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Profile of the Social Network in Photo Sharing Systems

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ABSTRACT

People, who interact, cooperate or share common activities within the photo sharing system can be seen as a multirelational social network. The results of their activities, i.e. tags, comments, references to favourites and others that semantically connect users through multimedia objects, i.e. pictures are the crucial component of the semantic web concept. Every online sharing system provides data that can be used for extraction of different kinds of relations grouped in layers in the multirelational social network. Layers and their profiles were identified and studied on two, spanned in time, snapshots of Flickr population for better understanding of social network structure complexity. Additionally, for each of the identified layers, a separate strength measure was proposed in the paper. The experiments on the Flickr photo sharing system revealed that users are inspired by both the semantic relationships between objects they operate on and social links they have to other users. Moreover, the density and affluence of the social network grows over course of time.

Keywords

social network, multirelational social network, social relationships, photo sharing system, Flickr, Web 2.0

INTRODUCTION

The systems such as Flickr or YouTube, which are typical examples of Web 2.0 systems, provide the opportunity to publish and share multimedia contents authored and maintained directly by their users. These users collaborate and influence one another, exchange their knowledge, share common activities and comment others' achievements. They also establish groups of collective interests as well as have the opportunity to enumerate directly their acquaintances.

Web 1.0 and some internet services like email system enable to extract and analyze social networks based on data about activities of single users (Culotta et al., 2004; Kazienko and Musiał. 2008; Kazienko et al., 2008). However, Web 2.0 facilitates collaborative actions of users in which informal, dynamic groups of people cooperate or share common interests with one another. Contents presented in photo publishing systems like Flickr concurrently establish semantic relationships between users through authorship, references and opinions about published multimedia objects (MOs) or shared tags. For example, a comment to the photo made public in Flickr is the sign of similar interests with the author and the commentators of this picture. Moreover, this common topic may be directly described by the content itself. Additionally, most of these relations are visible for all system users what increases their sense of community.

Users act using semantic premises and relationships between multimedia objects they are interested in. Nevertheless, they simultaneously exploit social links to people they know or like.

The main goal of the paper is to analyze profiles of the different layers within the complex multidimensional social network extracted from the data available in the photo sharing system. These layers can reflect both semantic and social inspirations of user activities. The former result from recent user needs and interests whereas the latter correspond to users' acquaintances and social preferences.

RELATED WORK

People who interact with one another or share common activities form a social network. Overall, a social network is treated as a finite set of individuals, by sociologists called actors, who are the nodes of that network, and ties that are the linkages between them (Garton et al., 1997; Hanneman and Riddle, 2005). However, the characteristic of regular social networks differs from social networks existing in the Internet and the global network provides a vast amount of diverse data useful for social network analysis (SNA), e.g. for the estimation of the user social position (Kazienko and Musiał, 2007) or finding significant individuals or objects (Bruns, 2007). Internet-based social networks can be either directly maintained by web

systems like Friendster (Boyd, 2004), MySpace (Ahn et al., 2007), and LinkedIn or extracted from data about user activities in the communication networks like e-mails, chats, blogs, homepages connected by hyperlinks (Adamic and Adar, 2003), etc. Some researchers identify the communities within the Web using link topology (Flake et al., 2000), while others analyze the emails to discover the social network (Culotta et al., 2004; Kazienko et al., 2008).

The multimedia sharing systems like Flickr and YouTube can be also seen as social networks, where relations among users are extracted from common communication or activities. Flickr, was the subject of some studies but to date it was rather treated as a social tagging system that enables users to mark their pictures with tags and then share these tags with other users (Kennedy, et al., 2007; Nov et al., 2008; Rattenbury et al., 2007). The new human relations emerge from users' common tags (Marlow et al., 2006). However, the relations can be extracted also from other data available in the system and this is the basis to treat online publishing systems as multirelational social networks, in which there may be more than one kind of relation between two users (Wasserman and Faust, 1994). Study on Web-based social networks also revealed importance of relation dynamics and global growth pattern of the network structure (Golbeck, 2007).

The functionality of multimedia sharing systems that enables to tag and share the tags between users gives the opportunity to create the semantic web from ties between tags. The semantic web "provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries" (Berners-Lee et al., 2001). In other words, the semantic web can be seen as the network of metadata about resources that are available in the system and can be shared among the users (Downes, 2005). Although semantic webs and social networks were developed separately, nowadays they are often analyzed together (Mika, 2007). It means that researchers try to extract semantic webs from data about social networks and the other way around. Nevertheless, the work that is done in this area yields for deeper insight.

SOCIAL NETWORK IN THE PHOTO SHARING SYSTEM

Definition 1. *A social network SN in the photo sharing system PSS is a tuple (U,L), where U is the finite set of non-anonymous user accounts registered in the given PSS. A single tie i.e. linkage $l_{ij}=(u_i,u_j)\in L$, which denotes the connection from user $u_i\in U$ to user $u_j\in U$, exists if and only if there exists any communication from u_i to u_j, or if there exists direct intentional link from user u_i to u_j, or if there is any common activity of both u_i and u_j. The last case results in existence of two ties $(u_i,u_j)\in L$ and $(u_j,u_i)\in L$. The set U must not contain isolated users, i.e. $\forall u_i\in U\ \exists u_j\in U, i\neq j\ ((u_i,u_j)\in L \vee (u_j,u_i)\in L)$.*

