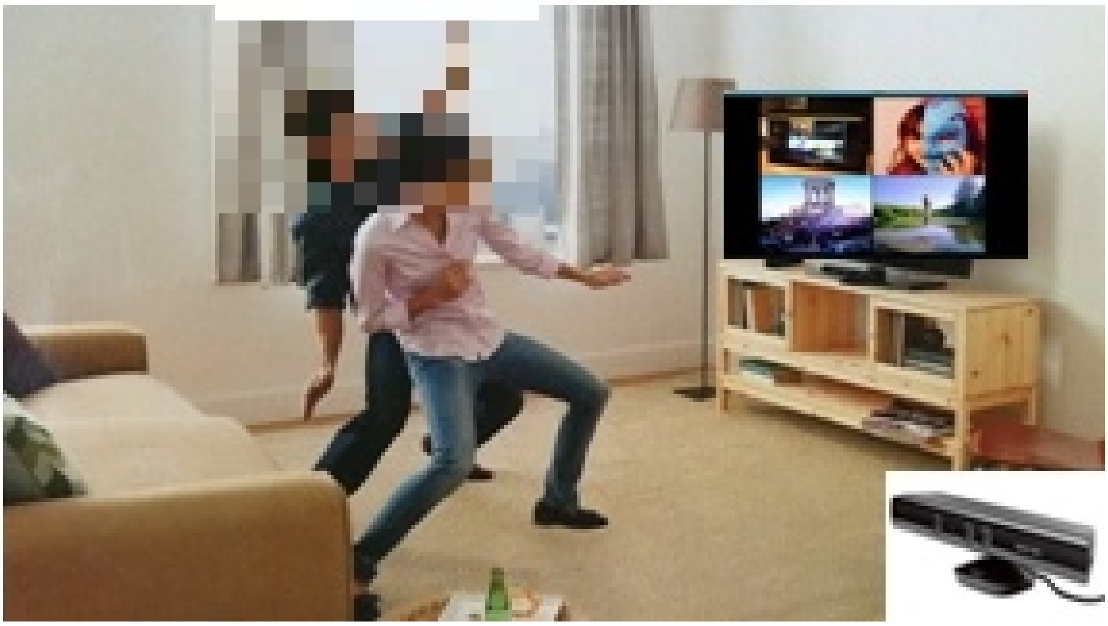

FIGURE 10.1: Future interaction with our photo sharing application. Adopted from [22].

larger screens at home or in the workplace using interaction design techniques could be a potential research area in the future.

10.4.5 Increasing the number of photo sharers on the display

In the field study of 4Streams we found that there is a demand for visualisation of multiple photo streams on larger screens. The participants reported that the current size of the photos on the screen was fine. However, in all versions of our application the number of people who could share their photos using our application was up to four. Potential future research could be to increase the number of people in larger screens and to find the threshold for the maximum number of photos that can be displayed on the screen. Moreover, other interface layouts can be proposed for visualisation of the latest visual status of large numbers of people and to investigate whether there is any value in this approach.

10.4.6 Organisation of multiple photo streams

We have described the current organisation tools and algorithms for photo collections in the literature review. Moreover, in our research, a new approach for presentation and visualisation of photo streams was proposed. The results showed that, by using timeline and control buttons, the users were able to search their photos manageably. However, there is still a need to design new interfaces for the automatic organisation of multiple photo streams collected by different people, capture devices and social networks. A potential future research could be to design and implement an interface to organise multiple photo streams automatically between users using photo metadata and features in different layouts.

10.4.7 Adding other media such as video and audio to our system

As can be seen in the current trend, as well as from our findings from the user study, people tend to share their videos alongside their photos because video provides more detail about an event. Moreover, audio photography [2] could be a potential future of photo visualisation since audio alongside photo provides better reminiscing of the past. Therefore, designing a system to support a package of photo, video and audio photo sharing, and visualisation is another potential future research area driven from our work.

Appendix A

Appendix

Interview schedule

Opening:

- Who are you and what do you do with your digital photos?

Photography practice:

- How do you take your photos?
- How do you organize your photos?
- How do you share your photos? How often? With who?

Watching multiple photo streams with single window slideshow

- What surprised you in this study?
- What do you like about the system?
- Did you talk about the experienced that you had with other friends in this study? Can you explain?
- What do you like about this interface?
- What was not so good about this interface?
- Was that easy to learn using the system?
- What errors did you face to?
- What do you think about the interaction within the elements of the screen such as buttons and sliders?
- What do you recommend to enhance the single window slideshow?
- Can you draw a new interface for this?

