AGENT-MEDIATED PERSONAL PHOTO SHARING

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ABSTRACT

With the rapid growth of personal digital content created by a wide array of digital devices, photo sharing across the network has become a routine demand. Existing approaches to photo sharing require much user manipulation, and the process tends to be tedious and time-consuming. This research proposes "Photo Agent," a multi-agent system that facilitates sharing of digital photos based on a user's personal social network. In particular, this paper illustrates the process of social network construction from photo metadata annotated by a face detection and recognition module. Moreover, performance of the agent-mediated *Intelligent Sharing Tree* algorithm is compared with Gnutella-like sharing algorithm in content delivery. With photo agents providing *proactive recommendation* and *autonomous delivery*, photo sharing can be achieved in a human-centric manner.

Keywords: Multi-Agent System, Photo Sharing, Metadata, Social Network, Recommendation

1. INTRODUCTION

The digital revolution has dramatically changed our modern lifestyles. The proliferation and ubiquity of digital cameras and camera-phones has made it possible for ordinary people to create daily personal memories. People enjoy the convenience of taking photos anytime, anywhere, and in any situation. In 2004, digital cameras started to push traditional film cameras out of the US markets. According to IDC, worldwide digital camera shipments will reach 94 million units in 2006. Meanwhile, worldwide sales of camera-phones have outpaced digital cameras since 2004 [7].

Digital photos provide a popular and powerful media for experience sharing. People have a natural desire to share experiences with family and friends, either to keep each other updated on their individual 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 significant personal events like birthday, wedding, graduation and vacation are also favorite subjects for sharing. In addition, many people choose to use more than one cameras when taking pictures of a large group so each gets to keep the picture. Wouldn't 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. When we need to share a large number of photos, existing tools like e-mails or online albums can be quite tedious and time-consuming. To facilitate sharing of valuable experience, we propose the "Photo Agent," a multi-agent system that will 1) spontaneously infer the user's social network according to the metadata of photos, 2) proactively offer recommendations of sharing targets, and 3) autonomously cooperate with one another to guarantee efficient delivery of photos.

The remainder of this paper is organized as follows. We start by describing the challenges of the photo sharing tasks and reviewing related work on photo sharing and social networking in Section 2. The overall architecture of the Photo Agent is described in Section 3. Section 4 defines the *photo metadata* and presents an approach to social network construction. The photo sharing mechanism is explained and its performance compared with Gnutella-like sharing mechanism in Section 5. Finally, this paper summarizes the current results with suggestions for future research direction in Section 6.

2. BACKGROUND

This section discusses the challenges we have while dealing with personal digital photos and reviews related research in the fields of photo management, content sharing, and social networking.

2.1 Challenges

As digital cameras have become increasingly pervasive, people are empowered to capture many

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aspects of their daily activities with minimal efforts. As a result, there is an explosive growth of personal digital photos today. However, almost everyone who uses a camera has experienced the frustration of not being able to find the images taken a while back. Therefore, *how to organize personal digital photos* is one of the challenges for any individual today. Unlike well-organized content produced/owned by businesses or government offices, e.g. mass media or digital archives, personal digital photos are typically stored without much structure and maintained in the habit of each individual. Without diligent use of good photo management software consistently over time, imagine the impossible task of locating a specific picture ten years later. In addition, people create photos not only for memory preservation but also for sharing, either to keep each other updated on personal events or to preserve and relive precious moments in common experiences. Without having enthusiasm to constantly share photos with friends and family across the Internet, people always need to spend lots of time and energy to find a way to make sure the delivery of photos. Therefore, deciding *what to share* and *in what way to share* is definitely the challenge people need to face with today. In this paper, we focus more on how to improve the photo sharing process. Some existing tools and research trying to reduce the challenges to some degree and help people to do better photo management and sharing will be described in the next subsection.

2.2 Related Work

There are quite a few software tools available, both commercial packages and free services, for managing digital photos. For example, ACDSee, Paint Shop Photo Album, and iPhoto are popular applications that offer photo sharing via emails, web, prints, or CDs. Many portals, such as MSN and Yahoo!, host personal photo albums for sharing over the web.