All communication, direct links or cooperation are based on individual features of PSS available for users. The set of linkages L is derived directly from data about user activities such as tagging, user groups, comments to multimedia objects (MOs), favourite MOs or contact lists. Each of the activity may bind users in a different way so it forms a relation of the certain kind. The tie $l_{ij}=(u_i,u_j)\in L$ exists if and only if there exists at least one relation of any type. Thus, every tie l_{ij} can consist of one or more relations r_{ij} which are connections of the specific type from u_i to u_j. Three kinds of relations can be distinguished:

1. *Direct intentional relation* r_{ij} from user u_i to u_j exists if user u_i directly points to u_j, e.g. by adding u_j to the u_i's contact list.
2. *Object-based relation with equal roles* r_{ij} means that users u_i and u_j meet each other through the meeting object and their role a in relation to the object is the same. They can participate in common activity in the same way, e.g. two users comment the same picture, both add the same object to their favourites or both use the same tags to describe their photos (Figure 1a).

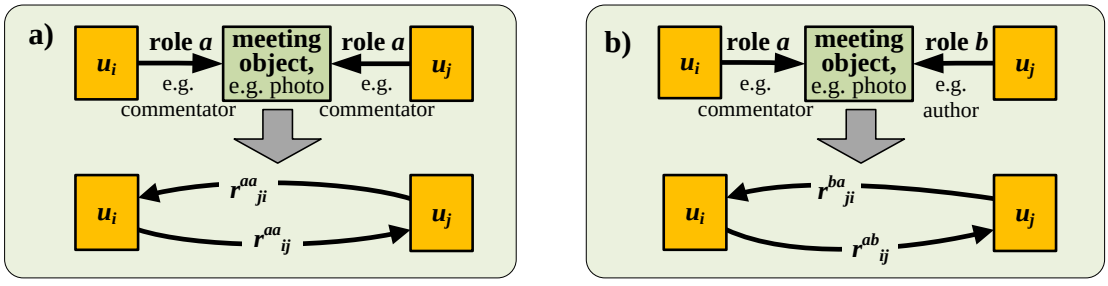

Figure 1. The object-based relation with equal roles: commentator (a), and different roles: commentator and author (b)

3. *Object-based relation with different roles* r_{ij}^{ab}, r_{ji}^{ba} – is the relation between two users u_i and u_j that are connected through the meeting object but their roles *a* and *b* are different, e.g. user u_i comments a photo (role *a* – commentator) that was published by u_j (role *b* – author) (Figure 1b). A non zero relation r_{ij}^{ab} entails the non zero relation r_{ji}^{ba}.

Note that object-based relations are usually relevant to interests common for two or more users whereas direct intentional relations reflect mutual acquaintance. It means that object-based relations are more thematic while direct intentional are more social. All of them enable to create the strongly related semantic group of users.

RELATION LAYERS IN THE PHOTO SHARING SYSTEM

The concept of social network and ties that aggregate different types of relations was applied to the Flickr photo sharing system, in which photos are multimedia objects MO. Users can publish their pictures in Flickr, mark them with tags, create groups and attach their photos to them, build their own lists of favourite photos published by others, maintain contact lists linking to their acquaintances as well as comment photos authored by others. All these activities reflect common interests or acquaintances between users and enable to create the multirelational social network.

During the research nine types of relations were identified in Flickr: relations based on contact lists – R^c, shared tags used by more than one user – R^t, user groups – R^g, photos added by users to their favourites – R^{ff}, R^{fa}, R^{af}, and opinions about pictures created by users – R^{oo}, R^{oa}, R^{ao}. Relations based on contact lists (R^c) represent direct intentional relations. Tag-based (R^t), group-based (R^g), favourite-favourite (R^{ff}), and opinion-opinion relations (R^{oo}) are typical object-based relations with equal roles, whereas favourite-author (R^{fa}), author-favourite (R^{af}), opinion-author (R^{oa}), and author-opinion (R^{ao}) are object-based relations with different roles. All these relations correspond to nine separate layers in one multirelational social network (Figure 2).

