Study on real world relations among humans and objects using cellular phone and barcode

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Abstract

The purpose of this research is to find the methods for understanding our lifestyles by analyzing the relational network among humans and objects. We created a cellular phone application for use as our experimental system that can read barcodes. Users can describe the relations between humans and objects or objects and objects using this application. We experimented using this application and conducted a quantitative analysis of the relational network among humans and objects. Relational networks among humans and objects extracted from this experiment are described, and benefits and values of these networks for users are discussed.

Keywords: Real World, Cellular Phone, Barcode, Relation, Network, Degree Centrality

1 INTRODUCTION

There has recently been a lot of research on the achievements of the ubiquitous society [1]. We now have the ability to store data on objects that we use in our lives, and we can conveniently use this data whenever we want. For example, KDDI[1] carried out an experiment in which people can read barcodes attached to commodities by using a cellular phone and find related information from November, 2005 to March, 2006. In KDDI's experiment, users can describe their impression of the commodity when they read the barcode and post it on a blog using their cellular phone [2]. Then, the information on the commodity is automatically retrieved and displayed by the Amazon[2] web services.

There was also an experiment on registering all the things in a person's house in a database [3]. However, these experiments do not take the relations between humans and objects or objects and objects into consideration.

The image on the left in Figure 1.1 shows a situation where people are talking and eating. We assume that a network exists in this scene [4]. The figure on the right in Figure 1.1 shows only the network map among humans and objects. In this network, the nodes consist of the humans and objects, and links consist of the relations between them. This network is very complicated and makes a *small world* [5] in which the distance between two nodes is very short. The social network analysis method is available for any complex world and is very effective for understanding the property of such complexity [4]. For example, we can evaluate centrality of nodes based on the *degree centrality* which is the simplest method [6]. We formed a hypothesis that important nodes or links which is effective as the method of understanding our lifestyles exist in the relational network among humans and objects.

The purpose of our research is to find these important nodes or links, and confirm the methods of understanding our lifestyles by analyzing the relational network among humans and objects. Therefore, we conducted an experiment to extract the relational network from our surrounding living environment, like in the house, by using a cellular phone application that can read barcodes. Users can describe the relations between humans and objects or objects and objects using this application. There are three advantages of using a cellular phone and barcodes. First, we can easily make[3] QR codes to compare with RFID tags. Second, cellular phones,

[1] Japanese IT and Telecommunications Company
[2] http://www.amazon.co.jp/Web
[3] We made QR codes using a label printer.

basically reading tools, are widespread in Japan. Third, we can collect data that are closely related to the real world, because we carry them anytime and anywhere we go.

This paper consists of following sections. In Section 2, we describe our experimental system. In Section 3, we describe the experimental results and consideration by using a quantitative analysis on the relational network and network visualization map. In Section 4, we make discussions on the experiment. We conclude in Section 5.

2 EXPERIMENTAL SYSTEM

Figure 2.1 is an overview of the experimental system that we constructed for this research. First, we gave objects ID numbers by attaching QR and JAN codes to them. Figure 2.2 shows examples of the QR code and JAN codes. A QR code is a two-dimensional barcode developed by Denso Wave Co. Ltd. in 1994. The QR code can store a number of characters [7]. A JAN code is a one-dimensional barcode that can be attached to almost any commodity in Japan. Second, we read the barcodes which store the ID numbers using the i-Appli[4] application available on Japanese cellular phones (NTT DoCoMo). Then we described the relations between humans and objects or objects and objects using this application. Third, we can send the data about relations among humans and objects to a server where we could see the relations on a web browser.