Watching multiple photo streams with multiple windows slideshow

- What surprised you in this study?
- What do you like about the system?
- Did you talk about the experienced that you had with other friends in this study? Can you explain?
- What do you like about this interface?
- What was not so good about this interface?
- Was that easy to learn using the system?
- What errors did you face to?
- What do you think about the interaction within the elements of the screen such as buttons and sliders?
- What do you recommend to enhance the multiple windows slideshow?
- Can you draw a new interface for multiple windows slideshow?

Transitions

- What do you think about each transition? Any suggestion for improvements?
- Which transition was your favourite? Why?
- Can you rate each transition in a paper that I will give to you in a way that I will explain?

FIGURE A.1: The interview guidance of phase 1 for user experience study of multiple/single windows slideshow

Experiment form:

Initial interview	• m/f • Age • Occupation • Have you ever used any social media or web based photo sharing applications? Can you tell me their names and how did you use them? • How do you watch or share your photographs? • Introducing the application before starting the experiment.
Speed adjustment condition 1 (log)	• Adjusting the speed for comfort • Starts with the fastest • In the middle of the presentation the speed will be changed to the slowest
Tasks and questions	a. Showing their picture i. Gist: can you remember and tell me about this picture? ii. Narrative: Can you remember what happened next? iii. Parallel: Can you remember what happened in parallel with other next? iv. Verify by search b. Showing other picture i. Gist: Did you see this picture and what do you think is happening in this picture? ii. Narrative: Can you remember what happened next? iii. Parallel: Can you remember what happened in parallel with you next? iv. Verify by search c. Into which photo stream slideshow window you paid attention more? Why? d. Which stream was your favourite? Why? e. Which stream had more interesting content in? f. Can you remember which stream had more pictures? g. Did you like the distribution of photos? If not, what is the desirable form of photo distribution for you?
Search time	-------- 1-own: 2 - other:
Speed adjustment condition 2 (Real proportional)	• Adjusting the speed for comfort • Starts with the fastest • In the middle of the presentation the speed will be changed to the slowest
Tasks and questions	a. Showing their picture i. Gist: can you tell me about this picture? ii. Narrative: Can you remember what happened next? iii. Parallel: Can you remember what happened in parallel? iv. Verify by search b. Showing other picture v. Gist: Did you see this picture and what do you think is happening in this picture? vi. Narrative: Can you remember what happened next? vii. Parallel: Can you remember what happened in parallel? viii. Verify by search c. Into which photo stream slideshow window you paid attention more? Why? d. Which stream was your favourite? Why? e. Which stream had more interesting content in? f. Can you remember which stream had more pictures? g. Did you like the distribution of photos? If not, what is the desirable form of photo distribution for you?
Search time	-------- 1-own: 2- other:
Speed adjustment condition 3 (Fix)	• Adjusting the speed for comfort • Starts with the fastest • In the middle of the presentation the speed will be changed to the slowest

Figure A.2: Experiment guidance of phase 2 for evaluation of temporal aspects of multiple photo streams

Tasks and questions	a. Showing their picture i. Gist: can you tell me about this picture? ii. Narrative: Can you remember what happened next? iii. Parallel: Can you remember what happened in parallel? iv. Verify by search b. Showing other picture i. Gist: Did you see this picture and what do you think is happening in this picture? ii. Narrative: Can you remember what happened next? iii. Parallel: Can you remember what happened in parallel? iv. Verify by search c. Into which photo stream slideshow window you paid attention more? Why? d. Which stream was your favourite? Why? e. Which stream had more interesting content in? f. Can you remember which stream had more pictures? g. Did you like the distribution of photos? If not, what is the desirable form of photo distribution for you?
Search time	-------- 1) own : 2) other:
Final Interview	1. How do you feel about the experience that you had with the system? 2. What are the differences between this application and other photo sharing applications or social network website? 3. Would you like to share your photos in this way? 4. Has this application the potential to change your photography habit? In what way? 5. Which conditions(log, real and fix) was your faviourit condition? 6. Where and for what situation you use each condition? 7. How did you find the experience of search using this application?

