4streams: An ambient photo sharing application for extended families

Sam Zargham
Centre for Vision, Speech and Signal Processing
University of Surrey
Guildford, GU2 7XH, UK
s.zargham@surrey.ac.uk

Janko Ćalić
Centre for Vision, Speech and Signal Processing
University of Surrey
Guildford, GU2 7XH, UK
j.calic@surrey.ac.uk

David M. Frohlich
Digital World Research Centre
University of Surrey
Guildford, GU2 7XH, UK
d.frohlich@surrey.ac.uk

ABSTRACT

In this paper we describe a novel photo sharing system called 4streams. This is an ambient photo display that allows a small group of users to keep in touch through a kind of visual twitter feed of concurrent photographs from their mobile phones. The photographs of up to four users are displayed in a dynamic collage in the four quadrants of a dedicated ambient display, with photographs to each quadrant arriving in real time as photographs are taken/uploaded. Historical photos can also be browsed or played back in lockstep with each other, as a reminder of what each member of the group was doing over the same period of time. The system was trailed over seven weeks by an extended family distributed over three countries. The findings suggest that the system increases the social connection and presence between children, parents and grandparents of an intergenerational family living apart. This was not only through 'visual status' images of family members living in different places, but also through updates of collocated members travelling away from home, and deliberately crafted images designed to elicit responses or trigger discussions in other media. The implications of these findings for theories of photo sharing are discussed.

CCS Concepts

•Human-centered computing → Field studies; User interface design;

Keywords

Photo sharing, multiple photo streams, visualization, user studies

1. INTRODUCTION

Digital photo sharing has grown rapidly with the proliferation of capture devices, social networking and file sharing services. In addition to typical photo-related activities, such as editing and archiving, new ways of photo browsing and visualization have emerged as critical aspects of digital 'photoware'. Not only has photo sharing become a means of social communication [15], but also an easy way of establishing a chronology of images for memory, identity, and narrative [16]. Furthermore, the emergence of Web services articulating photo sharing through **photo streams** and **timelines**, has highlighted the importance of chronology [11, 9] as the key feature in organising and presenting personal photos. Indeed, the ability we have to document our lives in ever increasing detail, and compare them to others, raises new issues for the design and management of time-related **media streams** in general [10, 6].

This paper is the third in a trilogy of studies exploring the display of multiple photo streams (MPS) in a new form of time lapse photography. In a first photo sharing system reported at HCI 2012 [18], we described the presentation of multiple photo streams allowing users to browse and replay a historical stream of photos from their individual collections, in tandem with each other. These were displayed in a dynamic collage in the four quadrants of a dedicated display, and advanced together in real-time, or some simple multiple of real-time, according to the time stamp of individual photos. At HCI 2013 we reported a variety of algorithms for modifying the speed of presentation of multiple photo streams, and an experiment to derive user preferences between algorithms when viewing two streams side-by-side [17]. In this paper, we report the design and testing of a final system, called 4streams, which uses these preferences to create an ambient display four live streams of photographs as they are taken by four different individuals. The primary aim of this system is to support a stronger sense of social presence between four close friends or family members, than is currently experienced by asynchronous photo sharing or text-based communication. These photographs operate as a kind of visual twitter feed indicating the current activity of each mobile person, when viewed from any of four situated displays. After describing the motivation and design of this system, we report a small-scale case study of its use by a single extended family to help them keep in touch with each other over a seven week trial period. This forms part of a broader PhD enquiry involving other kinds of groups (not reported here).

2. RELATED WORK

It is now commonplace for photographs to be taken and shared on a daily basis. Some dynamics of photo sharing

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have been described by Frohlich [8] in a "diamond framework". This showed three solitary and three social interactions between photographer, subject, audience and photograph. Social interactions included reminiscing between photographer, subject and photograph, as well as two types of storytelling between either the photographer or the subject, and an audience and photograph. These latter activities were originally conceived to apply to co-present photo sharing or "phototalk", although they can also be interpreted to apply to asynchronous postings of photographs and comments on social networking sites.

People now make extensive use of social networking sites such sites as Facebook, Instagram and Flickr to share and comment on photographs asynchronously. This has raised issues of privacy for photo circulation and the size of the social network involved. Previous studies have shown that people often want to share their photos with smaller circles of friends [2, 3] such as family and close friends. Hence, sharing photos to small groups has different motivations and needs than sharing with wide circle of friends such as social media.