Meanwhile, most of the time, people share their experience to their social space, Social network sites [12] like Friendster and Orkut, provide photo sharing functions to help people connect and exchange experience. In particular, services like GJPix, Buzznet and Flickr integrate photo sharing, blogging and social networking into a new platform for personal information organization and exchange.

The "Photo Agent" was proposed to support human-centric photo sharing over a peer-to-peer network [8]. The users can simply specify which pictures are to be shared with whom, and the agent will deliver the photos autonomously. Instead of using Gnutella-like algorithm [2], the Photo Agent utilizes an intelligent sharing tree (IST) to accomplish the actual delivery of the content. Google offers *Hello* to enable sharing of high-quality pictures instantly and securely over any speed connection in an instant-message style.

Garage Cinema Research at UC Berkeley aims to enable daily media content consumers to become daily media producers with increasingly powerful media capability of today's mobile devices. Mobile Media Metadata (MMM) [4][5] uses context-aware mobile media technology and applications that leverage contextual metadata (spatial, temporal and social) to infer photo content and support media management. MMM automatically suggests sharing recipients based on sharing frequency and Bluetooth-sensed co-presence. With these technologies, MMM strengthens people's motivation to share photos on constrained user interface, i.e. their mobile phones.

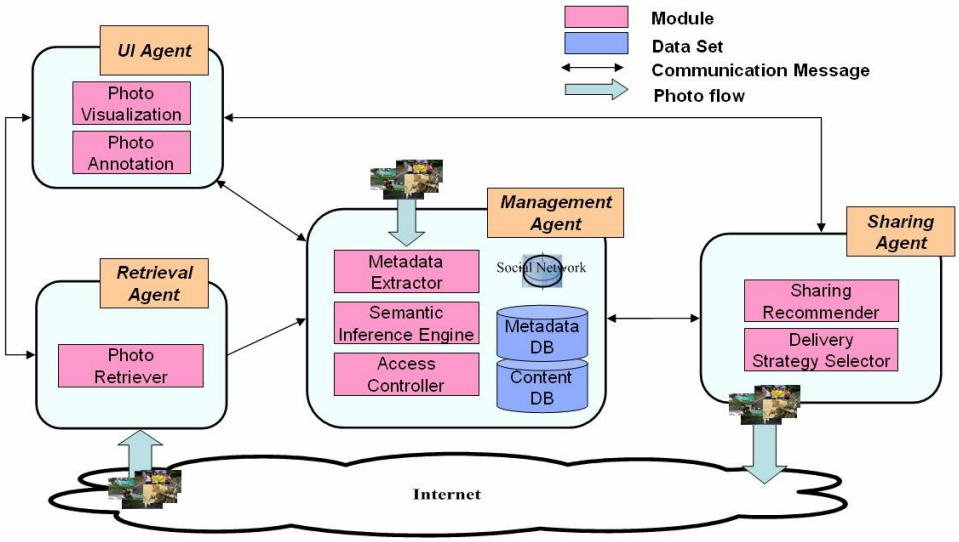

Figure 1: A multi-agent photo sharing architecture

Besides, several approaches to constructing social network automatically have been proposed [13]. For example, one may construct a social network based on the user's email inboxes [3], existing emailing lists [6][11], and the web links [3]. Social networks can help the information dissemination process.

3. SYSTEM ARCHITECTURE

The multi-agent architecture of the Photo Agent is depicted in Figure 1. The system consists of *Sharing Agent*, *Retrieval Agent*, *Management Agent*, and *UI Agent*. The four agents collaborate to present and manage photos, as well as to accomplish the sharing task.

Sharing agent is a major agent in charge of the overall sharing process. A sharing agent help a user have better sharing experience in two steps. First, a sharing agent proactively recommends sharing targets to a user according to the relationship information in user's social network. Second, when a user accepts the recommendations, a sharing agent can automatically send photos and autonomously ensures delivery in a way of multi-agent collaborations. With the help of a sharing agent, a user can spend more time to decide what to share instead of spending lots of time to concern about whom to share and in what way to share.

Retrieval agent is responsible for handling sharing messages from other sharing agents and automatically filtering photos according to user's preferences. User's preferences are maintained in a profile with RDF/XML format and can be expanded easily owing to RDF/XML document's flexibility. Taking the benefits of a retrieval agent, a user can get what he/she want from lots of photos shared across the Internet.