FIGURE A.3: Experiment guidance of phase 2 for evaluation of temporal aspects of multiple photo streams

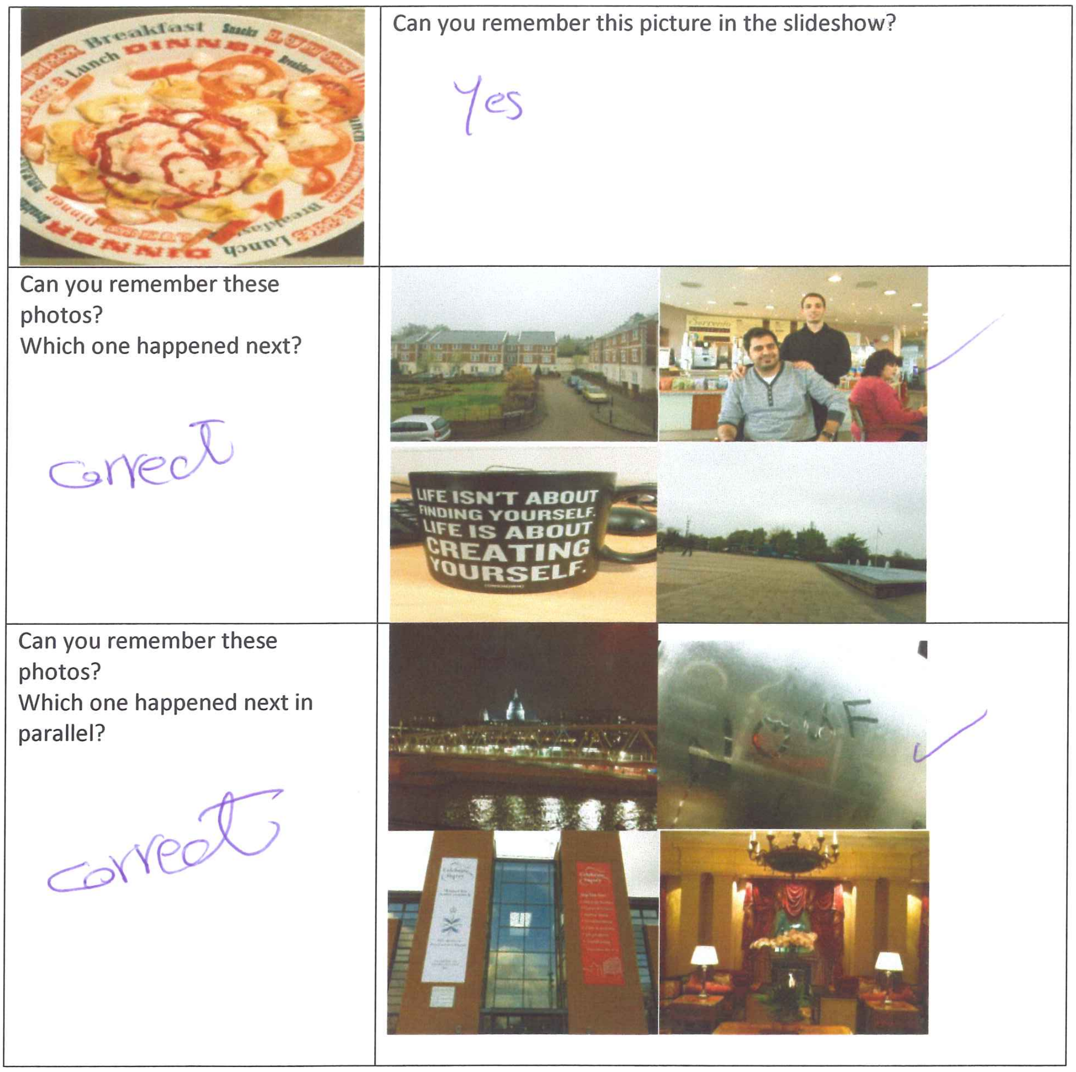

Figure A.4: The form for evaluation of the comprehension in visualisation of multiple photo streams

Pre and Post-trial interview schedule (90 min)

Switch on the audio recorder...

Pre Interview

1. Can you introduce your self and how long have you been as a family?
2. How do you stay in touch with other members of family when you are apart?
   a. Between you
   b. Between other members of family
   c. Youngerts
   d. Olders
3. How do you take and share photographs today? Can you say alittle bit about that?
   a. Family members
   b. Friends
   c. How often do you take pictures?
   d. What device?
   e. Who do you share those photos with?
   f. How do you share?
4. What social media do you use? Which one involves the sharing of photos?
5. How do you share photos using those media?
6. What kind of photos do you share with different people?
7. What kind of issues do you have with photo sharing today? How can the experience be improved?
8. Do you like photo sharing? Why?