Previously, in [12, 1, 14], digital photos were shared at the same time and same place in co-present manner between small groups. In [12], they designed and implemented a collocated-synchronous mobile photo sharing application which was called Mobiphos. In another co-present photo sharing device [14], 4photos, was a collaborative photo sharing device to stimulate conversation around a dinner table. It did this by presenting a changing display of photographs from the Facebook pages of dinner party guests on four faces of a rhomboid display, with the option to manually freeze and duplicate a single photo to all four faces for discussion.

MobShare [13] was an application for adding camera phone images immediately into organized web album and notifying the other users by email. The main contributions of this application have been immediate sharing, tagging by phone's address book, discussion environment, combination and comparison of pictures by photographers.

For sharing photographs in small groups, a photo sharing device [4] was designed to be with elderly people and their family members share their photos with them. The device was a digital photo frame and users were able to share their photos via MMS or Email. However, these transport mechanisms were primarily unidirectional and subject to network delays which compromised the real-time nature of the postings.

Our own 4streams system differs from those above, by primarily supporting the live display of smartphone images on a series of distributed displays. In this respect we are examining the interplay of both smartphones and ambient displays within a small group of people, rather than either device alone. Users near each display are become connected to each other psychologically in real-time as a new photograph is taken on any other remote user's phone, through the immediate appearance of that photo. In addition, when the owners of each photo stream come together to a shared event to take photographs, their joint activity is automatically documented back on their individual displays for later review. A final scenario of use is similar to that of Mobiphotos and 4photos. It is possible for some owners to visit one owner around a single co-located display. In this case, historical photos from each owner can be browsed in lock-step together over different periods of past time and at different speeds of replay. This makes for an interesting conversation that is not currently supported by any other photo sharing technology, including 4photos. In this paper, we examine the potential of this technology for helping a single extended family to keep in touch over distance.

3. DESIGN

As mentioned above, we designed 4streams to let a small group of users upload their photos straight away from their smartphones to ambient displays of all other users. This was done by adding the 4streams system as a friend in Facebook. This allowed users to effectively post their latest 'visual status' simultaneously to multiple ambient displays, including their own. Moreover, this novel interface let users observe their photos chronologically and concurrently in a grid of four adjacent windows. This design enables visualization of concurrent events and experiences within a small group of users such as family, whether they were collocated or not. The concurrency of presented photo streams is achieved by transforming intervals between capture time stamps of two consecutive photos from the presented streams into intervals between appearances of the respective photos in the interface. This interface is installed on a Microsoft Surface Pro tablet to be used as a digital ambient display at home environment.

4streams did not have a separate upload page. The upload engine of this version was Facebook. Therefore, user was able to select the photos that he took and use the Facebook page to upload them in any album that he wanted. Moreover, user was able to upload a photograph straight after taking any photos using the Facebook integrated application on current smartphones. Regardless of any album in Facebook photo collection that he saved the photo, the photo would save into our system if the system was on and connected to the internet. Due to the privacy concerns and ownership of the photos, the users' tagged photos in Facebook will not be used in 4streams in the current design.

The requirements to visualize the shared photos via Facebook on 4streams was to add 4streams to the users' Facebook friends and if the user was sharing the photo with 4streams or a circle of friends with 4streams as one of them, the photo was presented on the display. In the upload phase, the system saved the photo and the information such as the person who uploaded the photo, the date and time that photo was uploaded on Facebook.

After uploading photos from multiple users, the photos were shown on the display and following that the system made a beep to notify the user of the arrival of a new photo. 4streams contained four slideshow windows which showed multiple photo streams concurrently from different users. In addition, the system showed the latest photos that were uploaded from multiple users on their slideshow window. Therefore, they were able to see the latest visual status of their small groups such as family and compare them with their own photo stream. Figure 1 illustrates the 4streams interface on a Microsoft Surface Pro tablet.

When the application starts, it is on full screen mode. In this mode, four slideshow windows; each contain the photo streams from different users appear on the screen. Each slideshow window shows the latest uploaded photo from each user. It took only 2 seconds for a photo to appear on the display after the upload. The full screen mode of the 4streams can be seen in Figure 2.

