Beyond Memories: Weaving Photos into Personal Social Networks

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Abstract

A picture is worth a thousand words. A personal photo collection may reveal the complex social interactions between the person and his/her social contacts. As digital cameras have become increasingly pervasive, people are empowered to capture many aspects of their daily activities and social interactions with minimal effort. This research explores the hypothesis that social connections can be extracted from knowledge about the people and events in the pictures. This thesis defines the *personal social network* (PSN) as a model of personal social behavior, and proposes a practical approach to weaving a personal photo collection into a PSN. The resulting model is used to make photo sharing recommendations by spreading activation over the PSN. The experimental results showed that the PSN constructed automatically from photos can achieve good performance, yielding an average precision of 80% with a recall of 75%.

Introduction

Throughout the history of photography, advances in camera technology have a profound impact on on the way people view and use photos. For many years, film cameras have been used to capture memorable moments or to chronicle historical events. The proliferation and ubiquity of digital cameras and camera-phones today has enabled ordinary people to enjoy the convenience of taking photos anytime, anywhere, and in any situation, thereby making it possible to create *digital personal daily memories* with ease. In 2004, digital cameras started to push traditional film cameras out of the US markets. According to IDC, worldwide digital camera shipments are expected to reach 94 million units in 2006. Meanwhile, worldwide sales of camera-phones have outpaced digital cameras since 2004 (Future Image, Inc. 2003). Digital photography has resulted in a tremendous increase in the number of digital images. The digital imaging revolution has not only changed our personal experience in photography but also offered a new perspective on our social life.

The Social Uses of Photos

Photographs have played significant social roles for many decades. Research on social uses of personal photos indicated their uses for personal and group memory, creating and maintaining social relationships, self-expression, self-presentation, and functional uses (House *et al.* 2005). For example, people use photos to record their daily activities, happenings, and friends. Many people send photos to their distant friends and family to reinforce connections and nurture relationships. In addition, photos provide a popular and powerful media for experience sharing, when people communicate with others either face-to-face or across the Internet. It is a natural desire for us to share experiences with friends and family, either to keep each other updated on personal events or to preserve and relive precious moments in common experiences. For example, people love to share pictures of their kids with the grandparents; photos from personal events like birthday, wedding, graduation and vacation are also favorite subjects for sharing. Now that picture taking has become an everyday activity, more and more daily happenings can be captured in photos.

Photo Metadata

What goes through your mind when you look at a picture? A large amount of information may be gleaned from a picture, including *who* was there, *what* activity was going on, *when* and *where* the photo was taken, as well as the *emotion* at that moment. Such descriptions constitute the metadata of a photo. In this research, we define *photo metadata* to include the following key properties:

- People: who are depicted in the picture
- Event: what is going on
- Time: when is the picture taken
- Location: where is the picture taken
- Resolution: the pixel width×height of the picture
- Ownership: the person who owns the picture

Manually annotating the photo metadata is a tedious task. In a related line of research, we are exploring various techniques for extracting and mining photo metadata (Huang, Lu, & Hsu 2005). The standard JPEG format for digital photos embed much useful metadata in the EXchangeable Image File format (EXIF). Attributes such as time, resolution, ISO, aperture and shutter speed can be easily extracted from

EXIF. It is easy to approximate photo ownership by combining the make/model information from EXIF with knowledge about camera ownership. With the growing availability of GPS-equipped devices, location information may be captured along with the picture. We have experimented with mining event information using a statistical photo classifier, and extracting people information using a face detection and recognition module based on the Intel OpenCV library.

The research reported in this paper focuses on making sense out of the photos once the metadata are (partially) acquired. The photo metadata are represented in Resource Description Framework (RDF), a standard metadata language for web resources (Manola & Miller 2004). Not only does RDF provide a framework for describing and interchanging metadata but it facilitates resource sharing, search, and reuse. Given that digital photos are often stored on personal storage devices, RDF makes it easy to harvest and aggregate metadata in such a distributed environment.

Every photo tells a story. A collection of photos may tell a more interesting story spanning across time, location, and people. In particular, we are interested in modeling the social relationships of a person based on his/her photos. This paper proposes a novel approach to constructing the personal social networks (PSN) by mining and analyzing the "people" and "event" metadata of a collection of photos. This research also examines how *spreading activation* over the PSN can be used to generate recommendations on photo sharing tasks.