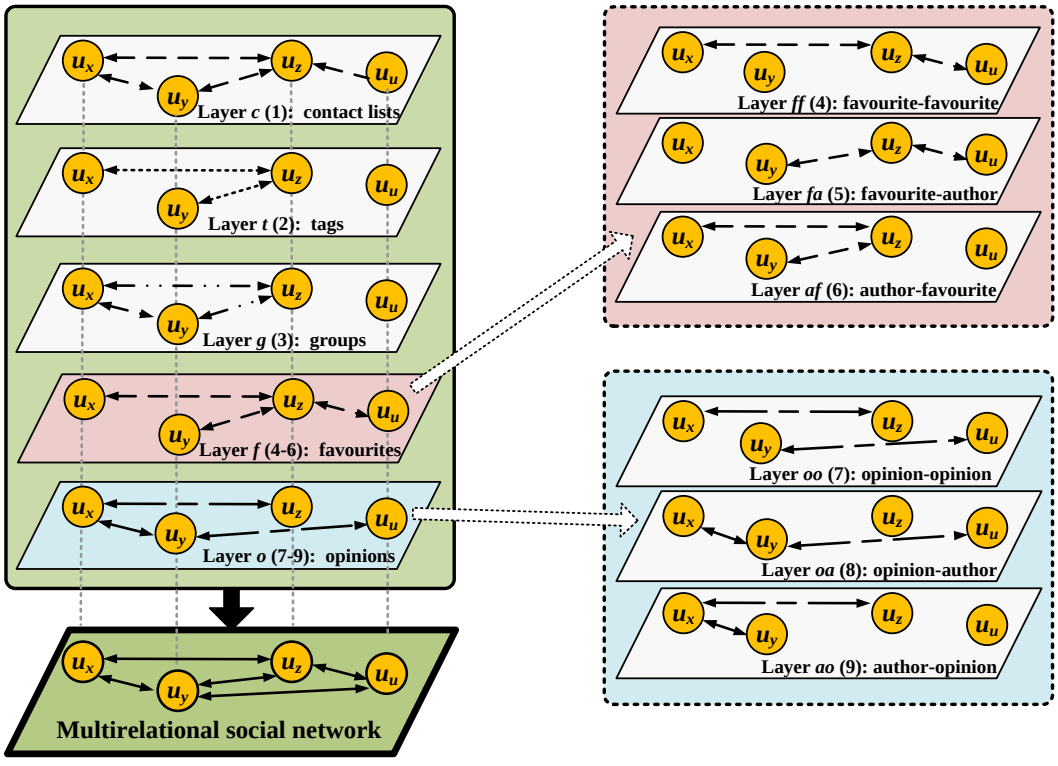

Figure 2. The relation layers in Flickr

A relation can be transformed to the valued form using either unary (1) or real values. These values express the strength of the relation.

Relations Based on Contact Lists

The information about user u_i's relations based on contacts are derived directly from u_i's contact lists (C_i). The relation r_{ij}^c from user u_i to u_j denotes that u_j belongs to u_i's contact list. The strength value s_{ij}^c of the relation r_{ij}^c is calculated as follows:

$$s_{ij}^c = 1/n_i^c, \quad \text{if } u_j \text{ is in the } u_i\text{'s contact list}, \tag{1}$$

where $n_i^C = card(C_i)$ is the number of all u_i's relations derived from the contact list, i.e. the length of u_i's contact list C_i.

Relations based on contact lists are kind of direct intentional relation:, u_j does not have to be conscious that another user u_i has added u_j to u_i's contact list.

Relations Based on Tags

The tag-based relation r_{ij}^t between user u_i and u_j can be derived from information about tags they share. The general process of extraction of tag-based relations from raw data is presented in Figure 3.

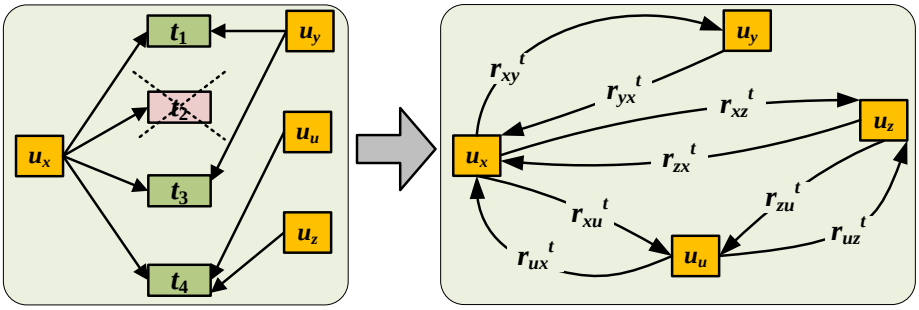

Figure 3. Extraction of tag-based relations

All tags that have already been used by at least two users form the set of tags T. The relation r^t_{ij} between two users u_i and u_j exists if both of them have used at least one common tag to describe their photos. The strength value s^t_{ij} of such relation is expressed as follows:

$$s_{ij}^t = n_{ij}^t / n_i^t, \tag{2}$$

where n_{ij}^t – the number of tags common for users u_i and u_j; n_i^t – the number of tags used by u_i.

Note that it is not important how many times tag t_k was used by two users but the fact that t_k was used at least once.

Tag-based relation is an object-based relation with equal roles since all users have the same role towards the picture they tag.

Relations Based on Groups

The data about groups to which user u_i belongs enable to create the relations based on groups. A group contains some MOs published by a set of authors and for that reason it aggregates authors (group members) of photos placed in it. Let G be the set of all groups that consist of more than one member. The group-based relation r_{ij}^g from user u_i to u_j denotes that u_i and u_j belong to at least one common group $g_k \in G$ or to be precise there are some groups that contain photos authored by u_i and simultaneously some photos published by u_j. The strength value s^g_{ij} of r_{ij}^g is:

$$s_{ij}^g = n_{ij}^g / n_i^g, \tag{3}$$

where n_{ij}^g – the number of groups to which belong MOs published by users u_i and u_j; n_i^g – the number of groups containing user u_i's photos.

Relations Based on List of Favourites

The next three types of relations are derived from the data about photos that were added by some users to their favourites (Figure 4). The relation favourite-favourite r_{ij}^{ff} from user u_i to u_j exists if both users marked at least one common photo as favourite. The relation author-favourite r_{ij}^{af} from author u_i to user u_j exists if user u_j has marked at least one u_i's photo as u_j's favourite. The relation r_{ij}^{af} also results in another relation favourite-author r_{ij}^{fa} from user u_i to author u_j. Similarly, r_{ij}^{ff} results in r_{ji}^{ff}. For example, when the photo MO_m authored by the new user u_i was marked as favourite by the first user u_j, then this fact creates two new relations r_{ij}^{af} and r_{ji}^{fa}. When the other user u_k marks the same photo MO_m then four new relations of three types are generated: r_{ik}^{af}, r_{ki}^{fa}, r_{jk}^{ff}, and r_{kj}^{ff}.

