Automatic Estimation of Influence of Acquaintances in a Social Group and Its Key Influencers from Their Communication and Location History

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Abstract. Information can be delivered to a target person with maximum efficacy via a specific information transferer. We developed a compass system that established an anonymous method to analogize in-city acquaintances and used location information and each visitor's smartphone to detect analogically the significant influencers of a target person. Based on the data regarding information transferred between group members and their location history, we derived a model for estimating how acquaintances influence each other in a social group and for locating influencers.

Keywords: Social city, Social graph, O2O, LBS, location based services, Area differentiation, Ambient communication, Spatial marketing, Behavioral marketing, Human communication, Positioning, Mobile system.

1 Introduction

Fundamentally, human beings are social and their desire to connect with others is universally acknowledged. A reason behind this nature is that we confirm our existence through mutual support and participation in the society [1]. However, social networking services (SNSs), which we use daily, do not completely satisfy our desire for an organic relation with others in real spaces. Foursquare, which puts "colocation," "co-encounter," and "co-activity" into practical use and helps people to connect with others, does not provide comprehensive attention to connections already established by people.

The social media revolution was ignited by the emergence of Facebook in 2004. Since then, the tidal wave of social media has fascinated people and completely changed the perspective of how they share information and communicate with each

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other. Alvin Chin's and Daqing Zhang's comprehensive review of a sequence of these movements indicates [2] that there is no room to doubt the business opportunity and market scale in the field of social media, especially for online-to-offline (O2O) and location-based social networking (LBS) services such as Facebook and Foursquare. And social network analysis using information transmission in online SNS was reported [3].

Today, there are thousands of useful services making our communication simple and easy, and to socialize with others, we no longer have to depend on being in the same place and at the same time as them. Thus, the main purpose for our physical visit to certain places has shifted from being communication-oriented to being material-oriented, and physical spaces such as cities and shopping complexes are evaluated by their practical functions, which lead to the fading away of our belonging to spaces. Most people do not pay attention to the differences between cities for the purpose of shopping, working, or even residing there. We have been studying spatial and behavioral marketing along with the so-called "commoditization of real spaces" and the changes caused by it from the perspectives of area-differentiation strategy and ambient-communication strategy.

In addition to the problem of commoditizing real spaces, there is a need to resolve deep-rooted problems over online and offline communication against the background of the drastic growth in e-commerce and mobile computing. The situation around O2O and LBS sheds light on challenges that current SNSs present. For example, users start disliking an information source, such as a shop or a shopping complex for promoting information, perceiving its announcements like spam. In addition, real spaces are suffering from so-called "showrooming," where the consumption process does not complete within the offline environments and shop spaces function merely as showrooms [4][5].

Standing on the understanding of the challenges as described, we developed a system to analyze an intra-city social graph to enable visitors access local content through their friends in Grand Front Osaka (GFO), a large-scale complex facility, via the latest social network service, the compass system. This communication ecosystem not only provides reliable information or amplifies the reasons behind a visit but also lets users become a hub for their friends and others within their intra-city social graph. From this viewpoint, our approach is different from other SNSs in terms of its success in making fans of real spaces and satisfying their desire for mutual support and social participation.

We conducted an experiment in November 2013 to evaluate the validation of information shared via a user's friends (intra-city social graph). This article summarizes the experiment outcomes and analyzes the relationship between shared information and behavioral changes.

2 Grasp of Visitor Position by Compass System

GFO offers a compass system that aims to anonymously guess the interpersonal relationships of the person who visited the town. This compass system presumes the

mobile terminal position by using wireless LAN access points and the user's smartphone terminal by referring to the radio field strength the terminal receives and the position of the access point [6]. Moreover, this system has the ability to perform a check-in when visitors stop by each spot in town. It was observed that the compass system required only 60 minutes or less to differentiate two people from among unspecified town visitors after the two had succeeded in checking-in to a target spot [7].

In this study, the function of the compass system has been enhanced to make possible its use outdoors, to analogize the interpersonal relationship of a traveling group. The GPS function of the terminal was used together with the positioning system, and the function that allows checking in at an arbitrary point was installed. In addition, a smartphone application that achieves photograph sharing using proximity communication was developed as a tool to examine how information received from a specific acquaintance influenced the addressee. The information transmission situation in a travel group and the moving pathway of everybody can be grasped by using positional GPS logs and the information added to each photograph. Moreover, the experiment tested the design of a method for grasping the influence level in the group by using these pieces of information.

3 Information Propagation via Proximity-Based Photo Sharing

We provided the participants with a smartphone application for sharing pictures, built on top of a mobile resource sharing platform called ShAir [8]. Owing to the ad hoc peer-to-peer wireless communication capability of the platform, pictures were automatically shared whenever the participants moved close to each other. Capturing pictures was the only operation the participants performed in the application, which avoided an additional burden on the participants for sharing operations. Proximity-based sharing naturally limited recipients of pictures to a subgroup of the participants traveling together. Pictures were gradually and eventually shared with other participants, as people from different subgroups met and as subgroups' members changed over time. Subsequently, pictures were shared between participants; thus, permitting us to witness information propagation among the participants. To keep a track of this, when a user captured a picture, the application attached an auxiliary header to the picture file and stored the user ID as well as a timestamp. The header was shared along with the picture, and whenever another user received the picture, the application added their user ID and another timestamp to the header. Fig. 1 shows a screenshot of the application with a picture and a list of the user IDs and timestamps associated with the picture.