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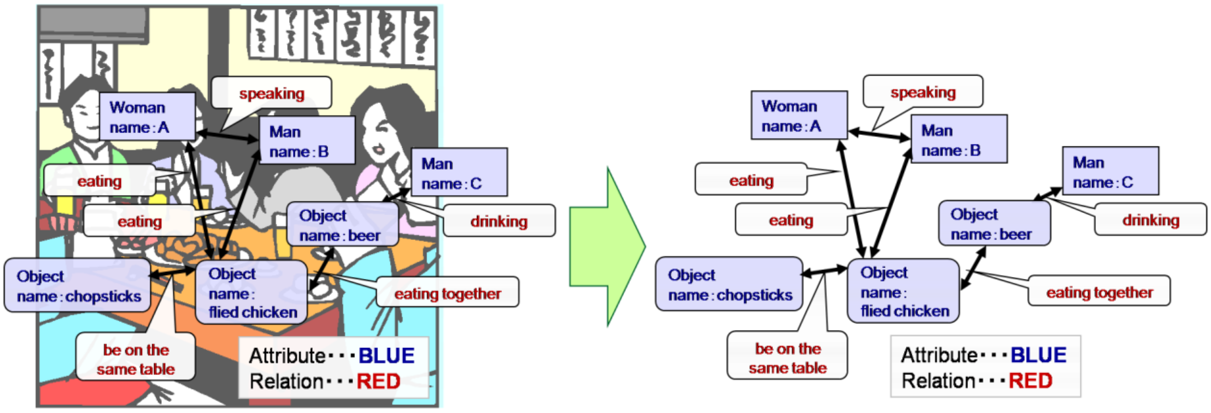

Figure 1.1 Relational network extracted from one situation where people are talking and eating.

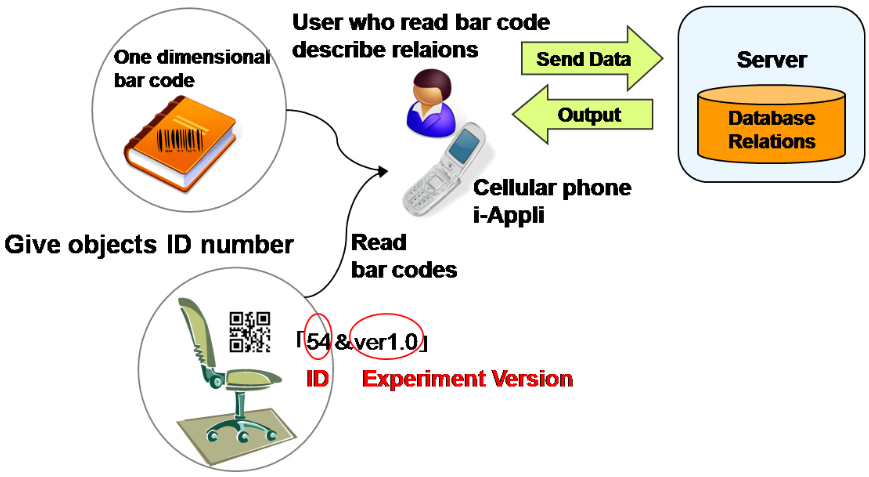

Figure 2.1 Flowchart of entire experimental system

(Giving objects ID numbers by barcodes, reading barcodes using a cellular phone application, describing the relations between humans and objects or objects and objects, and sending and receiving the relational data between the application and the server).

[4] Java application of NTT DoCoMo’s cellular phone.

2.1 METHOD OF GIVING ID NUMBER TO OBJECTS AND HUMANS

Figure 2.2 QR code (left) and JAN code (right).

We gave objects and humans ID numbers. There are two ways of giving ID numbers to objects. The first is to attach a QR code that we printed onto the objects. QR codes can store information on the ID number and the version of the experiment, such as “54&ver1.0” (Figure 2.2 (left)). The second is to read the JAN codes (Figure 2.2 (right)), which can be appended to almost all commodities, such as plastic bottles, books, and so on. The number of JAN codes parallels the ID numbers. We gave ID numbers to humans when they downloaded i-Appli for the first time.