Figure 1: The 4streams interface on a Microsoft Surface Pro tablet

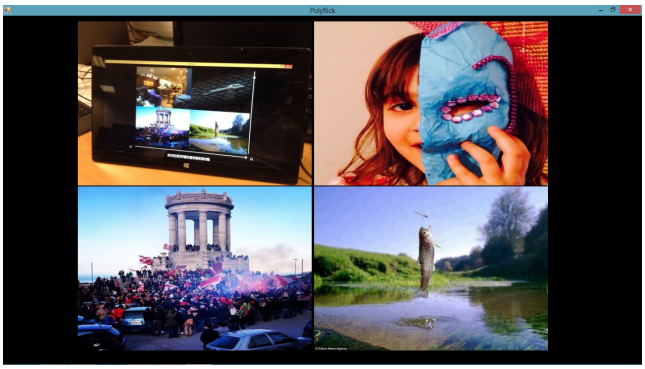

Figure 2: The 4streams' full screen mode: Each slideshow window is dedicated to a user and users can follow their latest visual status

The setup mode appears when a user touches or clicks on any of those four photos in full screen mode. In this mode, the slideshow windows become smaller. The downsizing of the photos results in having more space on the screen. Therefore, we placed a horizontal time-line under the four photos to see the users previous photos and enabling user to compare them chronologically. by changing the slider, the closest photos to the chosen date will appear.

There was a vertical slider on the right side of the screen after date and time information which was enabling the user to control the speed of the slideshow. The transition type of the slideshow that was chosen for 4streams was logarithmic transition [19] that previously presented as an appropriate transition for slideshow mode.

On the left side of the slider there was a playback button and on the right side of the slider there was a play button which allows the user to to control the slideshow. By clicking on any of the photos on the screen in setup mode, the system goes back to full screen. Therefore, user was able to watch the slideshow of multiple photo streams on full screen mode as well. The Figure 3 shows the setup mode interface of the system.

By dragging a photo in setup mode, the system goes to single window slideshow mode which enables the user to see the photo stream that belongs to the owner of dragged photo. Controlling elements in single window slideshow mode are the same as setup mode and the only difference is that the stream of one user instead of multiple photo streams was shown. The original size and dimension of the image was kept during the presentation in this mode. There is a back button on up-left side of the window by which the system goes to setup mode. The screen shot of the single window slideshow can be seen in Figure 4.

Figure 3: The 4streams' setup mode

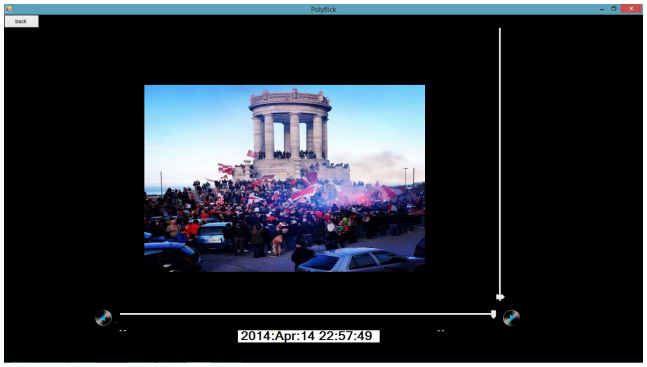

Figure 4: The 4Streams' single window slideshow mode

4. SYSTEM ARCHITECTURE

The system architecture in this application comprised of four layers which were client, user interface, application and data layers which can be seen in Figure 5. The client layer had two parts. The first part was a Windows machine which enables the user to run the application. The second part was a smartphone or any other computer which can be connected to Facebook in order to upload photos.

The second layer was user interface. This layer had two parts. 4streams' user interface was the first part which was the design contents of our system. All of the elements that were explained in design section, were in this layer. The other part of this layer was Facebook's user interface which has been developed by Facebook. The 4streams' user interface was connected to the first part of the application layer which was a windows machine and the Facebook's user interface was connected to the source where photographs were