The remainder of this paper is organized as follows. We start by reviewing some related research on social networks, spreading activation, and personal experience sharing. Then we introduce the definition of a personal social network (PSN) and the process of mining a personal social network. Using PSN to make recommendations on photo sharing is explained next followed by the evaluation results of recommendations. Finally, we conclude the current contributions and outline future research directions.

Related Work

This section provides a brief overview of previous research in the fields of social networks, spreading activation, and personal experience sharing.

Social Networks

A *social network* is an abstract representation of the social relationships among individuals within a community. Research in a number of academic fields have demonstrated that social networks operate at many levels, from families up to the level of nations. They play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals. In (Watts 2003), Watts provided a comprehensive account of the *new science* of social networks.

In recent years, automatic construction of social networks from various data has become an important research topic in information mining. Several approaches to constructing social networks have been proposed in (Yu & Singh 2003). For example, a social network may be extracted from mailing lists and web links (Culotta, Bekkerman, & McCallum 2004). On the other hand, research by (Farnham, Portnoy, & Turski 2004) and (Song *et al.* 2005) took advantage of social networks to model and predict the user behavior in daily email usage. In addition, Alex Pentland have done series of research to mine social networks according to physical data, such as face-to-face social interactions (Grips & Pentland 2006) (Pentland 2005). Lots of social signals, such as facial expression, body language, and tone of voice, are used to predict human behaviors and relationships, combining with the proximity information to build social networks.

There are many social networking sites, such as Friendster[1] and Orkut[2] on the Internet today. They deploy a variety of tools to help connect friends, business partners, or individuals with specific interests. The concept of modeling a person with his/her *InterestMap* was proposed in (Liu & Maes 2005), which mines the personal profiles from the knowledge base of social networking sites.

Spreading Activation

The term of *spreading activation* originated from psychological studies of the stimulation interaction process of the human brains and the mechanism of human memory. It was first applied in computer science to process semantic networks in artificial intelligent, and has since been used in many fields such as information retrieval. Spreading activation is designed to propagate *energy* across a network. Given a set of initially activated nodes, the process repeats to spread the activation energy to the closest connected nodes. The process terminates when there is no newly activated nodes. A detailed survey of the applications using the spreading activation technique in IR is given in (Crestani 1997). Although the concept of the spreading activation mechanism is the same in different fields of the computer science, the details of controlling the spreading activation process are usually designed according to the specific applications. The features of the constrained spreading activation model can be found in (Crestani & Lee 1999).

Personal Experience Sharing

In 1945, Vannevar Bush posited Memex as "a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility" (Bush 1945). The digital storage technology today makes it possible to store all of one's digital media, including documents, images, sounds and videos for memory management, searching (Gemmell, Lueder, & Bell 2003) and story telling (Gemmell, Aris, & Lueder 2005). Moreover, our memories comprise not only the content but also any contextual information about the content. Research on pervasive computing and context-aware technology has developed and utilized sensors to log context information, so as to infer human activities and to facilitate reliving of experiences (Suzuki *et al.* 2005; Kern *et al.* 2004).

[1] http://www.friendster.com/

[2] http://www.orkut.com

Personal Social Modeling

In this section, we discuss the phenomenon of personal photography today and present our hypotheses in modeling personal social behaviors based on photos. The *personal social network* (PSN) will be defined, followed by a description of mining the PSN from the metadata of a personal photo collection.

Personal Photos and Social Networks

People in the 21st century have witnessed incredible leaps in the development of digital photography during the past decade. With successive introductions of new digital cameras of higher quality and smaller size, digital photography has become so pervasive that it is no longer a luxury for people to capture their personal experiences anytime and anywhere. Having a camera at hand at all times is no imagination. Indeed, more and more personal photos are being created by amateur photographers just like you and me simply to capture everyday happenings and social activities.

Check out any photo sharing sites like Flickr[3] and Buzznet[4], you are sure to find lots of photos depicting common social activities. For example, co-workers may get together to celebrate over drinks in a karaoke bar after a product launch, taking snapshots for fun. Friends may go on a vacation together, recording their trip on camera. Families often enjoy a feast together, shooting pictures for the shared memory. In general, people in stable relationships tend to get together in various social settings. Occasionally, people serendipitously meet up with long lost friends, and take pictures to preserve the special moment.

Based on these observations, we propose the *Social Familiarity Hypothesis* on modeling personal social behaviors as follows.

