Analysis of service network through in different community structure

Bujie Xu[1], Ken-ichiro Ogawa[1], Naoki Higo[1], Taiki Ogata[2], Takayuki Nozawa[3], Koji Ara[4], Kazuo Yano[4], Yoshihiro Miyake[1]

[1]Department of Computational Intelligence and Systems Science, Tokyo Institute of technology, Yokohama, Japan

[2]Research into Artifacts, Center for Engineering, the University of Tokyo, Kashiwa, Japan

[3]Institute of Development, Aging and Cancer, Tohoku University, Sendai, Japan

[4]Center Research Laboratory, Hitachi Ltd., Tokyo, Japan

Abstract

The paper provides a new approach to analysis the interaction of people in service network. On one hand, network is analyzed from two different viewpoints. Specifically, we separate the network into the community of service providers and the community of service receivers. Moreover, another community detection is held based on the weight of face-to-face interaction in the network. On the other hand, we use people's upper-body movement to reflect face-to-face interaction between them. Based on the two kinds of viewpoints, face-to-face interaction in a same community is compared with that between different communities. We find out that different community separation of a network would influence the smoothness of communication in communities and between communities.

Keywords:

Service network, face-to-face interaction, community detection

1 INTRODUCTION

In recent years, service industry plays a more and more important role in contributing to countries' economics. It becomes the mainstay industry in many developed countries, like Japan. According to Japan's GDP report, services contribute to 71.4% of Japan's GDP in 2012 [1]. The importance of service makes it a pressing topic in science and technology.

When service is described, a simple model always be introduced (Fig. 1(A)). Service is thought to be an interaction between two objects. Generally, service provider provides service to service receiver. In this model, however, the interaction among service providers and among service receivers have not be considered. In fact, service is more complex in real world like in Fig. 1(B). Interactions do not only happen between service provider and service receiver. Service receivers are usually influenced by not only providers but also by other receivers. Moreover, sometimes, service providers need to corporate with each other to satisfy receivers [2]. From the above, it is necessary to consider all these interactions in service. Thus, we have to analysis service in networks.

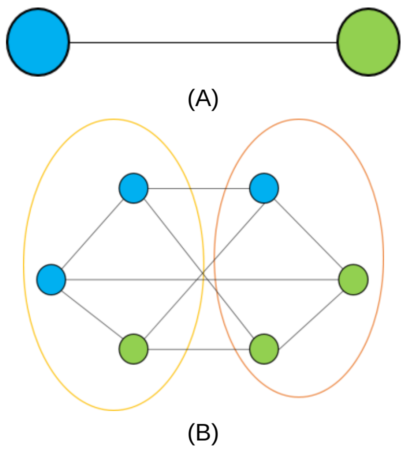


Fig.1 Service model. Blue nodes represent service providers, green nodes represent service receivers, edges show the interaction. Fig. 1(A) shows service between two objects and fig. 1(B) shows service network.

In the network, we focus on two key things. One is the objects, which are service providers and service receivers. The other one is the interactions in the network.

Usually, service providers and service receivers are considered as independent research objects. In fact, one way to separate service network is by the position of objects [3]. Put simply, the network could be separated into two communities, one is the service providers, the other one is service receivers. Like Fig. 1(B), service providers and service receivers are separated by colors. In this case, the interaction between service providers and between service receivers could be considered interaction in communities, and interaction between service providers and service receivers is the interaction between communities. However, only consider the position of objects is not enough, because interaction itself is also crucial part in the network [4]. When the weight of interaction between objects is considered, the result of community separation would be totally different. As in Fig. 1(B), the objects in yellow circle and objects in red circle could also be considered as communities. In this kind of community separation, service providers and service receivers could be in the same communities. In other word, they may share the same context. Positions are no longer matters here. Service receivers may play service providers' role. For instance, customers are regarded as important as producer in promoting service. The first viewpoint investigate the feature of the two objects of service, and the second viewpoint focus on the main approach of service. They are both necessary in considering service.

The last and vital thing is face-to-face interactions. To analyze the interaction between people, people's upper-body movement is focused in the paper. According to Alex Pentland [5], human beings have two channels to communicate with each other, one is the linguistic channel, and the other one is the non-linguistic channel. He called the signals which human beings provide in the non-linguistic channel honest signal. He suggests it play the same important role with the linguistic signals. Besides, many researches have indicated that the embodied synchrony phenomenon of upper-body movement can improve the quality of smooth communication, which is the prerequisite of successful service.