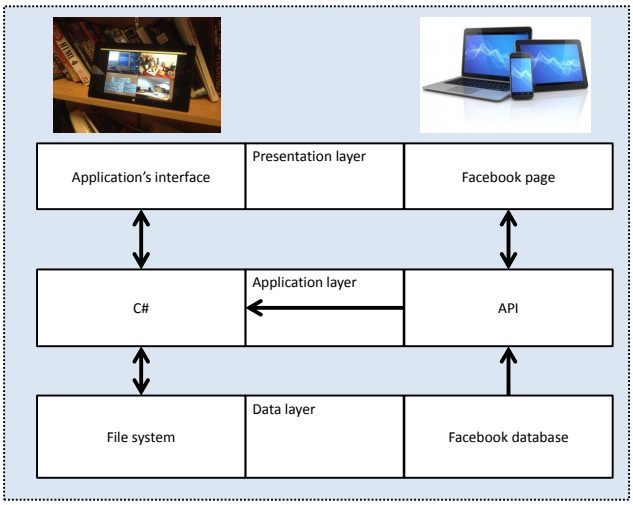

Figure 5: The architecture of the 4streams

uploaded.

The third layer was application layer. This layer also had two parts. The first part was C# developing tool which was the engine and controller of the 4streams' user interface. The other part in this layer was API part which sends the Facebook's information to C# developing tool and Facebook's user interface.

The fourth layer was data layer. In this layer, the first part was a file system, which stored the photos and their information that C# developing tool obtained from API. The other part was Facebook database which was connected to Facebook API for transferring the information through Facebook interface and C# developing tool.

5. USER EXPERIENCE STUDY

5.1 Participants

A trial of the system was conducted in the summer and autumn of 2014, with three groups of people including a friendship group, a family group and a workgroup. The findings were rich and complex and differed between groups, so we report those from the family group in this paper with a view to publishing other results later. Essentially the family found the most value in distributed use of the system as designed, while the workgroup found most value in its co-located use within an office space. The friendship group lived too close to each other to need ambient displays in addition to their smartphones, but requested the photo streaming display for their phones.

The family group was an extended family of four, based around an employee of the University of Surrey. Two members of a family including a father (F1) and mother (F2) were living in the United Kingdom (Country 1). The grandmother (F3) was living in Continental Europe (Country 2) and the niece (F4) was living in the United States (Country 3). Hence, this study aimed to evaluate the impact of the system in live sharing of photos with ambient display on those family members who were living together and those who were stretched in other places. Hence the photographers included were 3 females and 1 male. Their age range was from 38 to 68, with an average age of 41 years. In addition, the UK family contained two small children aged 8 and 5 who were active audience members of the ambient display but not contributors to it.

5.2 Initial Setup

To conduct this study, two Microsoft Surface Pro tablets (D1 and D2) were provided, the 4streams application was installed on the devices and then they were given to the participants. The tablets had Microsoft Windows 8 as an operating system. The tablets were touch screen with an external keyboard. One of the tablets was used in the F1 and F2's house in Country 1 and the other tablet was used in F3's house in Country 2. F4 took photographs as a contributor to the other displays, but used Facebook on their smartphone to check images from F1-3. The participants were asked to keep the Microsoft Surface tablets on and running in a location of their choice in the home, as a dedicated photo display. The extended family group used the system and participated in the present study for 7 consecutive weeks.

5.3 Data Collection and Analysis

A combination of quantitative and qualitative data collection was used in the trial. Quantitative data was collected in the form of logs of system use, including the uploading of images from Facebook and manual interactions to toggle between one or four photos and review prior photos. Qualitative data were collected in the form of pre and post-trial interviews, and photographs themselves, which could be analysed for content. Interviews were conducted in the UK home and over skype to the other locations. Pre-trial interviews explored existing practices of photo sharing and patterns of communication within the extended family, while post-trial interviews explored the use and value of the system in comparison to existing practices. Various descriptive statistics of system use and photo display were generated from the logs, while interviews were transcribed and imported into Nvivo for thematic analysis. This was done in tandem with a content analysis and classification of photo types, to identify categories of photo sharing associated with the values discussed in the interviews. In the results that follow, we summarise the quantitative findings first to frame the qualitative analysis that follows and in part explains the photographs and activities that were shared.