Management agent handles the organization, physical storage, and access control of the photos. It is also in charge of extracting, reasoning and maintaining the photo metadata. While the photos are kept in the file system, the metadata are stored in a database. In addition to information captured by the camera and stored in the image, the management agent extracts people from a photo using a face detection and recognition component. Moreover, a management agent analyzes metadata of photos to look for the relations between photos and people, and constructs the user's social network. A management agent provides photo metadata and user's social networks to the sharing agent to facilitate photo sharing, and updates metadata from the retrieval agent during retrieval.

UI agent is in charge of communication between the user and the Photo Agent system for importing photos and notifying users of incoming photos. In addition, the UI agent should provide a user-friendly interface for a user to visualize and annotate his collection of photos in order to specify semantic descriptions about them.

4. PHOTO METADATA

What goes through your mind when you look a photo? Actually every photo has a story. A large amount of information may be gleaned form a photo, 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 can constitute photo metadata, which can be a structured description of the photo content. Moreover, a collection of photos can tell more interesting story spinning across time, location, and people. In particular, the social relationship can be revealed to some degree while browsing a pile of photos. This section first defines photo metadata and the representation of metadata, and then presents a specific method for social network construction from people identified in the photos.

4.1 Structured Representation

In addition to deciding what should be included in the photo metadata, we also need to decide how the photo metadata should be represented. The Resource Description Framework (RDF) has been proposed as a standard metadata representation for resources on the web [9]. RDF provides a framework for describing and interchanging metadata in order to facilitate resource sharing, search, and reuse. In particular, RDF makes it easy to aggregate and harvest metadata in a distributed environment.

For each photo, we define its metadata to include the following key properties:

1. People: *who* are depicted in the picture
2. Event: *what* is going on
3. Time: *when* is the picture taken
4. Location: *where* is the picture taken
5. Resolution: the width×height of the picture
6. Owner: the person who owns the picture

The EXchangeable Image File format (EXIF), which is embedded in a JPEG image, defines attributes such as time, ISO, aperture, and shutter speed etc. Items 3 and 5 of the photo metadata can be easily extracted from EXIF. Combining the make/model information from EXIF and auxiliary information about camera ownership, it is possible to decide photo ownership. We further assume that location information is obtained from a GPS device, event information can be derived using a statistical photo classifier, while people information is extracted using a face detection and recognition component based on the Intel OpenCV library.

This paper focuses on representing and creating the metadata about *people* in the photo(s). Without loss of generality, we assume that all other metadata are either extracted from EXIF directly or obtained from the user at the time of photo uploading. We adopt the *Friend-of-a-Friend* (FOAF) [1] ontology, which defines a simple vocabulary designed to describe people and their relationships. The FOAF vocabulary specification is written in RDFS/OWL with machine-readable XML syntax to allow simultaneous deployment and extension. The FOAF namespace includes terms for FOAF Basics, Personal Information, Online Accounts/IM, Projects and Groups, as well as Documents and Images.

The metadata for each photo consists of an instance of the class foaf:Image together with a collection of RDF statements with properties like foaf:topic and foaf:depicts to describe the event and people in the photo respectively. For example, as is shown in Figure 2, the metadata for Photo A specifies that Persons A, B, and C appear in Photo A. Person D can discover that Photo A matches his interest specified by the property foaf:topic_interest. The complete FOAF description may specify a person's name, email, homepage, IM accounts, project and group etc. The foaf:knows property is used to capture the relationships among people. Figure 2 shows the RDF model of Photo A, and the three persons in the picture know one another.

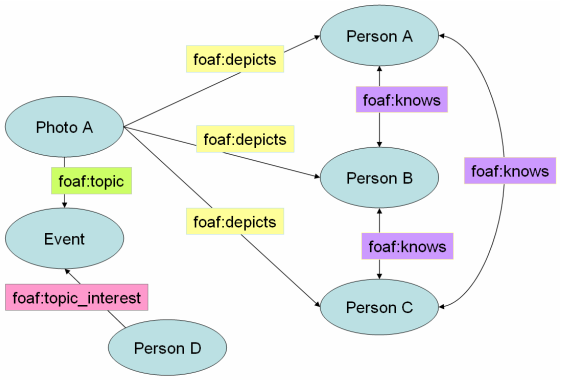

Figure2: FOAF-based photo metadata

Such *social networks*, along with the photo metadata can bring semantics to the photos, thereby enabling better presentation and sharing [10].