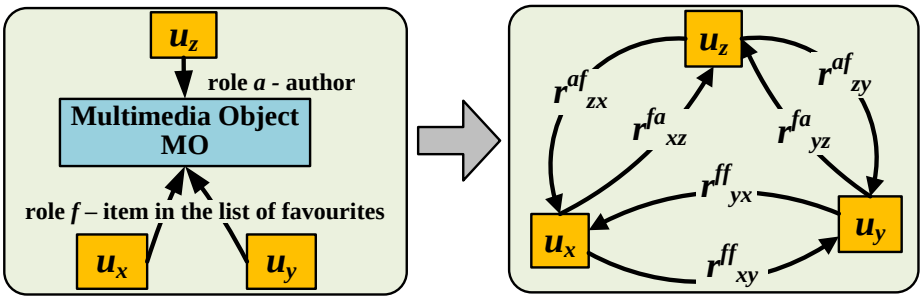

Figure 4. The process of extracting relation based on favourites

The strength value s_{ij}^{ff} of relation r_{ij}^{ff} is calculated as follows:

$$s_{ij}^{ff} = n_{ij}^{ff} / n_i^f , \quad (4)$$

where n_{ij}^{ff}, n_i^f – the number of photos marked as favourite simultaneously by u_i and u_j or only by user u_i, respectively.

To evaluate strength value s_{ij}^{af} of relation r_{ij}^{af} the following formula is used:

$$s_{ij}^{af} = n_{ji}^{fa} / n_i^a , \quad (5)$$

where n_{ji}^{fa} – the number of photos marked as favourite by u_j and authored by u_i; n_i^a – the number of all photos added by u_i and marked by others as favourite.

Finally, the formula for strength s_{ij}^{fa} of relation r_{ij}^{fa} is:

$$s_{ij}^{fa} = n_{ij}^{fa} / n_i^f , \quad (6)$$

where n_{ij}^{fa} – the number of photos marked as favourite by u_i and authored by u_j; n_i^f – the total number of photos marked as favourite by u_i.

Relations based on favourites are kind of object-based relation with either equal (R^{ff}) or different roles (R^{af}, R^{fa}), Figure 1.

Relations Based on Opinions

The last three types of relations can be extracted from information about commented pictures. The relation opinion-opinion r_{ij}^{oo} from user u_i to u_j exists if both users commented at least one common photo. The relation author-opinion r_{ij}^{ao} from author u_i to commentator u_j exists if user u_j commented at least one u_i's photo. The relation opinion-author r_{ij}^{oa} from commentator u_i to author u_j exists if user u_i created opinions to at least one u_j's photo.

The strength value of the above relations are as follows:

$$s_{ij}^{oo} = n_{ij}^{oo} / n_i^o , \quad (7)$$

$$s_{ij}^{ao} = n_{ji}^{oa} / n_i^a , \quad (8)$$

$$s_{ij}^{oa} = n_{ij}^{oa} / n_i^o , \quad (9)$$

where n_{ij}^{oo} – the number of photos commented simultaneously by u_i and u_j; n_i^o – the total number of photos commented by u_i; n_{ij}^{oa}, n_{ji}^{oa} – the number of photos commented by u_j and authored by u_i and vice versa commented by u_i and authored by u_j, respectively; n_i^a – the total number of pictures authored by u_i and commented by others.

Similarly to favourites, relations based on opinions are kind of object-based relation with either equal (R^{oo}) or different roles (R^{ao}, R^{oa}), Figure 1.

MULTIRELATIONAL SOCIAL NETWORK

According to Definition 1 social network $SN=(U,L)$ in PSS contains a set L of ties derived from data about direct intentional links, common activities or communication between users U. Ties (linkages) can be generated based on all previously discovered relation layers and in this way we obtain multirelational social network (Figure 2). The tie from user u_i to user u_j in the multirelational social network exists, if there exists at least one relation from u_i to u_j. As a result, set L is the sum of all relation sets identified within the system:

$$L=R^c \cup R^t \cup R^g \cup R^{ff} \cup R^{fa} \cup R^{af} \cup R^{oo} \cup R^{oa} \cup R^{ao}, \quad (10)$$

However, tie $l_{ij}=(u_i,u_j) \in L$ reflects only the fact of connection from u_i to u_j. Hence, similarly to relations, we can assign real values called strength of linkage s_{ij}^l to each existing tie $l_{ij} \in L$ based on strengths of all component relations.

$$s_{ij}^l = \frac{\sum_k \alpha_k * s_{ij}^k}{\sum_k \alpha_k}, \quad (11)$$

where k is the index of relation layer (Figure 2), for Flickr we have k=1 for R^c, 2 – R^t, 3 – R^g, 4 – R^{ff}, 5 – R^{fa}, 6 – R^{af}, 7 – R^{oo}, 8 – R^{oa}, 9 – R^{ao}, α_k – static coefficient of the kth layer importance; s_{ij}^k – strength of the kth relation from u_i to u_j.