In this paper, we provide a method to analyze organization and service network based on people' interaction and upper body movement data in six organizations. Specifically, we separate each organization into communities in two different viewpoints and compare the embodied synchrony phenomenon of people in the same communities and people from different communities. We find out that different community separation of organizations would influence the smoothness of communication in communities and between communities.

2 METHOD

2.1 Data measurement

In this study, we use the Hitachi business microscope [6,7] which uses an acceleration sensor and an infrared sensor to measure time series data of body motion and people's interaction. This device was advocated to workers in each organization. Workers wear the device as in Fig. 2 at work and take off it after work. For body motion data, three axis acceleration signals are captured for 2 seconds every 10 seconds at 50 Hz to calculate the norm of the signals. The frequency of zero-crossing points across the average acceleration norm for every 10 seconds is then calculated as motion rhythm. In the paper, x_t^i [HZ] means the motion rhythm. Here, i is the sensor wearer's label, t is the time. x's value shows the intensity of body motion, the more the zero-crossing points are, the bigger x is.

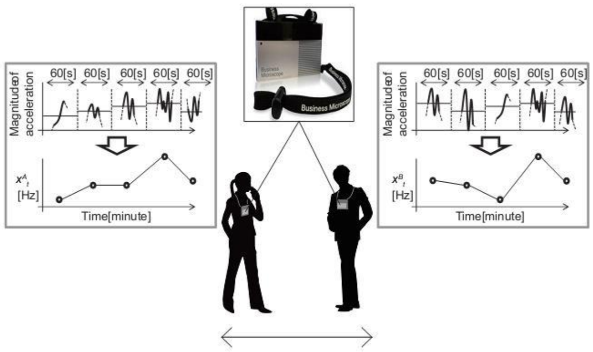


Fig.2 The wearable sensor (Business Microscope). This equipment is attached on the upper torso of a participant.

For face-to-face interaction data, it is measured by the infrared sensor every 10 seconds. The valid zoom for the sensor is 120 angle in horizontal position and 60 angle in vertical position. If two people wear the sensor meet within a radius of 2 meters (Fig. 2), their IDs will be recorded. Here, 2 meters is based on Hall's research [8]. They have showed that business communications are often taken in a distance from 1.2 meters to 3.6 meters. From the face-to-face interaction data, we can figure out that every person meet how many people and whom were they meet in a specified time.

To be noted, in the study, the body motion rhythm data and face-to-face interaction data was all processed into per minute.

People in 6 organizations participated into this study. Table 1 shows the type of each organization, the number of research objects, and the duration of days for the research. Research objects are the people who had wear the device at least one time. The valid days are the days that the number of people who wear device is above 10% of the total population of the organization. These data is provided and controlled by world signal center (Hitachi).

2.2 Embodied synchronization

Given the upper-body movement frequency data, we calculate the difference of people's upper-body movement when they have interactions. If the value of upper-body movement frequency of two people are close, in other words, the difference of the frequency is closer to zero, they are regarded to be synchronize easier. In order to show the upper-body movement's difference of all communication pairs, and to find out the pattern of the difference, we displayed the distribution of the difference of upper-body movement in communities and between communities. To understand the features of distribution, standard deviation and kurtosis are used for detailed analysis. Here, Y shows the difference of communication pairs' upper-body movement frequency.

$$Y = \{\{\pm\left|x_t^i - x_t^j\right| \,\big|\, t \in T_{ij}\} \,\big|\, (i, j) \in E\} \qquad (1)$$

where T_{ij} means the time people i and j had face-to-face interaction. E is the set of users' labels. In order to show the distribution of body motion rhythm difference clearly, we set Y symmetric by 0[Hz].

2.3 Community detection

In the paper, we provide two ways to separate the organizations into communities. The first way is based on the real community information. The information shows the department to which each person belongs. The second way is based on Newman's [9] method to detect community in weighted network. In fact, these two methods look at organizations from two different viewpoints. One is from the communities' occupational function, that is, position viewpoint, the other one is based on the people's interaction in organizations.

The real department information is showed in table 1. Every organization is composed of some departments, and every people belongs to one department. We use this mapping relation to detect communities in organizations.