5.4 Results

5.4.1 Trial Phases

The study ran from 10th July 2014 for seven weeks throughout the summer. This included the summer holidays of family one with F1 and F2, and entailed them travelling to visit the grandmother for different periods of time. Essentially, the father (F1) and mother (F2) travelled separately to stay with the grandmother (F3) for different parts of the summer, due to conflicting work requirements. The two children travelled with the father and returned with the mother in the following phases:

1. Start of the study in Country 1
2. Travel of F1 to F3 in Country 2 with both children
3. Return of the F1 to Country 1
4. Travel of F2 to F3 in Country 2
5. Return of the F2 to Country 1 with both children

5.4.2 *The Photos Sent*

The number of photos taken and sent by each participant Is shown in Figure 6. This shows that the father and mother (F1 and F2) were the most active photographers, supplying 56 of the 71 photographs in total. The grandmother (F3) and niece (F4) were less active for different reasons. The grandmother took fewer photographs of her own and was less familiar with the Facebook interface than other family members. She mainly enjoyed seeing photos from others. The niece was an active user of her smartphone, but was more selective about which photos she shared with the family group.

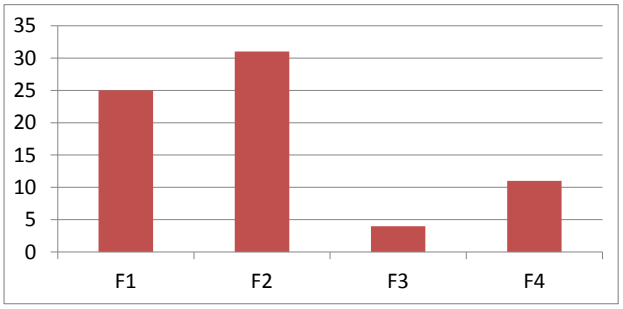

Figure 6: Total photos sent by each participant.

Analysis of the distribution of photos over the different travel phases of the trial, showed increased use when the grandmother was alone. This is shown by the average number of photos uploaded per day in each phase - see Figure 7.This illustrates increased activity on behalf of F1 and F2 to share photos with the grandmother at a distance, and less need to do so when at least one of them was with her. This also indicates a reduced need for F1 and F2 to share photos to each other in Phases 2 and 4 when they were apart, perhaps because the UK partner was still working.

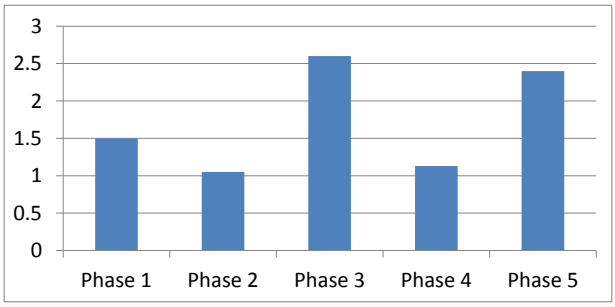

Figure 7: The average photos uploaded per day in each phase

5.4.3 *Content Analysis of the Photos*

To analyze the content of the sent photos a categorization technique was used which adopted from [5] to classify the sent photos in a meaningful way for social connectedness. The categories were: Messages, greetings, everyday life, regular events, special events and something funny or aesthetic. The content of the each of the categories is described in more detail below to show what kind of photos were shared in different proportions within our system.

Messages.

This category contained 28.16% of the photos which were the second biggest category. Typical examples were the photos of the baggage before travelling, the screen shots of the application and the photos from the foods.

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 the meal that they cooked and prepared. F1 was taking photos of his coffee preparation time and his mug. F1 shared a photo of the white board in his office. The same as F1, F4 shared a white board message which was saying: "Days until Nina leaves". Another example was when F2 shared a photo of the Lego kit that a child was playing with.

F1 took a photo of the train station with the message " Mind the gap " to show that she has arrived to her destination. Also, F2 took a photo of a notice board which contained the opening times of the local supermarket and shared it with F1 using the application. F1 took photographs of the garden of the grandmother in Country 2 to show the new honey harvest tools.

F1 and F2 shared a photo of a fox which was on 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 his son's garden. F1, F2 and F4, three participants of this group shared photos which can be categorized as messages. Figure 8 illustrates the sample photos from messages category.

Figure 8: The shared photos examples in messages category

Greetings.

The percentage of photos in this category was 9.85 %. It typically contained photos of people posing for the other family members. F1 took photos of a dog in Country 2. F1 and F2 both took some selfies. In overall, there were 4 photos which could be considered as a selfies.

F1 shared a photo of his childhood which was a good reminiscing for him and other members of the family. F4 shared a photograph with her parents showing that they were waving their hands for other members of the family. F1, F2 and F3 shared photos in greetings category. The sample photos of greetings category can be seen in Figure 9 .