Strength of linkage aggregates all strengths from all relation levels discovered in the system. Note that values of all strengths both for relations and for ties are from the range [0;1].

LAYER COMPARISON

One of the aims of this paper is to compare the different relation layers in the multirelational social network based on the data from the Flickr system.

There exist several measures to estimate the similarity between two layers. For valued relations, we can use Pearson correlation coefficient, Euclidean, Manhattan, or squared distance, whereas for binary relations, the Jaccard or Hamming measure can be utilized (Hanneman and Riddle, 2005) .

In this paper, the first enumerated measures – Pearson coefficient $p(R_1,R_2)$ is applied to calculate the similarity between two layers of relations R_1, R_2. Symbols R_1 and R_2 correspond to any two relations existing in Flickr. This coefficient is particularly useful when the relations between two users is directed and real valued. The range of the Pearson coefficient is [–1,1]. Value $p(R_1,R_2)$= –1 means that the corresponding relations within two layers are opposite while $p(R_1,R_2)$= 1 means that two layers have exactly the same relations and their strengths are fully correlated.

Moreover, the layers can also be compared based on some binary measures like graph density, i.e. normalized union – M1= $\frac{card(R_1 \cup R_2)}{card(U) * (card(U)-1)}$, binary cosine similarity – M2= $\frac{card(R_1 \cap R_2)}{card(R_1) * card(R_2)}$, binary Jaccard coefficient –

M3= $\frac{card(R_1 \cap R_2)}{card(R_1 \cup R_2)}$, or others. The values of all these binary measures from M1 to M3 are from the range [0,1]. Note that measures M2 and M3 operate on intersection of two sets of relations and for that reason they are good indictors of the overlapping of both sets. In case of in a sense complementary relations like R^{oa} and R^{ao} or R^{fa} and R^{af}, the measures M2 and M3 can be the sign of the common social background of both relations. It would mean that people reciprocate the interest of others, due to personal conduct rather then the semantic correlation between objects they published.

EXPERIMENTS

The experiment that examines the nine relation layers over generic aggregated ties, was carried out on two Flickr datasets. In January 2007, the data about almost 2 million users was downloaded from the Flickr web portal. Next, due to limited resources only top 1,000 users, who most extensively used tags, were selected together with all their associated data like contacts, groups, authored pictures, tags, comments, favourite photos. A year after, the process was repeated. Therefore two datasets presents state of activity of the same Flickr users in January, 2007 and February 2008, respectively.

Based on this data nine relation layers were extracted: *c, t, g, ff, fa, af, oo, oa, ao* (Figure 2). Users, who did not maintain any relation in any of the layers, were excluded from the further research. Finally, the cardinality of the user's set (*U*) equalled 745 in 2007 and 945 in 2008. Then, using Eq. 1 to 9, the strength of each relation in each layer was evaluated for both datasets.

	Year	R^c	R^t	R^g	R^{oo}	R^{oa}	R^{ao}	R^{ff}	R^{fa}	R^{af}	L (ties)
No. of relations (% contribution in ties L)	2007	263 (0.16%)	3,194 (1.94%)	163,446 (99.52%)	288 (0.18%)	940 (0.57%)	461 (0.28%)	32 (0.02%)	156 (0.09%)	18 (0.01%)	164,233 (100%)
	2008	1,464 (0.23%)	632,330 (98.95%)	192,396 (30.11%)	1,278 (0.28%)	1,278 (0.20%)	1,257 (0.20%)	0 (0%)	318 (0.05%)	318 (0.05%)	639,033 (100%)
No. of non-isolated users (% of U)	2007	191 (26%)	361 (48%)	679 (91%)	106 (14%)	264 (45%)	135 (18%)	31 (4%)	143 (19%)	16 (2%)	745 (U) (100%)
	2008	408 (43%)	916 (97%)	735 (78%)	319 (34%)	397 (42%)	397 (42%)	0 (0%)	242 (26%)	242 (26%)	945 (U) (100%)
Average strength	2007	0.73	0.07	0.07	0.10	0.28	0.36	0.97	0.92	1	0.008
	2008	0.25	0.08	0.06	0.04	0.05	0.05	0	0.43	0.58	0.08
Strength std. deviation	2007	0.30	0.14	0.11	0.17	0.32	0.35	0.12	0.19	0	0.016
	2008	0.26	0.11	0.09	0.098	0.16	0.12	0	0.36	0.35	0.11
Avg. number of relations per user	2007	1.4	8.8	240.7	2.7	3.6	3.4	1.03	1.1	1.1	220.5
	2008	3.6	690.3	261.8	4.0	3.2	3.2	0.0	1.3	1.3	676.2
Meeting object		N/A	Tag	Group	Commented MO			Favourite MO			Photos
Number of objects	2007	N/A	1,718	13,057	81	3,112	1,613	32	140	18	17,905
	2008	N/A	481,931	35,826	2,855	4,787	4,787	0	810	810	427,914
Relations per object	2007	N/A	1.86	12.52	3.56	0.30	0.29	1	1.11	1	9.17
	2008	N/A	1.31	45.66	0.63	0.27	0.27	0	0.4	0.4	1.5
Graph density	2007	0.05%	0.58%	29.49%	0.05%	0.17%	0.08%	0.01%	0.03%	0.03%	3.29%
	2008	0.16%	70.88%	21.57%	0.20%	0.14%	0.14%	0%	0.04%	0.04%	7.96%
Strength density	2007	0.03%	0.04%	1.99%	0.01%	0.05%	0.03%	0.01%	0.03%	0.00%	0.24%
	2008	0.04%	5.90%	1.29%	0.01%	0.01%	0.01%	0.00%	0.02%	0.02%	0.62%