2.2 CLIENT SYSTEM (CELLULAR PHONE APPLICATION)

Figure 2.3 shows the experimental procedure. We can read QR codes or JAN codes by starting i-Appli and the barcode reader. Then, we describe the relations or attributes and send them to the server. In particular, we describe what we do as a relation and describe the name of the objects as an attribute. We can describe relations between objects and objects by reading two barcodes in series when we use two objects concurrently. Figure 2.4 shows screen images of the i-Appli for this experiment. We can send relations or attributes simply and easily using this i-Appli.

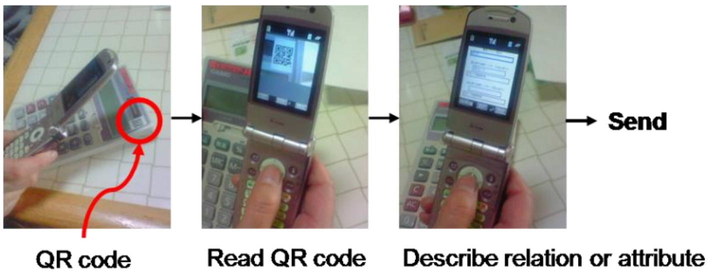

Figure 2.3 One type of experimental situation. A user can read a barcode and describe relation or attribute.

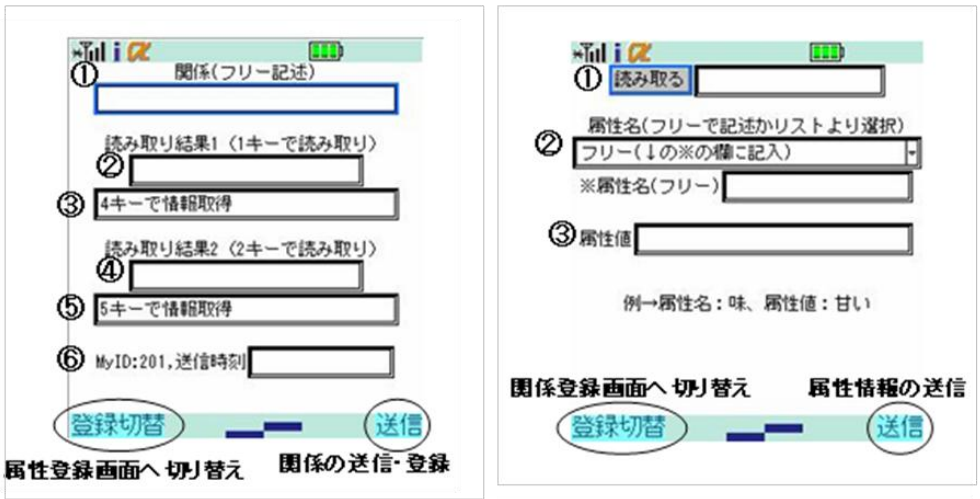

Figure 2.4 Screen image of i-Appli display.

Left side of the Figure 2.4

(1) We can input a description of a relation in this blank space. (e.g. ate, used together)

(2) Display the content of barcode by pushing the “1” key.

(3) We can get specific information about (2) by pushing the “4” key.
(4) Display the content of barcode by pushing the “1” key.
(5) We can get specific information about (1) by pushing the “4” key.
(6) Our ID number and time you last sent information.

Right side of the Figure 2.5
(1) Result of reading QR code.
(2) We can input an attribute’s name here. (e.g. color, height)
(3) We can input an attribute value here. (e.g. red, 3 inches)

2.4 SERVER SYSTEM

Figure 2.4 shows the server system for this experiment. Users can enter data in the database from their cellular phone through CGI. Users can also see the attribute data of the objects on the cellular phone, which are stored on the database. In addition, users can see the registered data on the database using the browser. There are three types of views. First, we can see the database table directly through easy viewing. Second, by choosing one ID number, we can see all the ID numbers and subsequent information that is related to the ID number chosen. We call this page the ID page, and Figure 2.5 shows a screen image of this ID page. Third, when we choose one, two, or three human ID numbers, we can see all the relations they have registered. In Figure 2.4, NETWORK CGI 1 makes the second type possible, and NETWORK CGI 2 makes the third type possible.