Hypothesis 1 *Given a collection of photos, the* familiarity*, or the strength of social relationship, of two individuals should be*

- *proportional to the* frequency *that they appear in the same picture,*
- inversely *proportional to* the number of people *photographed together in the picture, and*
- inversely *proportional to the* distance *that they appear in the same picture.*

In other words, the chance of two close friends showing up in the same picture is much higher than if they were merely casual acquaintance. Intuitively, a picture of exactly two people indicates a stronger relationship than if they simply happen to appear in a group picture. Similarly, two people next to each other may imply more interaction between the two. Given that we don't have a reliable way of collecting the distance data, and its correlation is the weakest, this paper focuses on the first two factors in the proposed model.

[3]http://www.flickr.com/

[4]www.buzznet.com

Personal Social Network

A social network is a social structure between actors, either individuals or organizations. It indicates the ways in which they are connected through various social bonds which can be any of kinship relations (for example, father of and brother of), social relations (friend of, student of, and so on), affective relations (loves, hates, and so on), material exchange (such as business transactions), common behaviors (for example, wears the same jeans or goes to the same bar) and mutual support (such as financial help, paper coauthoring, and work cooperation), epidemic spreading (such as **S**evere **A**cute **R**espiratory **S**yndrome transmission), information dissemination (for instance, music sharing, document distribution, and email exchange), or physical interaction (such as face-to-face communication). A social network also plays a fundamental role as a medium for the spread of information, ideas, and influence(Song *et al.* 2005). A social network is typically depicted as a graph in terms of nodes and ties. Nodes denote the individuals within the community and ties denote the interpersonal relationships between individuals. Each link on the social network should encode the connection *type* of the corresponding social relationship, as well as its connection *strength* between the two individuals. The type of a social relationship may be represented as any of involved social events. The strength of a social relationship ranges from casual to intimate.

A personal social network (PSN) is an ego-centric social network representing different social connection types and strengths. Formally, a PSN is defined as a labeled directed graph $G(V, E)$, where V and E represent the node set and edge set respectively. A unique node $v_0 \in V$ denotes the focal person, and all other nodes $\{v \mid v \in V \wedge v \neq v_0\}$ denote his/her social contacts. Each directional link $e_{ij} \in E$ is represented as (τ_{ij}, σ_{ij}) denoting the type τ_{ij} and strength σ_{ij} of the social connection from the originating node v_i to the target node v_j. Given the set of all social events Σ, the type property of an edge τ_{ij} is defined to capture the set of social events in which both people participated. That is,

$$\tau_{ij} \subseteq \Sigma. \quad (1)$$

The strength property of an edge σ_{ij} measures the *familiarity* between the two individuals denoted by v_i and v_j, and has a real-numbered value between 0 and 1.

$$0 < \sigma_{ij} \leq 1. \quad (2)$$

Ideally, the strength property should be defined as a vector of real numbers, one for each social event type. The total connection strength is defined as a weighted sum of the components strengths. A PSN can therefore model personal social behaviors along different social dimensions. For example, you may prefer partying with your friends rather than with your grandfather despite the strong connection with your grandfather in kinship. For simplicity of presentation, we consider strength as a single quantity in this paper. Figure 1 shows a sample PSN, visualized by Vizster (Heer & Boyd 2005), for the focal person "kghost".

Mining PSN from Photos

How do we construct the personal social network of an individual? Based on the *Social Familiarity Hypothesis* out-