4 Grasping the Foreign Tourist's Action

To investigate this idea (grasping the influence level in the group), the information flow and individual loci of a group of 15 incoming tourists was recorded. All travelers possessed smartphones with our Android application installed, which obtained GPS positional information at one-minute intervals and shared photographs captured by

individuals within the group. The travelers were based in an Osaka hotel and they interacted throughout the eight days. As illustrated in Fig. 2, received information appeared to trigger an action among the travelers. The plot exhibits the temporal progression of the traveler's distance from the spot where the photograph was captured. The pattern in which the person who received a photograph captured in a certain place moved to that place was frequently observed through the experiment period.

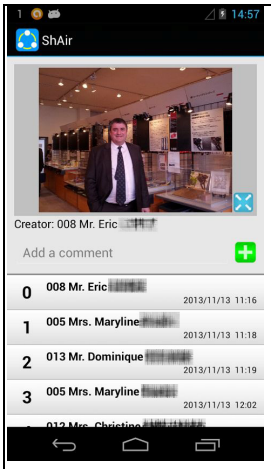

Fig. 1. Screenshot of the photo-sharing application. ShAir.

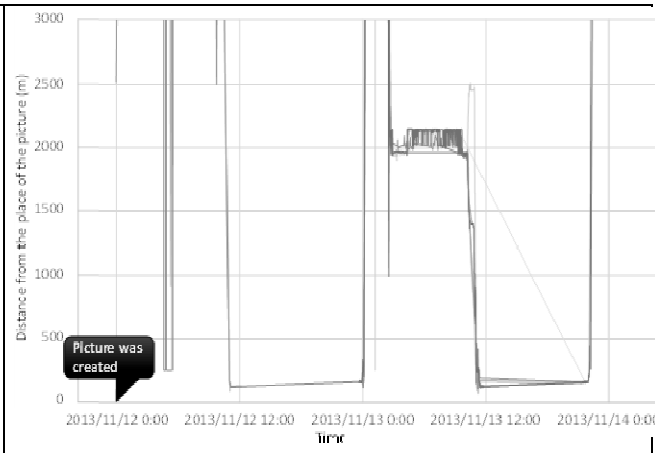

Fig. 2. Action after photograph is received by smartphone, application program

5 Interpersonal Influence Levels in a Travel Group

To elucidate how group members are influenced by photograph exchange at a place P taken by other members, we constructed a model that explains how pictures travel and influence the behaviors of members. In this model, how pictures travel is explained by the Markov model of state vectors of logical values, each representing whether a member has received or not received a photograph of place A from member B. Assume that members A, B, and C in the group send pictures to member D. The state vector of D then contains three logical values. Initially, D′s state vector is (0,0,0), implying that D has acquired none of the pictures sent from members A, B, and C. When member D receives a photograph from A, the state vector changes to (1,0,0).

The output of this process alters from Has not visited place P to Has visited place P. These two states are assumed to depend on the state vector, which contains information on the photographs sent from other members. The whole model is illustrated in Fig. 3.

Table 1. Probability of reaching an outcome from different state vectors.

State vector			Probability of reaching state Has visited place P
0	0	0	0.1
0	1	0	0.1
0	0	1	0.3
0	1	1	0.7
1	0	0	0.5
1	1	0	0.6
1	0	1	0.8
1	1	1	0.9

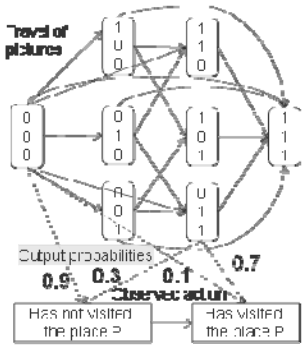

Fig. 3. Model of photograph exchange and behavior influence

The Markov model progresses from left to right. In this figure, the numbers beside the arrows pointing from the state vector to the output are probabilities. For example, the arrow from (0,0,0) to the state *Has not visited place P* is accompanied by 0.9, implying that when member D has acquired no pictures of place P, the probability that member D has not visited P is 0.9. These probabilities from the state vector to the output can be computed from GPS records and logs of picture-sharing via ShAir. We then perform regression analysis between the state vectors and probabilities of reaching the state *Has visited place P*. For example, assume that the probabilities of reaching this state are as listed in Table 1.

Regression analysis yields the following results:

1st element: 0.4
2nd element: 0.15
3rd element: 0.35
y-intercept: 0.05

Here, the 1st element is a logical value indicating whether or not member D receives a photograph of place P from member A. The slope of the 1st element appears to explain the influence of member A on member D. In this algorithm, all steps for elucidating the influences of a member can be processed automatically from the given GPS and ShAir log data. Furthermore, models can be extended to more members easily.

6 Summary and Discussion

We made a customization of the GFO's official location-based smartphone application "compass system" to enable users to use it not only inside the GFO but also in other areas, including outdoor spaces. Then we conducted an experiment with the cooperation of 15 French tourists visiting Japan as a group in November 2013 to create intra-city social graph anonymously, to evaluate validation of information shared by a user's friends (intra-city social graph) in a physical space, and to estimate a person's influence over the group. This paper summarizes the experiment outcomes and analysis of the relationship between shared information and behavioral changes. Considering GFO's leading hardware and software, such as its 36 touch panel-operated digital signs that are capable of individual certification by an NFC (Near Field Communication) reader/writer, the facility complex will contribute to advanced and flexible studies. We now envisage a user who would like to use the facility via biometric information, e.g., heart rate and brain wave. We define our next tasks to study the growth opportunity of LBS using personal data and to examine the application of NFC/RFID (Radio Frequency IDentification) to cities along with activities to make them of international standards, and will continue to conduct further experiments and researches about the future of communication.

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