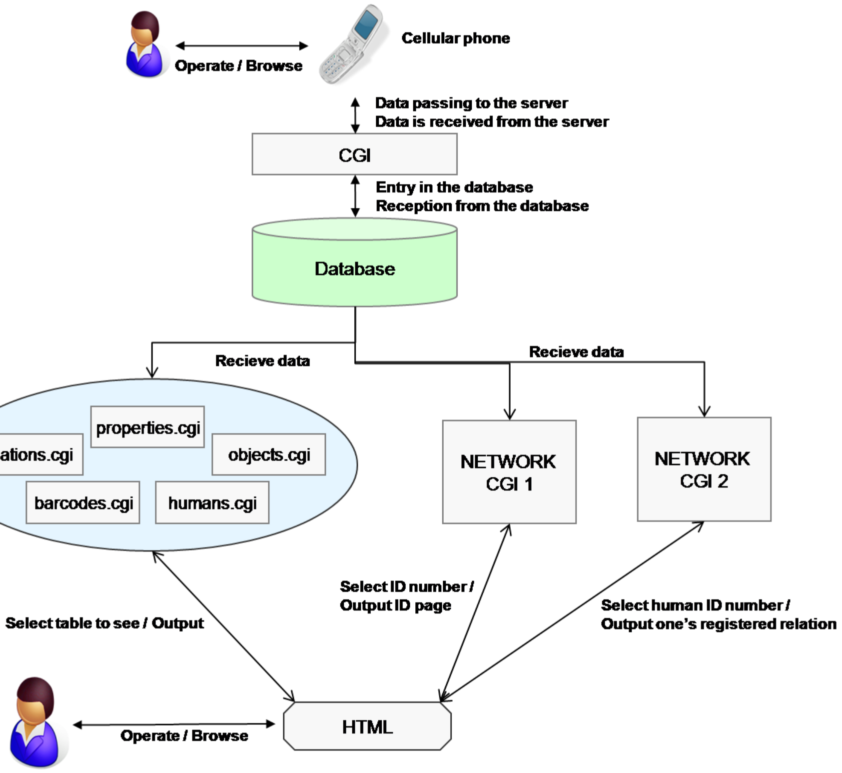

Figure 2.4 Server system.

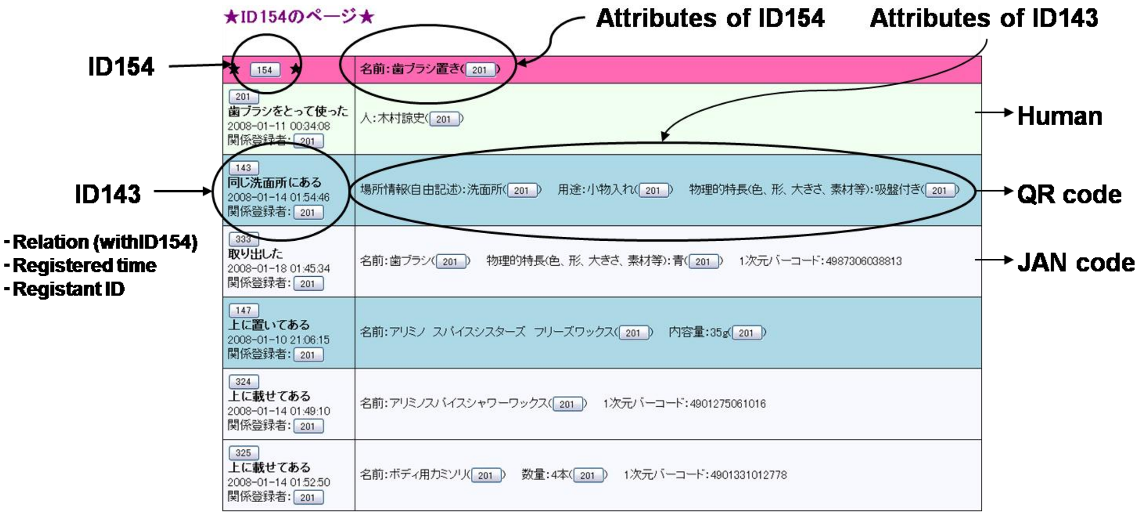

Figure 2.5 Screen image of ID page (ID154).