Another method is to detect communities in communication networks. In order to show the relationship of people in communication network, we regard people as nodes, and their interaction (say encounter) as edges. In addition, the weight of edges show the length of time people meet. Therefore, the weights represent the strengths of connection from one people to another in the network. Since the communication in this study is defined to be communication between two people, the network matrix will be undirected and symmetric. In this study, we use the Newman's community detection method is based on edges' betweenness in network. The edge betweenness of an edge in a network is defined to be the number of shortest paths between vertex pairs i, j in network that run along that edge, summed over all i and j. In this study, we call the network *G*. The community detection algorithm is as follows:(1) Calculate edge betweenness of network G, ignoring the weight; (2) Divide each edge betweenness by the weight of corresponding edge; (3) Remove the edge with the highest betweenness/weight; (4) Calculate the modularity [9] which shows the separation quality; and (5)Loop this calculation. Then, choose the separation which has the highest modularity score [10].

3 RESULT

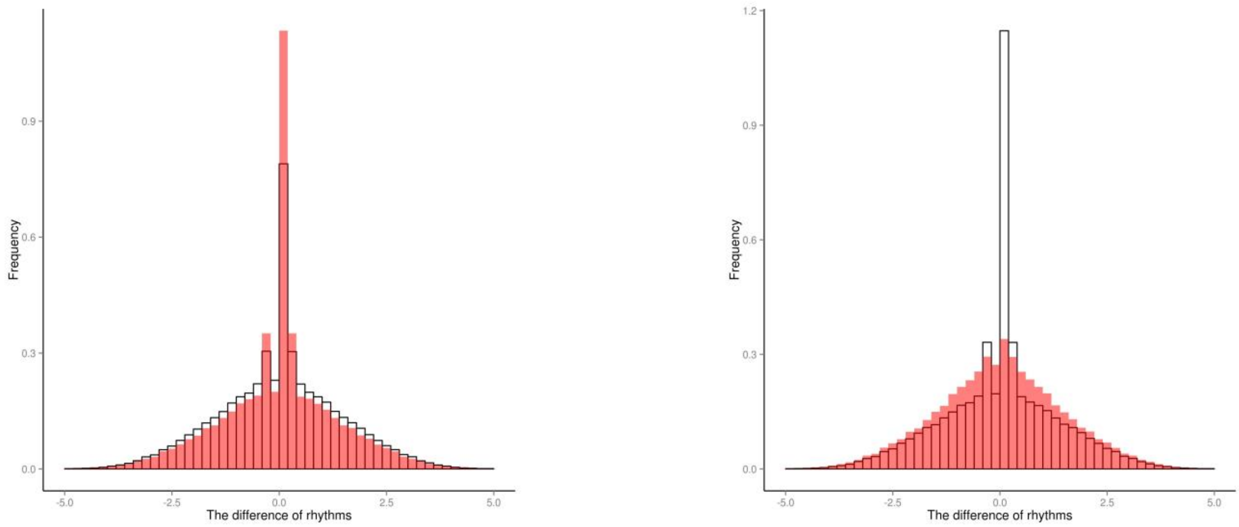
Fig. 3 shows the result of community detection from organization C by two different methods. Fig. 3(A) and 3(B) depict the results by real department and by communication, respectively. Fig. 4 shows the distribution of body motion rhythm difference in communities and between communities in organization C. Fig. 4(A) and 4(B) show the distribuions in communities (red histograms) and between communities (black-edged hhistgrams). In fig. 4(A) the communities are detected by real department information, and in fig. 4(B) the communities are detected by Newman's methods. We will discuss the result by the histograms and their statistic results.

Table 1: Summary of organizations. ”Type” expresses the category of organization. ”Department” shows the community information of each organization. ”Participants” is the number of research objects (people). ”Days” is the total duration for analysis. Organizations A, B are different companies. Organizations D, E, F are different divisions of the same company

Organization	A	B	C	D	E	F
Type	R&D	Wholesale	Development	Development	Development	Development
Department	A-B	A-E	C1-C10	P1-P10	Q1-Q6	U1-U6
Participants	163	211	219	144	109	124
Days	41	48	56	58	57	57

(A) (B)

Fig .3 Community detection from organization C. People in a same community is showed by the nodes in a same color. Fig. 3(A) shows the communities detected by department information, Fig. 3(B) shows the communities detected by Newman's method.



(A) (B)

Fig .4 Distributions of body motion rhythm difference in organization C. Fig. 4(A) and 4(B) show the distributions in communities (black-edged histograms) and between communities (red histograms). In fig. 4(A) the communities are detected by real department information, and in Fig. 4(B) the communities are detected by Newman's methods.