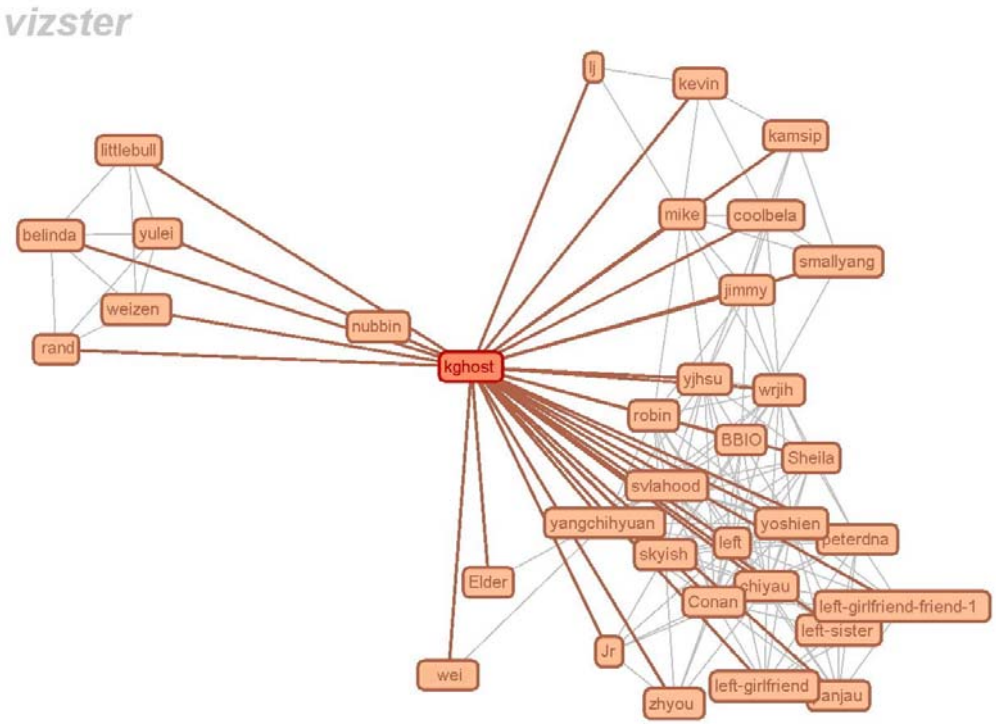

Figure 1: A Sample PSN.

lined earlier, this research proposes a practical approach to mining the personal social network for any given individual from his/her personal collection of everyday photos.

Given a collection of photos Π, each of which has been tagged with the "event" and "people" metadata, the metadata are assumed to be correct even if possibly incomplete. We create a single node v_i for each person i appearing in any photo $\pi \in \Pi$, and one edge from node v_i to node v_j if person i shows up with person j in any photo $\pi \in \Pi$.

Definition 1 *The* type *property τ_{ij} of edge e_{ij} is the set of events discovered from the metadata of any photo $\pi \in \Pi$ in which persons i and j appear together. That is,*

$$\tau_{ij} = \{\epsilon \mid event(\pi) = \epsilon\}. \tag{3}$$

It should be noted that the type property is symmetrical, so we have $\tau_{ij} = \tau_{ji}$ for any pair of edges e_{ij} and e_{ji}.

Let N denote the total number of photos in the collection Π, n_i and n_j denote the number of photos containing person i and person j respectively, and n_{ij} denote the number of photos containing both person i and person j.

Definition 2 *The* strength *property σ_{ij} of edge e_{ij} is a function of the frequency of persons i and j co-occurring,* diluted *due to the number of people in the same picture. That is, we have*

$$\sigma_{ij} = p_i \cdot \log \frac{N \cdot d_{ij}}{n_i \cdot n_j}. \tag{4}$$

The leading term $p_i = \frac{n_i}{N}$ is the probability that person i appears in the collection, and it is intended to reduce the bias toward rare samples. The second term estimates the *co-occurrence frequency* using the concept of *pointwise mutual information* as follows.

$$PMI(i,j) = \log \frac{p_{ij}}{p_i \cdot p_j} = \log \frac{N \cdot n_{ij}}{n_i \cdot n_j}. \tag{5}$$

To account for the dilution effect of many people showing up in the same picture, the co-occurrence n_{ij} is substituted with the discounted co-occurrence $d_{ij} = \sum_{\pi \in \Pi_{ij}} \gamma(\#people(\pi))$, where Π_{ij} is the collection of photos with both person i and person j, and $\gamma(x)$ is a function such that $\gamma(2) = 1$ with $\gamma(x)$ decreases monotonically in value as x increases.

Figure 2 illustrates an example of mining PSN from a personal photo collection. The nodes in a PSN network represent the focal person "kghost"and his social contacts. The types and strengths of some edges are marked on the network.