4.2 Social Network Construction

How do we acquire the social networks of an individual? Instead of requiring each user to provide such information explicitly, this research explores the idea of constructing a person's social network from a collection of photos tagged with "people" and "event" metadata. We postulate that the relationship between any two people correlate with the *frequency* that they appear in the same picture. In other words, the chance of two close friends showing up in the same photo is much higher than if they were merely casual acquaintance.

Given a collection of photos Π, let $N = |\Pi|$ and $n_i = |\Pi_i|$, where Π_i denotes the photos containing person i, and $n_{ij} = |\Pi_{ij}|$, where Π_{ij} denotes the photos containing both person i and person j. We define the probability of person j co-occurring in a photo collection of person i as

$$p_i(j) = \frac{n_{ij}}{n_i} \tag{1}$$

We can then define the *familiarity* between persons i and j to be their *mutual co-occurrence probability*, i.e.

$$F_1(i,j) = p_i(j) \cdot p_j(i) = \frac{n_{ij}}{n_i} \cdot \frac{n_{ji}}{n_j} = \frac{n_{ij}^2}{n_i \cdot n_j} \tag{2}$$

It is straightforward to see that $n_{ji=}\ n_{ij}$ holds. Furthermore, photos containing both person i and person j do not always reveal the same degree of familiarity of the two. In other words, the strength of their relationship can be assumed to be inversely proportional to the number of people photographed together. For example, a picture of exactly two people indicates a stronger relationship than if they simply happen to appear in a group picture. To capture such intuition, the following function $r(\pi)$ is applied to transform the familiarity measure in a given photo $\pi \in \Pi$. That is,

$$r(\pi) = w \cdot e^{-[P(\pi)-2]^2/M} + (1-w) \cdot e^{-[P(\pi)-2]/Z} \tag{3}$$

Which defines a weighted sum of a modified normal distribution in a variate $P(\pi)$, which calculates the number of people in a given photo π, with mean *2* and variance *M*, and an auxiliary term to create a longer tail on the right. Therefore, we can substitute n_{ij} with $\sum_{\pi \in \Pi_{ij}} r(\pi)$ as follows.

$$F_2(i,j) = \frac{\left(\sum_{\pi \in \Pi_{ij}} r(\pi)\right)^2}{n_i \cdot n_j} \tag{4}$$

The definition is further modified with a constant *K* to reduce the bias for favoring people in a relatively small number of photos n_i. We have

$$F_3(i,j) = \frac{n_i}{K+n_i} \cdot \left[\frac{\left(\sum_{\pi \in \Pi_{ij}} r(\pi)\right)^2}{n_i \cdot n_j} \right] \quad (5)$$

It follows that every collection of photos defines a personal social network with the *familiarity matrix*.

$$\mathrm{F} = (f_{ij}) = (F_3(i,j)) \quad (6)$$

Figure 3 illustrates a simple example of personal social network construction. The nodes in the network represent the people in the network. The edges represent the *familiarity* relationship between people. Each edge is associated with an *event type* and a *weight*, indicating the degree of familiarity between the two people under the specified social event. Given a collection of photos tagged with event type "Traveling" at the top of Figure 3, the management agent will construct automatically a social network of type "*Traveling*" based on the familiarity matrix as defined in (6). Let K = 40, M = 20, Z = 40, and w = 0.8, the resulting social network is shown below.