Table 1. Statistical data for relation layers in Flickr

Some statistics related to the proceeded data were presented in Table 1. The graph density for the *k*th layer was calculated using $\frac{card\left(R^k\right)}{card(U)*\left(card(U)-1\right)}$, whereas strength density: $\frac{\sum_{(u_i,u_j)\in L}\left(s_{ij}^k\right)}{card(U)*\left(card(U)-1\right)}$. To evaluate strength of linkage (Eq. 11), α_k=1 was assumed for every layer *k*.

In 2007, R^g was the largest layer. Majority of users (91%) belonged to at least one group and the number of relations in layer R^g constitutes 99.5% of all relations (ties) that exist within the entire multirelational social network (Table 1). The average number of members in the group equaled 5.6 and there were 11 groups with more than 100 users. Such a big number of relations within layer R^g resulted from the multiple profile of this layer. In other words, when a new user appears in the group of *N* users, it may cause that up to 2**N* new relations are created. In consequence, the average number of relations that one person maintained within R^g in 2007 was over 240 and the graph density was almost 30%. However this was not valid in the same extent for other object-based relations with equal roles like tag-based (R^t), favourite-favourite (R^{ff}), and opinion-opinion (R^{oo}). The relatively high number of relations concentrated by a single object: 12.5 for R^g, 3.56 for R^{oo}, and 1.86 for R^t results in small values of strength, in average below 0.1.

In 2008 R^g is not the biggest layer any more. Admittedly, still majority of users (77%) belongs to at least one group but R^g is the component of only 30% of all ties. The average number of members in the group increased 16 times up to 93.2 and there are now 1,811 groups with more than 100 users. Moreover, there exist 47 groups with more than 500 users. In 2008, the average number of relations per user in R^g is over 262 (9% growth) and graph density is 21.5% (36% decrease).

The snapshot of the described social network from 2008 exposes that R^t has become the most dense and strongest layer within the entire multirelational social network – it was included in 99% of all ties. As compared to 2007, it can be observed nearly 200 times higher number of relations in R^t layer in 2008 as well as the density on the level of almost 71% reveals significant growth.

The experiments revealed that "folksonomy" concept (tagging of photos) has been accepted by most of users. Hence, tags have become the most significant meeting object between users – growth from 48% to 97% of users participating in R^t. The number of used tags increased 280 times up to over 480 thousand!

The interesting fact is that users are likely to have only few contacts and their relation in layer R^c are therefore strong: in 2007 only 1.4 relations per user with average strength – 0.73 and in 2008 – 3.6 relations per user with average strength – 0.25.

In case of layers R^c, R^g, R^{oo}, R^{fa}, R^{af} the change of average relations per user between 2007 and 2008 is inversely proportional to the change of average strength, obviously with varies proportion factors. Contrary situation can be observed in R^t layer, where with growth of average relations per user rises the average strength. For the rest of layers (R^{oa}, R^{ao}), decrease of average relations per user is accompanied by decrease of average strength.

The average strength of relations for R^{fa} and R^{af} is very high (over 0.9 in 2007 and still very high – over 0.4 in 2008), which can be interpreted as a single user tendency to mark as favourite MOs of only very few other users they feel to be close to. This was also valid for R^{oa} and R^{ao} in 2007, nevertheless the strength was not so high. In 2008, R^{oa} and R^{ao} were significantly weaker. Overall, it probably means that people, who add to their favourites or comment MOs of another user, utilize for this purpose the acquaintance with that user rather than semantic relationships between MOs. Thus, the basis of R^{fa} and R^{af} as well as R^{oa} and R^{ao} is more social than semantic. This also effects direct intentional relations like contact-based R^c – the average strength was 0.73 in 2007 and 0.25 in 2008. The usage of more semantic approach in user activities would cause dispersal and downgrading of relation strengths. This can be observed for tag-based and all opinion-opinion based relations – the average strength is below 0.1 Thus, R^t and R^{oo} are more semantic based in opposite to others.

Afterwards, the layers have been compared by means of following measures: binary cosine similarity (M1), binary Jaccard coefficient (M2), Pearson coefficient (M3). M1 and M2 are binary measures, whereas Pearson coefficient respects real values of strength.