PSN for Recommendations

Is the PSN constructed from photos any good? Although the PSN constructed in this way may not be the *actual* personal social network, it still can represent a person's social space and model a person's social behavior to some extent. Therefore, the PSN can be applied to social related tasks. In

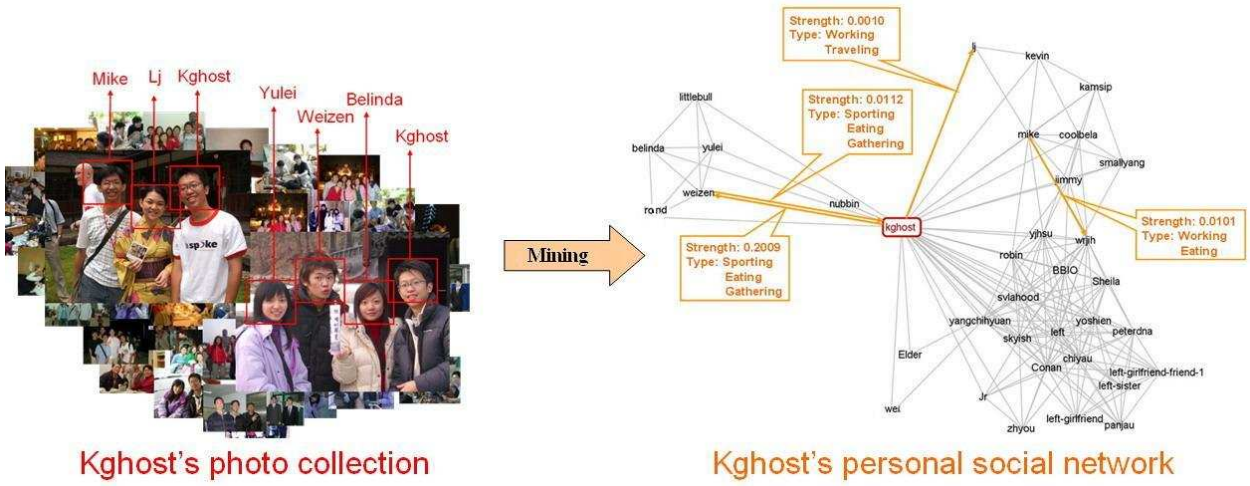

Figure 2: Mining the PSN from a personal photo collection.

this section, we describe the importance of personal social networks and select the task domain of *photo sharing* to illustrate how the PSN can be applied to make proactive photo sharing recommendations.

Effects of Personal Social Networks

People, unconsciously or consciously, expend considerable energy and effort in managing their own personal social networks for many purpose, relying heavily on personal social networks to accomplish many tasks. Personal social networks can facilitate labor recruitment, partner and job finding, information access and gathering, expertise location, content distribution, and etc. In recent years, lots of social context or interaction information are used to mine personal social networks, such as

- Texture data (Usenet, webs, homepages, emails, publications, chats, and etc),
- Physical data (proximity, body language, talk, tone of voice, and etc),
- Multimedia data (picture, audio, video, and etc).

Some research demonstrates possible benefits while integrating applications with the knowledge of personal social networks. Personal social networks in ContractMap (Nardi *et al.* 2002), which are extracted by analyzing the history of the user's email interactions, are used to design an advanced user interfaces that afford information and communication services, and provide a new principle for organizing data with the help of PSNs. PostHistory and Social Network Fragments (Viegas *et al.* 2004) use information of personal social networks to allow individuals to remember their past and construct stories for sharing. Two of them present a personal portrait for an individual through the context of their email interactions. In the Roles project (Fisher 2005), personal social networks are constructed by examining the interaction in Usenet newsgroup. It automatically detect and classify the distinct behaviors that emerge among users. With the help of personal social networks, it would be valuable to track the stability of both groups and the roles played by individuals in Usenet.

In this research, we choose the task domain of *photo sharing* as an example to show how the PSN mined from a collection of photos can be used to generate photo sharing recommendations and help people to have better experience in content sharing.

Proactive Photo Sharing Recommendations

Digital media are produced mainly to preserve life moments and reminiscing purposes. For example, people love to share pictures of their kids with the grandparents; photos from personal events like birthday, wedding, graduation and vacation are also favorite subjects for sharing. While doing experience sharing, photos indeed are the most popular and convenient media we use today to translate daily happenings and tell life stories. You may always see that most people prefer using several cameras to take pictures of a large group so each gets to keep the pictures. However, wouldnt it be nice if a single group shot can be shared by everyone in the group with minimal effort? Unfortunately, photo sharing today is mostly a manual operation. We have to think about with whom to share and use existing tools like e-mails and online albums which can still be quite tedious and time-consuming.