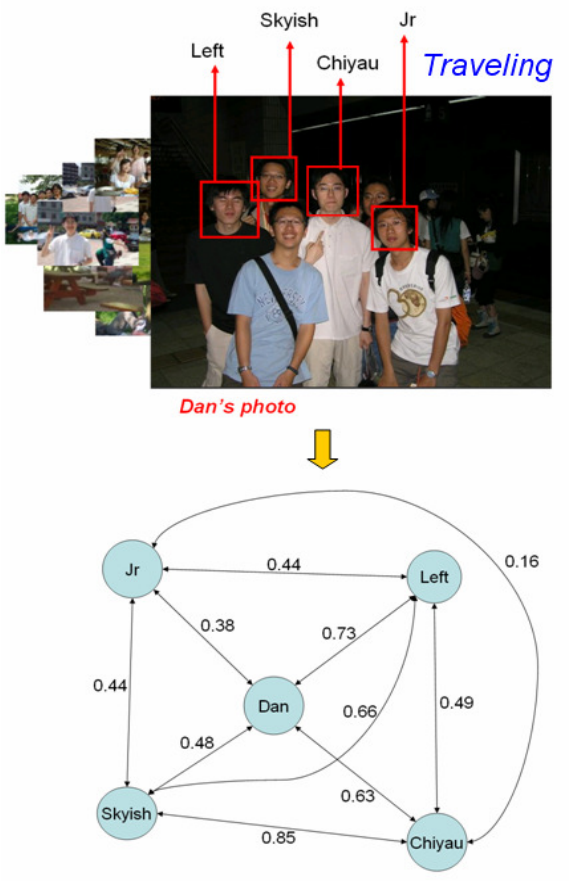

Figure 3: A social network of type "Traveling"

5. PHOTO SHARING MECHANISM

A sharing agent helps a user to do better photo sharing with two major steps below:

1. Proactive Recommendation
2. Automatic delivery

In the first step, a sharing agent takes advantage of the *sharing recommender* to help a user decide which photo is significant to be shared with whom. In the second step, a sharing agent autonomously cooperates with other sharing agents across networks to improve sharing efficiency and ensure photo delivery. With the help of these two steps, a user can just know with whom to share without concerning about how to share photos. Even though a user may not know with whom to share, a sharing agent can make suggestions for the user. The detailed mechanism of each step is described in the following subsections.

5.1 Proactive Recommendation

When there are new incoming sharing photos, a sharing agent uses the *sharing recommender* to offer suggestions of sharing targets. With suggestions, a user spends less time to manage photos and figure out how to share their photos more effectively. Figure 4 below shows the concept of proactive sharing recommendation.

Figure 4: The concept of proactive recommendation

The *sharing recommender* is the important component to deal with proactive recommendation. There are two steps depicted in Figure 5. With photos tagged with metadata, the *general sharing rule engine* generates an initial list of sharing targets based on some general sharing rules, such as "if person B is captured in the photo A, share the photo A with person B". Then, the *social relationship tracker* can infer meaningful people to expand the initial sharing list and give the sharing priority regarding the social familiarities in different social events. The social relationships can be derived from a person's social network in a way we mentioned in previous section.

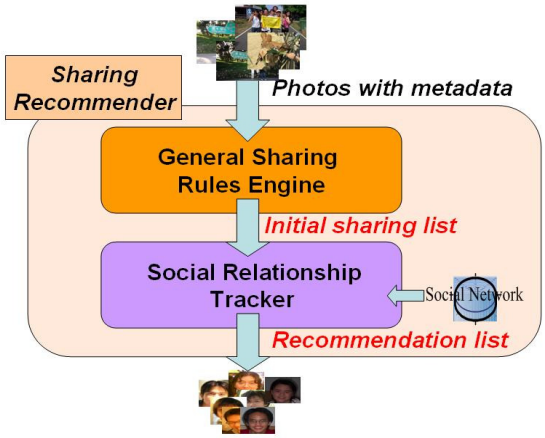

Figure 1: Sharing recommender

5.2 Social Relationship Tracker

A person's social network with different type of links gives a user a hint that how the familiarity between pairs of people is when people do different social events. For example, in Fiqure 3, Dan always likes to go traveling with Left due to high familiarity value of 0.73. While eating delicious food, however, Dan may not invite Left because they seldom get together to eat delicious food. Of course, Dan and Left must have few photos about eating delicious food. Besides, two people participate in the same social event shows they have the same interests regarding to the event. Therefore, the *social relationship tracker* can infer meaningful people to share with by tracking a social network.