3.1 Result on community detection

In Fig. 3, the nodes represent workers in organizations, and the edges represent the interaction between workers. Here, one person is depicted by the node with the same position in the network, and people in same communities are drew in a same color. It is easy to see that the result of two community detection methods is totally different. First, people who are in a same department (Fig. 3(A)) may be in different interaction communities (Fig. 3(B)). Second, people who are from different departments (Fig. 3(A)) could be in a same interaction community (Fig. 3(B)). It is to be noted that the same edge could be either edge in community or edge between communities in different community detection methods.

3.2 Comparison on histogram

The distribution of upper-body movement frequency of interaction pairs is showed in fig. 4. Note here that in Organization C, people in a same real department is more difficult to have embodied synchrony than people from different departments (Fig. 4(A)). Whereas, when separating community by the weight of people's interaction, embodied synchrony is easier to happen between people in a same interaction community than people from different communities (Fig. 4(B)).

3.3 Statistic analysis

Tables 2 and 3 show the results of statistical analysis, and in particular, the standard deviations (SD) and the kurtosis (Kurt) of the rhythm difference in communities and between communities. In table 2 the communities are subtracted by real department information, while in tabke 3 the communities are subtracted by Newman's method. "SD" indicates the standard dispersion of the distributions and "Kurt" indicates the peakedness of the distributions. The SD and kurt are defined as follows:

$$SD = \sqrt{\frac{\sum_{k=1}^{n}\left(y_k - \bar{y}\right)^2}{n}}, \tag{2}$$

$$Kurt = n\frac{\sum_{k=1}^{n}\left(y_k - \bar{y}\right)^4}{\left(\sum_{k=1}^{n}\left(y_k - \bar{y}\right)^2\right)^2} - 3 \tag{3}$$

where n is the count of set Y. As set Y is symmetric by 0, so $\bar{y}$ equals 0. In general, the bigger the kurtosis is, the more the near 0 part of rhythm difference has. Also, if the distribution has small SD and big kurtosis, it means that in percentage, more interaction pairs have embodied synchronization, and vice versa.

Table 2: The standard deviations and the kurtosis of the rhythm difference in communities and between communities. Communities are detected by real department information.

Organization	SD_{in}	SD_{btw}	$Kurt_{in}$	$Kurt_{btw}$
A	0.797	0.796	0.509	0.360
B	0.774	0.809	0.658	0.636
C	0.750	0.731	1.060	1.837
D	0.747	0.781	0.580	0.689
E	0.763	0.826	0.607	0.252
F	0.777	0.791	1.137	0.851

Table 3: The standard deviations and the kurtosis of the rhythm difference in communities and between communities. Communities are detected by Newman's method.

Organization	SD_{in}	SD_{btw}	$Kurt_{in}$	$Kurt_{btw}$
A	0.789	0.838	0.536	0.164
B	0.781	0.838	0.657	0.659
C	0.692	0.852	1.706	0.533
D	0.753	0.756	0.881	0.576
E	0.786	0.786	0.526	0.415
F	0.775	0.786	1.195	0.919

4 CONCLUSION AND DISCUSSION

Currently, the stage of service is shifting from a closed environment, which only has service providers and service receivers, to an open environment. Service network is consisted of the people that engaged in service, the environment of service, and all other elements that influence service. Therefore, service should be considered as such an open network system. In the paper we analyzed service in network, and reconsidered the service from different points of view.

The result shows that all of interactions among service providers, service receivers and interactions between them are important. Particularly, organization C clarifies the difference between two kinds of viewpoints. It suggests that the communication between people from a same department may be less smooth than the communication between people from different departments. Whereas, when people are in a same interaction community, their communication become smoother. To further consider this result in service network, people in a same department could be regarded as either service provider or service receiver. The result suggests that the communication among service providers or service receivers is worse than the communication between service providers and service receivers. On the other hand, when service providers and service receivers are separated into a same community, their communications tend to occur smoothly. This suggests that they share the same context in the same community. In this case, the difference of people's status in service becomes less important. Indeed, their roles could be changed. Service receiver could act as service provider to influence other receivers' choices.

One of the key points to successful service is making face-to-face interaction based on body movement smooth and efficient. Face-to-face signals associated with body movement are very important in analysing service network. In the future, this kind of signals will play an important role in the field of service research.

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