To facilitate sharing of valuable experiences, a PSN representing social relationships with others on various common experiences can help. Intuitively, each person does different social activities with different clusters of friends. For example, the friends traveling with you can be quite different from those playing basketball with you. A PSN is native to model this kind of behavior. Therefore, when you have new photos with "people"and "event" metadata, a PSN can be used to pro-actively find recommendations about whom you are eager to let them know what's happening to you.

Recommendations by Spreading Activation

Given a collection of photos and a PSN, predicting relevant people to share photos with is a kind of recommendation task. In this research, the spreading activation is the main technology used to generate recommendations. It is first applied in computer science technology to deal with the semantic network. In our approach, the structure of a PSN can be easily mapped to that of a semantic network. Nodes representing people in a PSN are analogous to those representing concepts in a semantic network. Edges representing social relationships in a PSN are analogous to those representing semantic associations. The process of the spreading activation working through the concept network to get semantically relevant concepts is similar to that working through the PSN to get closely relevant people.

Given a collection of photos with "people" and "events" metadata, the nodes for initial spreading refer to the union set O of people appearing on all photos. By propagating activation energy from initial activated nodes, the neighboring nodes connected to the initial nodes are injected energy and some of them exceeding the activation threshold again spread energy to next level neighbor nodes. In our customized algorithm, there is a energy decay factor $\alpha = 0.75$ which eliminates energy to some discount according to the number of hubs from the visiting node to the initial node. Also, the energy just spreads through the edges with the same *type* properties within the happening event set S of a collection of photos. The process is recursively repeated until no newly activated node. At the end of the process, the recommendation results are the people nodes containing the energy higher than a threshold. The details of spreading activation algorithm are shown in the following.

Algorithm 1 Energize

Given an activation network $G(V, E)$, a threshold θ, a decay factor α, initial spreading node set O, and happening event set S. Run this algorithm $|O|$ times for each node in O.

Require: energy e, node $v_i \in V$, degree d

```
energy(v_i) ← energy(v_i) + e
if energy(v_i) ≥ θ then
    for v_k ∈ Neighbor(v_i) do
        if ((t ∈ τ_ik) ∈ Σ) AND not visited(v_k) then
            e' ← α^d · energy(v_i) · σ_ik
            Energize(e', v_k, d + 1)
        end if
    end for
end if
```

Evaluation

In this section, we design an experiment to evaluate proactive photo sharing recommendation and show the initial results. Performance and challenges are also discussed in the following.

Data Set

First of all, we should collect piles of personal daily photos tagged with "people" and "event" metadata. However, there is no available standard data set to do the evaluation. Flickr, which is the popular online photo management and sharing website containing an abundance of photos labeled folksonomy tags, is a possible choice. Nevertheless, there are some limitations while using Flickr as our data set. First, Flickr has some storage limits for their free users. Lots of users can not upload all of daily photos on the website. Although we are not concern with representing *actual* personal social networks, it gives us less possibility to get each individual's unique expectations about his/her social space according to such kind of dataset. Second, the tagged metadata can be everything rather than just happening events and participant people due to folksonomy tags. Thereby, we still have to ask for volunteers to explicitly annotate "people" and "event" metadata.

Since the difficulty of getting data, we initially ask for the people in our lab as the volunteers to provide their photos and give tag information. In order to carefully and correctly evaluate the accuracy and practical usage of each individual's personal social network, the experiment is conducted on the data set we built via an on-line photo album which can be accessed on `http://photo.agent.csie.org/`. Figure 3 shows the web interface to collect "people" and "event" metadata. "People" metadata can be defined by each volunteer to represent their own acquaintances and do annotation. As for "event" metadata, there are ten predefined events in Table 1 for annotation. At present, this website contains 20 volunteers and half of them actively use this online album. There are about 5000 photos in the data set. The number of photos tagged with "people" and "event" annotation are more than 1500. In our data set, each photo album contains extra information about with whom to share photos, or recipients, in this album for doing performance evaluation.