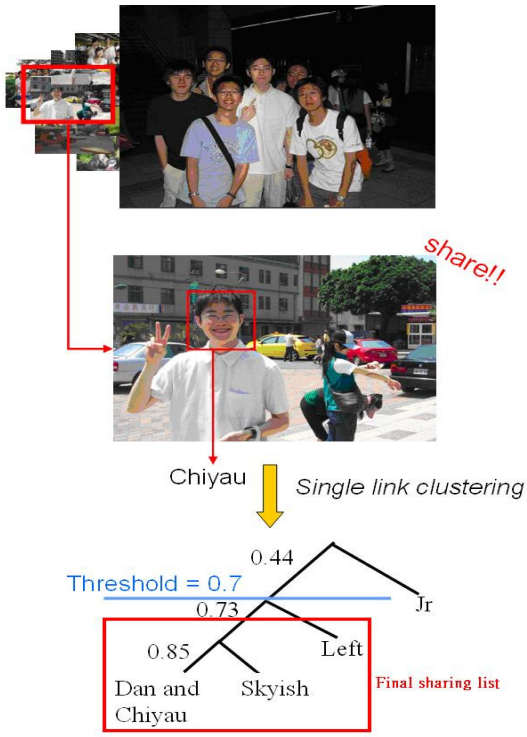

Figure 2: Inference of social relationship tracker

After the *general sharing rule engine* generates an initial sharing list, the *social relationship tracker* adds other meaningful people in the way of using single link clustering algorithm with a proper threshold. The example is given to show how the *social relationship tracker* offers final recommendations by examining the person's social network. In Fiqure 6, Dan has a collection of photos for traveling. When Dan wants to share a photo containing Chiyau, the *social relationship tracker* tracks his social network in Fiqure 3 and uses single link cluster algorithm to provide the final recommendation list of Chiyau, Skyish, and Left.

5.3 Autonomous Delivery

After deciding sharing targets, a delivery task is delegated to a sharing agent cooperating and communicating with other sharing agents to send photos and ensure delivery. To ensure the efficiency of delivery, a sharing agent use *delivery strategy selector* to cope with different network condition by adopting suitable strategy. The intelligent sharing tree (IST) algorithm is an initial strategy provided to use in the Photo Agent system. In IST algorithm, each involved agent cooperates to construct a sharing tree according to its resource criteria and available network bandwidth.

The IST algorithm is given below and the details of the algorithm are explained in our previous work [8]. The simulation results are shown and described in the following subsection as well as the experiment discussion.

IST Sharing with Global Information
Given global lookup tables Q, P and B, construct the sharing tree.

Require: $sharingLis\ t$: A list of nodes for tree construction

1: $relayList \leftarrow$ source node
2: **for** $i \in relayList$ **do**
3: **for** $j \in sharingLis\ t$ **do**
4: $S(j) \leftarrow \alpha \cdot Q(i, j) + \beta \cdot P(j)$
5: **end for**
6: $R \leftarrow f\left(B(i), |sharingList|\right)$
7: $Child(i) \leftarrow$ highest scoring R nodes from $sharingLis\ t$
8: $relayList \leftarrow relayList \setminus \{i\} \cup Child(i)$
9: $sharingLis\ t \leftarrow sharingLis\ t \setminus Child(i)$
10: **end for**

5.4 Simulation Environment

This paper compares the IST algorithm with Gnutella-like algorithm [2] which a source agent shares photos with target agents without others' help. In order to simulate vividly, a P2P network

simulation environment is constructed with 54% of agent peers having 2M/256k download/upload bandwidth, 39% of agent peers having 1M/64k download/upload bandwidth, 3% of agent peers having 10M/10M download/upload bandwidth, and the rest agent peers having 512k/64k download/upload bandwidth. The end-to-end connection, however, is not always with the high quality in the real world. Therefore, a portion of bandwidth is randomly assigned to simulate such dynamic network. For each run of simulation, an agent is arbitrary chosen as a source agent and the rest of agents are chosen as target agents. This paper totally runs 100 times of simulation for different network condition, and average total sharing time among these 100 runs.

The simulation runs with different sharing content size, ranging from 50 kilobytes to 50 megabytes. The number of target agents is ranging from 10 to 80 peers. The results of these two algorithms are shown from Figure 7 to Figure 10.

The simulation results show that the time cost of the Gnutella-like algorithm increases rapidly with the number of agents. However, the time cost of the IST algorithm grows smoothly relative to the Gnutella-like algorithm. From Figure 7 to Figure 10, the gap of total sharing time between two algorithms widens as the size of sharing content becomes larger.