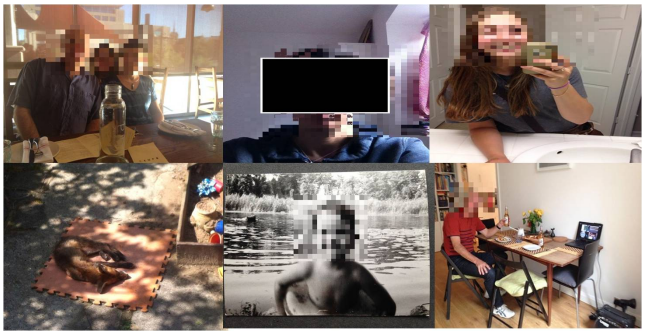

Figure 9: The shared photos examples in greetings category

Everyday life.

The biggest category was the photos which were taken of the everyday life of the participants with 46.47% of the photos. Examples are photos of the home environment and young children playing.

For example F1 uploaded photos of one child playing in Country 2 and F2 uploaded the photo of the other child playing in Country 1. There were photos of the home furniture which F2 and F1 uploaded when they were in Country 1 . F1 uploaded the photos of streets while he was driving. Most of the photos in this category have been shared for the family members when they were separated. The grandmother of the family was keen on seeing the photos of her grandchildren all the time and the father and the mother of family would like to see the everyday life of their children at times when they were not with them. F1, F2 and F4 shared photos in everyday life category. Figure 10 shows some photo examples in this category.

Figure 10: The shared photos examples in everyday life category

Special Events.

The special events had the same portion as the greetings category with 9.85 % of the photos. This category included photos of special events such as birthday party and concert that some of the participants have taken part in.

F4 shared photos of a concert. She also shared photos of her first trip to another city in Country 3 all on her own. F1 shared photos of the horse riding event when he was with his daughter in Country 1. F3 and F4 did not share any photos of a special event. However, when there was a special event, the amount of shared photos were more than one compare to other photos of other categories. The figure 10 presented the shared photos in special events category.

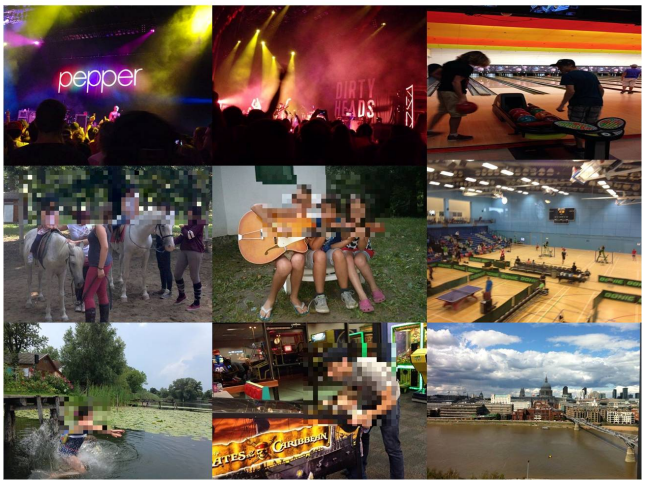

Figure 11: The shared photos in special events category

Funny or Aesthetics Photos.

The Funny or aesthetics was the smallest category with 5.63 %. The people who shared this kind of photos were the grandmother (F3) of the family F1 and F2. she shared a a photo of the flowers and the lake. F1 shared a selfie photo but he possed funny to make others laugh and therefore we considered this photo in funny categories. This category example can be seen in Figure 12.

Figure 12: The shared photos in funny or aesthetics photos category

5.4.4 *Image-based Communication*

Family members were enthusiastic about using ambient photos as a way of keeping in contact, especially because F3 was living in Country 2 and F4 was living in Country 3 and F1 and F2 were leaving the Country 1 in different periods to visit F3. Therefore, our system was used as an image-based communication tool to connect the family members using photographs. F1 and F2 used the system in phases 3 and 5 to update the older member of the family on everyday episodes of daily life. They also used it independently to communicate with each other when one of them was away, albeit at a slower rate. The diversity of images shared over the link reflects the diversity of reasons for sharing. Over time, participants sharing behaviours appeared to become more purposeful and deliberately crafted for the new medium. Rather than simply reflecting existing photo taking activities, participants started to take specific images as jokes, greetings and explicit messages for their other family members (see again Section 5.4.3).