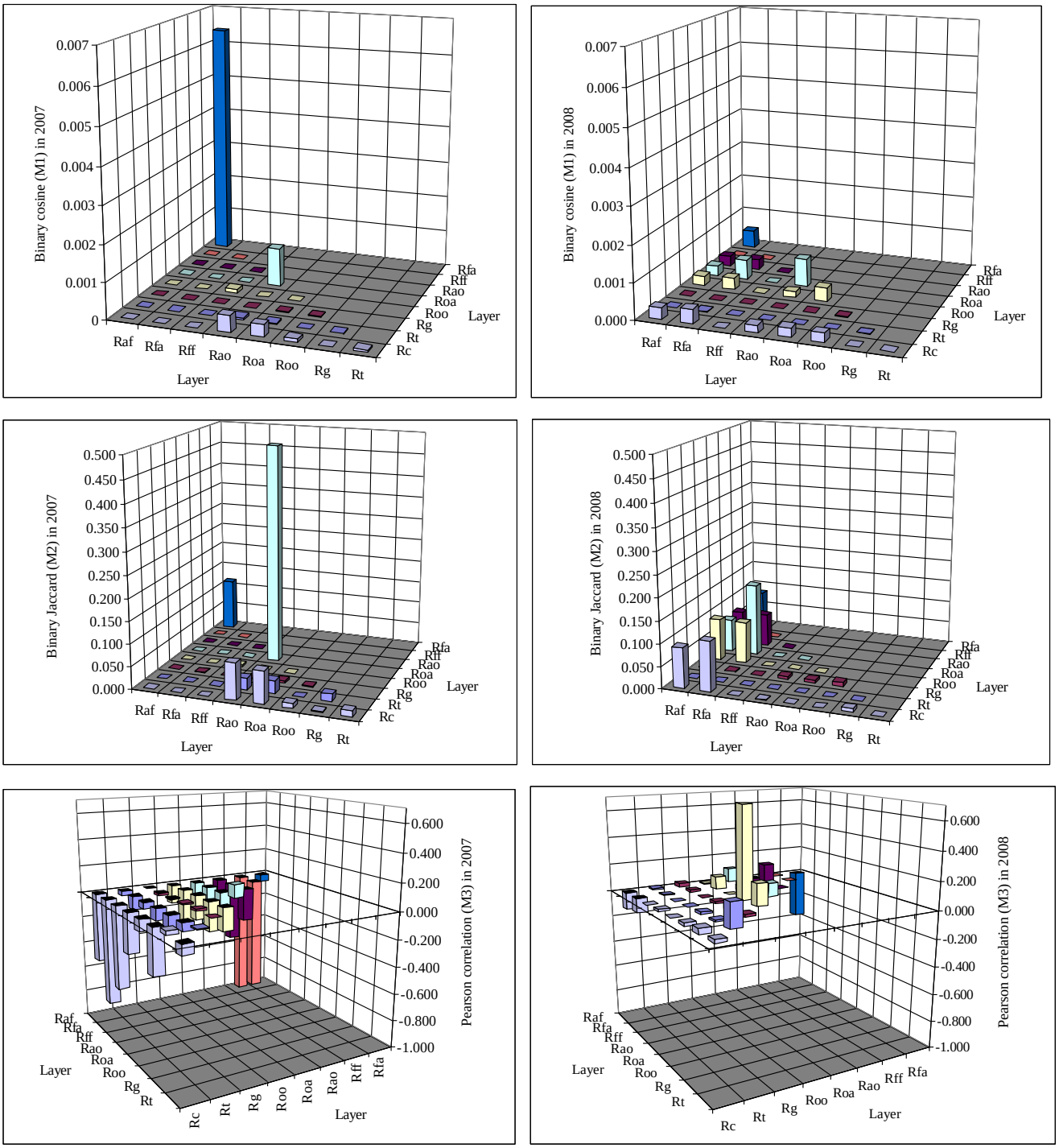

Figure 5. Similarity between relation layers: binary cosine M1, binary Jaccard M2, Pearson correlation M3

In 2007, the highest Pearson correlation M3 appeared between R^{oa} and R^{ao} (0.1) and in 2008, between R^{c} and R^{g} layers (0.03), Figure 5.

On the other hand, layers R^{ff}, R^{af}, R^{fa} were strongly divergent according to Pearson coefficient. Generally, two users who created relation r^{ff} by adding the same MOs as their favourite, create neither r^{af} nor r^{fa} relations between them. In 2008 there were no r^{ff} relations. It can stand for basically social profile of relations r^{af} and r^{fa}.

The general conclusion is that pictures are added to favourites due to their author rather than their subject. This rather social inspirations of activities based on favourites are additionally confirmed by the mutuality of relations R^{fa} and R^{af} – the highest value of binary cosine measure M1(R^{fa},R^{af})=0.0064, the second highest M2(R^{fa},R^{af})=0.12 in 2007 as well as the third highest M1(R^{fa},R^{af})=0.00049 in 2008. Values of M1 are the highest for the layers R^{fa} and R^{af} in case of their mutual correlation – M1(R^{fa},R^{af}) in both years. Even greater social involvement could be observed between R^{ao} and R^{oa} in 2007: the undisputed highest value of M2(R^{ao},R^{oa})=0.49, the highest Pearson correlation 0.1, and the second highest M1(R^{ao},R^{oa})=0.0011. Note that all others values of M1 in 2007 were below 0.0005 and for M2 below 0.085. Charts of M1 and M2 as well as to a large extent of M3 show for 2008 that R^{fa} and R^{af} are correlated with the other layers except R^{c} and R^{t} (Figure 5).

It generally means that if user u_i adds to favourites or comments pictures of user u_j then in many cases user u_j reciprocates by adding u_i's photos to their favourites or comments them, respectively. Similarly, if user u_i and u_j met each other while commenting somebody's else photo, they are also likely to comment their photos each other.

Overall, tag-based layer (R^{t}) reflect semantic relationships between users whereas the other layers, especially favourite-based and opinion-based (R^{fa}, R^{af}, R^{oa}, R^{ao} and R^{oo}) have more social profile.