Opening

1. How do you feel about the experience that you had with the system in general? Key Values?
2. What are the best and worst features?
3. How do you compare it with other communication systems? How did this application changed your sharing habit in compare to other communication sytems?
   a. Facebook
   b. Twitter
   c. Instagram
   d. Whats App
   e. SMS
   f. IM chat
   g. Photo display
   h. snapchat
4. Who else would you like to do this experience with in future?

Capture and Share

1. What device/devices did you use to take photos?
2. How often were you taking photos?
3. What kind of photos did you take?
4. Did you edit photos before sharing? Approximatly, how many of them?
5. Why did you share your photos with your family?

Figure A.5: Interview guidance for phase 3 in the field study of family group

Live Mode (Sam)

1. How did you feel about having 4 family members latest statuses via their photographs in one screen?
2. Where did you place the device?
3. Did your other family members or friends out of this group notice the device at home? Who were they? What was their reaction?
4. How often were you checking the screen?
5. When the display was attracting your attention?
6. How did you share the taken photos and with what device? Did you share all photos immidiatly after taking them? Did you share your old photos?
7. Did you take any photo when you were together?

Break (10 min)....

Review mode (Sam)

1. How often were you interacting with the system and reviewing the photos that you all took?
2. What techniques did you use to review your photos? (eg. Play, playback, timeline)
3. What was your common technique for reviewing photographs?
4. Can you tell us what happened between you briefly by watching the photographs that you took using the system?
5. Who was the most photo sharer between you? Why?
6. Was there any strange moment after watching your photo streams?
7. Have you experienced watching your photos as a group of family? How was the experience?
   a. What was the difference of collectively watching in compare to individually watching ?
8. What speed of slideshow did you use? (Fast, Slow) When did you use the fast speed and when did you use the slow speed? (e.g. Digital ambient display in slow mode and fast reviewing in fast mode)
9. Did you leave the device to play for a long time as a digital ambient display?

Figure A.6: Interview guidance for phase 3 in the field study of family group

10. Did you use the single window slideshow? How and when did you use that?
11. Whose photo stream did you see on that mode?
12. Which one did you use the most? Single or multiple windows slideshow? Why?

Design

1. How can we re-design the system better? Any improvment and change?
2. What do you think about A-symmetrical (Setting privacy for each person) design of this system?
3. How many people would you like to see on the screen? Can you explain more?
4. What is your idea about the size of the display and the number of people?

Switch audio recorder off...

Figure A.7: Interview guidance for phase 3 in the field study of family group

UNIVERSITY OF SURREY

Ethics **C**ommittee

Mr Sam Zargham
CVSSP
FEPS

25 June 2014

Dear Mr Zargham

Sharing and Visualisation of multiple photo streams EC/2014/74/FAHS

On behalf of the Ethics Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the submitted protocol and supporting documentation.

Date of confirmation of ethical opinion: 25 June 2014.

The final list of documents reviewed by the Committee is as follows:

Document	Version	Date
Letter from researcher in response to queries from reviewers, sent 04 June 14		16 June 14
Protocol Cover Sheet		16 June 14
Summary		08 May 14
Detailed protocol		16 June 14
Participant Information Sheet		16 June 14
Consent form		16 June 14
Semi-structured interview schedule for group discussions		08 May 14
Public Liability Insurance		15 July 13
Research Insurance Proforma		08 May 14
Note: Documents have been dated 08 May 14 and 16 June 14 in line with the date they were received from the researcher, in the absence of dates on the documents.		

This opinion is given on the understanding that you will comply with the University's Ethical Principles & Procedures for Teaching and Research.
If the project includes distribution of a survey or questionnaire to members of the University community, researchers are asked to include a statement advising that the project has been reviewed by the University's Ethics Committee.

If you wish to make any amendments to your protocol please address your request to the Secretary of the Ethics Committee and attach any revised documentation.

The Committee will need to be notified of adverse reactions suffered by research participants, and if the study is terminated earlier than expected with reasons. Please be advised that the Ethics Committee is able to audit research to ensure that researchers are abiding by the University requirements and guidelines.

FIGURE A.8: Ethics approval

2

You are asked to note that a further submission to the Ethics Committee will be required in the event that the study is not completed within five years of the above date.

Please inform me when the research has been completed.

Yours sincerely

Mrs Gill Fairbairn
Interim Research Liaison Manager, Research & Enterprise Support

Figure A.9: Ethics approval

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