The IST algorithm not only reduces the total sharing time but also balances the load of each involved agent. Although the IST algorithm has better quality to do sharing, the performance is not good in some special condition. In Figure 7, the Gnutella-like algorithm even has the same performance quality while sharing small size of content. Besides, if the network is junked, the sharing tree constructed by the IST algorithm is unbalance and the performance is almost near to the Gnutella-like algorithm.

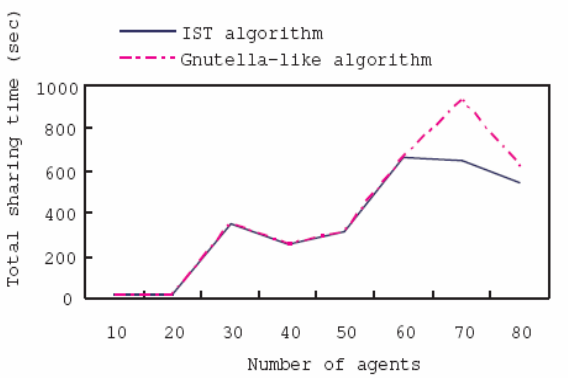

Figure 7: Sharing with 50 kilobytes size

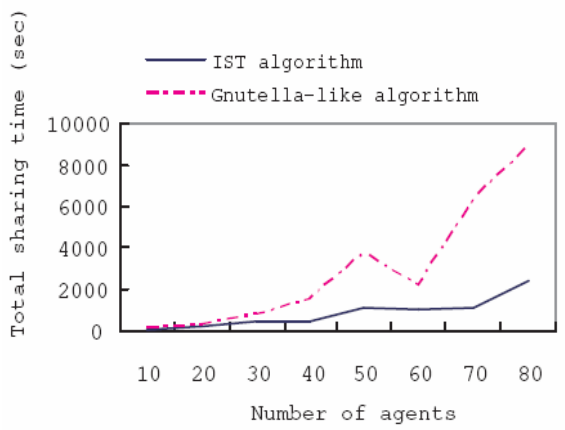

Figure 8: Sharing with 500 kilobytes size

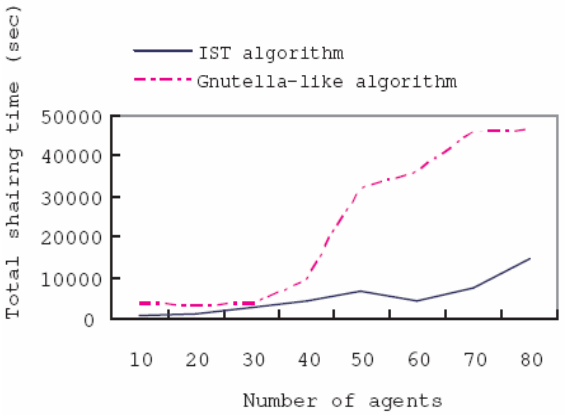

Figure 9: Sharing with 5 megabytes size

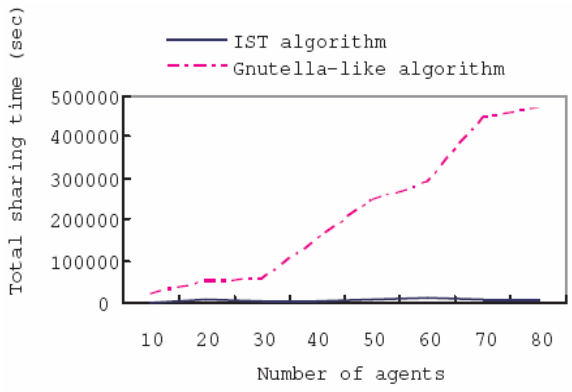

Figure 10: Sharing with 50 megabytes size

6. CONCLUSION

The proposed multi-agent system facilitates the tasks of photo sharing by cooperation of the agents in the system. Based on photo metadata to derive social networks expressed as RDF statements, users can share not only the photos but also the metadata of photos with other members within their social networks. Through the sharing mechanism, we share photos in more human-centric way. We are now collecting photos from ordinary people in their daily life and doing experiments to evaluate our work.

There are quite a few interesting issues to be investigated in future work. We can expect that with the advent of semantic web, there are going to be more applications using this approach because more digital content will be distributed with embedded semantics and the contained information can be reused across different applications. How to make a user create semantic statements and how to specify the relations between different statements are still a problem we are going to solve.

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