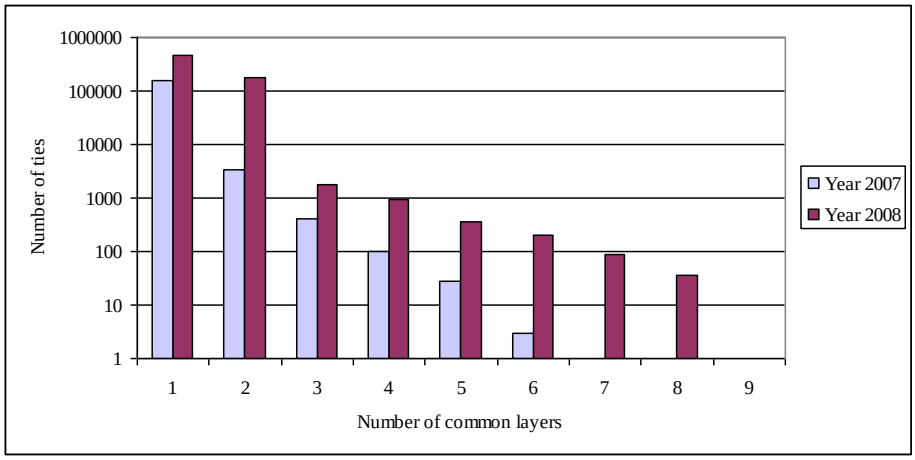

Figure 6. Number of ties in relation to the number of common layers

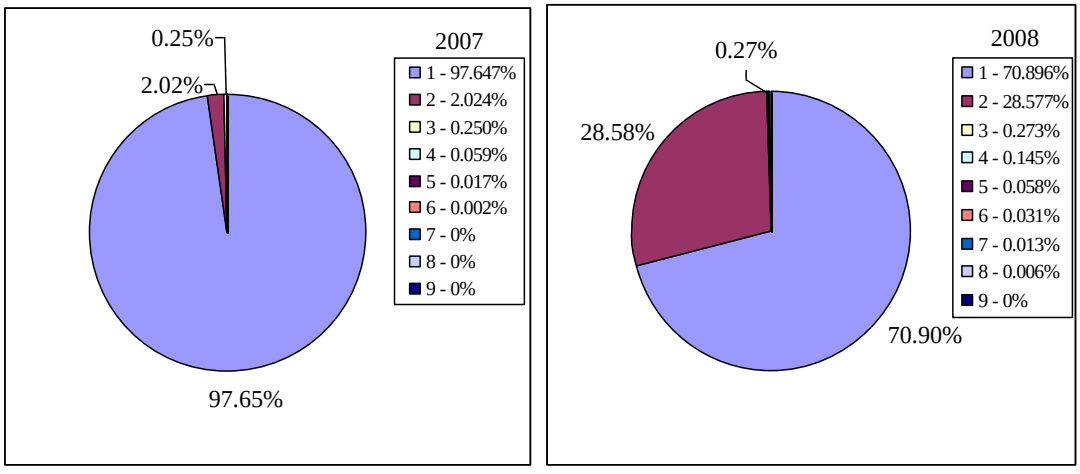

Figure 7. Distribution of number of common layers in entire multirelational social network

The relations in separate layers complemented one another in 2007 – the number of relations common for two or more layers is relatively small – 4,026 relations, less than 2.4% of total (Figure 6 and 7), see also intersection-based measures M1 and M2

in Figure 5.This trend was reversed in 2008 on the grounds of enormous increase of R^t that met with R^c while the other layers remained independent.

CONCLUSION

Flickr users form a social network of people with common interests or activities. The members of the social network can be related either directly or indirectly through an external object like commented picture, group or tag they share. Based on these different kinds of connections, many separate relation layers can be identified in the multirelational social network. These layers usually complement one another. Moreover, for the single user activity more than one relation in more than one layer can be created, e.g. a new comment on the single picture can result in new relations between commentator and photo's author (opinion-author and author-opinion relations) as well as between the commentator and all other commentators of this photo (many opinion-opinion relations).

The multirelational social network that aggregates all existing layers provides a comprehensive view onto relationships between users. It merges both semantic and social backgrounds of user activities. Semantic inspiration of users refer especially tag-based relations whereas opinion- and favourite-based relations that link authors with others interested in their photos reflect more social motivations. This duality shows that social networks in complex multimedia publishing systems should be considered using many different dimensions.

The spanned of over a year research revealed that tag-based relations (folksonomy) more and more dominate the multirelational social network created within the online publishing system. Over 360 out of 1,000 users utilized over 1,700 distinct tags in 2007 whereas 916 users from the same community used as many as almost 482,000 tags in 2008.

Overall, the multirelational social network becomes more affluent in its component layers year by year. As a result, users are more and more related to others through different dimensions – the number of ties linking the same set of users increased almost four times during one year.

The social network, which can be extracted from user activities, can support other cooperative actions of users like collaborative Information Retrieval or metadata management. It also facilities trust management between its members, targeted marketing (Kazienko and Adamski, 2007) and recommender systems.

All kinds of personal incoming and outgoing relations can be made visible for the user what would increase user's sense of community. Furthermore, users can even be unconscious of some relations they are involved in. Especially, object-based relations with equal roles like opinion-opinion or favourite-favourite can be utilized to extend the social network, e.g. by means of a recommender system.

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