Figure 3: Online album for collecting data set

Experiment Design

The goal of the experiment is to evaluate the performance of proactive photo sharing recommendation given a collection of photos. Since each photo album has information of expected sharing recipients, photos in each album are served

Table 1: Predefined social activities

Social Activities	
Celebrating	Dating
Drinking	Eating
Gathering	Playing
Party	Singing
Working	Traveling
Sport	Others

as a given photo collection to do evaluation in our experiment. Let δ denote the set of sharing recipients that the user expects to share with, ζ denote the set of recommended recipients that match the user's expectation to share with, and κ denote the set of sharing recipients that are recommended by the algorithm. Initially, the performance of recommendation is indexed by the precision and recall which are defined as

$$precision = \frac{|\ \zeta\ |}{|\ \kappa\ |}, recall = \frac{|\ \zeta\ |}{|\ \delta\ |}.$$

Comparing with other standard recommendation data set like MovieLens, our personal photo data set is relatively sparse in this stage, and the photo quantity variation among different users creates noise issue. For example, some people in our lab are outgoing and love to take photography but others don't have too much enthusiasm for photo taking. for statistic correctness, therefore, volunteers with four most abundant annotated photos are selected to evaluate the performance of the recommendation. Even though, we believe that this kind of variation and noise will be dissolved naturally in the future owing to more ubiquitous and delicate camera devices strengthening motivation for taking pictures.

The experiment is conducted on the data of these four volunteers. First, a PSN representing each personal social relationship is constructed in the way we mentioned above. Second, the spreading activation over a PSN with normalized link weight spreads energy among the nodes and finally generates recipient recommendations. Because photos in different albums can be shared with different clusters of people, there is no standard criterion to give recommendations For example, an album of graduation ceremony can be shared with large group of classmates and relatives. However, an album of Valentine's Day is only shared with the lover. Unlike the movie or shopping recommendations using the top N related recommendations, we recommend the sharing recipients with the energy exceeding the 10% of the highest energy level in the spreading process instead of generating fix number recommendations.

Results

In Figure 4, the performance results are given. The results demonstrate that on average, the spreading activation over a PSN recommends with an accuracy of about 80% with the standard deviation of 16% while the average recall is about 75% with the standard deviation of 13%. The results shows some interesting issues when we try to use a PSN to model a person social behaviors. According to the relatively high

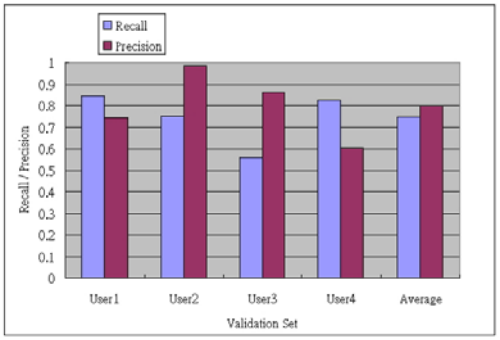

Figure 4: The evaluation on photo sharing recommendation

precision about the user 2, we find that the user 2 is a relatively introverted person. Therefore, he does not actively want the weakly-connected people to see photos while sharing experience. However, the user 3 has the outgoing and sociable characteristic. He is willing to introduce their friends to other clusters of acquaintances. The relatively low recall reflects this kind of personality while doing experience sharing. We believe that each person has their own sharing habit. Also, albums tagged with different social events and involved people are not shared in an equal way. How to make a PSN adapted to a user and how to provide a flexible mechanism to do recommendations for different types of collections of photos are the next step we consider.

Conclusion

This paper presents a novel approach to weaving personal social networks from personal photo collections. By exploring the hypothesis that social connections correlate with the "event" and "people" metadata of the photos, the type and strength of social connections can be computed. The *personal social network* has been defined to model social behavior of an individual, which is then used to make photo sharing recommendations using spreading activation over the PSN. Our experimentals showed that the automatically constructed PSN can achieve good performance, yielding an average precision of 80% with a recall of 75%. Although the experiment is preliminary, the results give us positive perspectives to go further. Comparing with different recommendation algorithms to verify our approach is the next step.

There are many possible extensions to the current research. For example, additional photo metadata, such as *ownership* or *distance*, can be taken into consideration in constructing the PSN. The temporal property captured in a photo collection can be used to model the dynamic and evolutionary interaction among people over time to better reflect the natural phenomena in human social interaction.

You are who you talk to (Fisher, Smith, & Welser 2006), who you work for, who you have dinner with, and namely who you socialize with. Therefore we think user profiles contain not only personal information, such as gender and interests, but also their personal social networks. In addition, there are many ways to extract personal social net-

works. Different social context or interaction information, such as emails, webs, publications, photos, and face-to-face communications, can be applied with different approaches to mine corresponding personal social networks. We believe such personal social networks can be combined and mixed in some way to give more compelling perspectives on behavior modeling.

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