This finding was also underscored by F3's way of photo sharing, in contrast to that F1 and F2. The oldest participant was very pleased about the photos she could see from other three family members. She expected them to share their latest activity or status in each new photo, which they broadly did. However, she was not keen on informing others about her current visual status, so she only shared her old photos and the progress of her garden plants and flowers.

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

F1 and F2 were sharing photos that convey the live communication to show their latest statuses mostly to F3 or 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 everyday. I found it really nice seeing the current activity of others so I could understand where F2 was and was there rain?"

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.

5.4.5 A Trigger for Other Communication Tools

Participants said that during this experiment, they used our system, phone and Skype as their communication tools between family members. They said that they were using Skype to talk to F3 in Country 2 while phone was the intra-country communication tool. However, our system provided a new platform for communication which was simply added to the existing tools.

We did not provide any option for comments or captions to contextualise a photograph shared on the display. Perhaps because of this, ambient photo sharing became a trigger for live photo sharing via phone or skype. 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. Of course he knew; he was just teasing. But 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. "

5.4.6 Children's Use of 4streams

In addition to the four members of the family who used the system, the two children of F1 and F2 were also frequent users and fans of the application. Each child would check the images throughout the day and recruit others into conversation about them. The photo streams became talking points for socialising within the family, in the same way as 4photos became a talking point for dinner party guests. In fact the children seemed to interact with the system more than the adults, and could become quite emotional about the connection it established with distant relatives, as F1 explained:

> " 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"

5.4.7 Watching Old Visual Statuses

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

> " 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 now 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."

5.4.8 *Table Decoration Tool*

The tablet displays were used like 4photos as table decorations in the home. In Country 1 the participants said that they placed the tablet on the dining table where it operated for most of the time. In Country 2, the device was moved between two tables. The first one was an indoor dining table and the second one was an outdoor table in the garden where most of the family members were gathering.

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

> " I can spend the rest of my life just watching 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"

6. DISCUSSION

Digitally connected people around the world are already taking many photographs per day on their smartphones and sharing them with each other over social networking sites like Facebook. In this context Facebook and others have introduced the concept of timelines and photo streams to help users visualize the ever-increasing volumes of images they have to deal with in a multi-party log. However, not everyone is digitally connected enough to benefit from this revolution, and those that are may still value a way of sharing and displaying their photographs with a much smaller groups of close friends as a method of keeping in touch. To address these needs we designed 4streams as an ambient multi-photo display service for four close friends to use via Facebook. Testing this with three distributed parts of an extended family, we wondered if it would increase their social presence and provide a new method of communicating in images.

The findings suggest that two parts of the family found particular benefit in keeping in touch with each other through ambient photo streams showing their respective images side-by-side. Communication between a young family and their grandparents appeared to be enhanced by 4streams, when installed in their respective homes. An early finding was in setting the system up to support separate image streams for the mother and father of the younger family, who were co-located for most of the trial but travelled separately to visit the grandparents with the children. This meant that two quadrants of the display related to family members in the same home, and could operate to keep them in touch with each other when travelling away. An additional asymmetry was represented by the interest of their children, who could not upload photographs to the system but enjoyed watching the time-lapse image streams of other family members, including their parents. Although not interviewed directly in the trial, the children's enthusiasm for the system became evident in adult accounts, and appeared to be heightened when receiving photos from grandparents or when living away from one of their parents. A distant niece found the system less valuable for themselves, but was nevertheless able to contribute photographs to a shared quadrant of their own on the other family displays. This is not surprising since the niece had no ambient display of their own but checked the images from her other family members via Facebook alone. Again these subtleties of connection show a number of ways of contributing to and benefiting from the 4streams system, beyond the symmetrical phone-and-display connection of four individuals as expected.

The diversity of photographs shared over the system appeared to reflect more than the ordinary diversity of photographs usually captured by participants. Some users fell into capturing photos to be viewed immediately by the other parties without the usual delay of intermittent checking of Facebook or other social networking sites. These included greeting shots conveying social availability, and pictures of handwritten or other messages designed to compensate for the lack of annotation facilities on photos. We also found that 4streams was used alongside other live communication methods such as phone or skype, and could trigger synchronous calls to discuss the appearance of particular photographs on a display such as a fox. This interplay between the asynchronous and synchronous use of the system was also evident in the co-located use of each display by family members and occasional extended family visitors. This could be seen in the reported recruitment of adults to the display by children, and in the review of historical photo streams. The ability to see the past activities of others in relation to your own activities, was a surprise feature of the displays and something which caused serendipitous reminiscing by participants. The co-located use of the displays was further accentuated by their positioning in the homes. Both parent and grandparent families placed them on tables where the families would gather to talk and eat. In this respect they became centerpieces for local conversation, as in the Microsoft 4photos prototype. However, unlike that system, the 4streams displays had a notification and review function outside meal-times, and acted to connect remote families through the instantaneous appearance of the same photograph on dual displays at the same time.

These complexities of photo capture, upload and display across people, devices and time are not well represented by Frohlich's [8] diamond framework, or the groupware matrix applied to different classes of 'photoware' in Frohlich et al [7]. The diamond framework represents the interaction of different people with each other and a single photograph, and was said to change configuration during different 'photo outings' at which the photo was shared. For any

individual user of the 4streams quadrant display, four photographs are perceived simultaneously, and change one-by-one over time as new photos are taken by remote photographers. This means that for any photographer watching the display, events in their own quadrant are recognized in the usual way, but may be recalled or interpreted from the other three quadrants simultaneously, depending on whether they appear as a subject in those images or not. Recollection or interpretation operate across all quadrants for any non-photographer watching the display, and change with each new image transition. When more than one photographer or non-photogapher are present around a display, reminisicing and storytelling conversation can take place as usual, but with respect to any one of four images. Two extra dimensions of comparison between images are invited by this arrangement. Comparisons between what different photographers or subjects were doing at the same time are invited by simultaneous presentation of multiple photos for the same moment. Other comparisons between sequences of images from the same stream are also invited through implicit photo narratives. Further research is required to investigate the nature of private contemplation of such displays and its implications for memory and imagination, as well as of phototalk around these displays and its implications for the dynamics of conversation and self-disclosure.

The groupware matrix covering photo sharing in same and different combinations of place and time (in Frohlich et al [7]) is also inadequate for representing the 4streams system. Most previous photo sharing systems fit into one of four cells given by the matrix, such as:

- Smartphone screen or tablet for co-present sharing (same time, same place)
- Skype for photo conferencing (same time, different place)
- Ambient display for place-based archiving (different time, same place)
- Facebook for asynchronous sharing (different time, different place)

The 4streams displays are primarily ambient displays and suitable for place-based archiving and visiting on an ad hoc basis. However, the fact that they are duplicated in other places and show image transitions together in real-time, gives them pseudo-conferencing qualities. They are not full-scale conferencing systems because users cannot interaction through them in real-time, but they do stimulate synchronised emotional and cognitive reactions in users who happen to notice the same image transition in two locations at the same time. Participants in the study began to exploit these properties by sharing photographs they expected to be perceived immediately, like greetings or messages describing live events. As delays in the checking of ambient displays crept in by recipients of these photos and messages, the system began to approximate a more conventional social network for images in which posts are asynchronous. These behaviours may have more in common with instant messaging than social network messaging because the display channel is continuously open, but the time intervals for checking the display are variable. Photographs may also be seen without assembling a 'reply' as such. Again, more research is needed to understand the social conventions that will develop around the use of live displays with multiple senders and recipients. Further variables that might be explored in such work include the platform for displaying images (PC, TV, projector, etc), techniques for interaction, and the number of photo streams represented. Given the attraction of tables as a domestic site for these displays, it would be interesting to implement 4streams on a circular or rectangular tabletop display, with photo panels in the position of placemats.

7. CONCLUSION

The representation of multiple photo streams (MPS) on an ambient display was found to be useful by three distributed families for keeping in touch with each other. Quadrants devoted to the photographs of different individuals across the families were updated in real-time across multiple displays, and could be browsed or animated in lock-step along a time line. The displays were used most intensively between a young family and their distant grandparents in both real-time and browsing mode to monitor ongoing and past activities. More surprisingly, they were used as a new form of image-based communication along with other methods, through the exchange or discussion of images crafted for the displays themselves. The asymmetric use of the displays across families and locations challenges existing conceptions of photo sharing, and warrants further practical and theoretical research of the MPS paradigm.

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