3 EXPERIMENT

We conducted an experiment to investigate the relations between humans and objects by using our system. Table 3.1 lists the specifics of the experiment. In addition, we twice sent out questionnaires. The first one was used to ask questions before the experiment. In this questionnaire, we asked subjects which objects in their house were important to them. The second one was used to ask questions after the experiment, and this questionnaire asked the same questions as the first.

We analyzed the relations between humans and objects quantitatively based on the social network analysis [8]. We used the Simple Network Analysis Tool[5], which is a tool for analyzing networks. For example, we analyzed the number of nodes, the number of links, the diameter of the graph, the average distance, the density of the graph, the transitivity, the degree centrality, and the central tendency [6, 9, 10]. In addition, we visualized the network by using Pajek[6], which is a network visualization tool. In Section 3.1, we analyze and take into account the nodes that are important in one's life by looking at the relational network that is formed by one person. Then, in Section 3.2, we analyze and take into account the relational network formed by two people. In Section 3.3, we analyze and consider the network formed by three people.

Table 3.1 Outline of experiment

No. of subjects	10
Days	5
No. of objects one subject registered	About 30~50
No. of relations one subject described	About 80~100

[5] http://www.geocities.jp/snatool/index.html
[6] http://vlado.fmf.uni-lj.si/pub/networks/pajek/

High degree nodes
on both two graph

Binary Graph

ID	Name	Degree
ID2002	Person A	14
ID200	Dining Table	6
ID198	PC Table	6
ID196	Cup	5
ID155	Disih	5
ID197	Dining Chair	4
ID183	Living Table	4
ID152	Hot Plate	4
ID186	Sofa	4

High degree nodes
on only binary graph

Multiple Value Graph

ID	Name	Degree
ID2002	Person A	20
ID200	Dining Table	11
ID155	Dish	8
ID196	Cup	7
ID198	PC Table	7
ID197	Dining Chair	6
ID193	TV Remote Controller	6
ID199	Note PC	6
ID180	Liquid Crystal TV	5
ID165	Washing Machine	5
ID2017	Kyogetsu (Shochu)	5
ID2016	Cigarettes	5

High degree nodes
on only multiple value graph

Figure 3.1 Degree centrality on binary and multiple value graphs.

3.1 ONE-PERSON NETWORK

We analyzed person A's network. Figure 3.1 shows the degree centrality of each object person A registered during the experiment. The left side of the figure shows the degree centrality of a *binary graph* and right side of the figure shows the degree centrality of a *multiple value graph*. The binary graph is a non-weighted graph of which the elements of adjacency matrix consists of 0 and 1. On the other hand, the multiple value graph is a weighted graph. If a subject describes and registers relations towards the same combination of objects, the number of registrations is reflected towards the elements of adjacency matrix. For example, if a subject registered a relation named *"I watched TV"* three times, we count it as three degrees. As shown in Figure 3.1, different objects rank higher on each side. Blue-circled objects are high ranking nodes on both the binary and multiple value graphs. These nodes cover the highest part of the ranking. Figure 3.2 shows the network visualization map of the blue-circled nodes. Red-circled objects rank higher only on the binary graph. We consider these objects to have relations with a wide range of other objects. Figure 3.3 shows the network of red-circled nodes. These nodes have many links. Green-circled objects, on the other hand, rank higher only on the multiple value graph. We consider these objects repeatedly used. Figure 3.4 shows the network of green-circled nodes. These nodes have thick links.

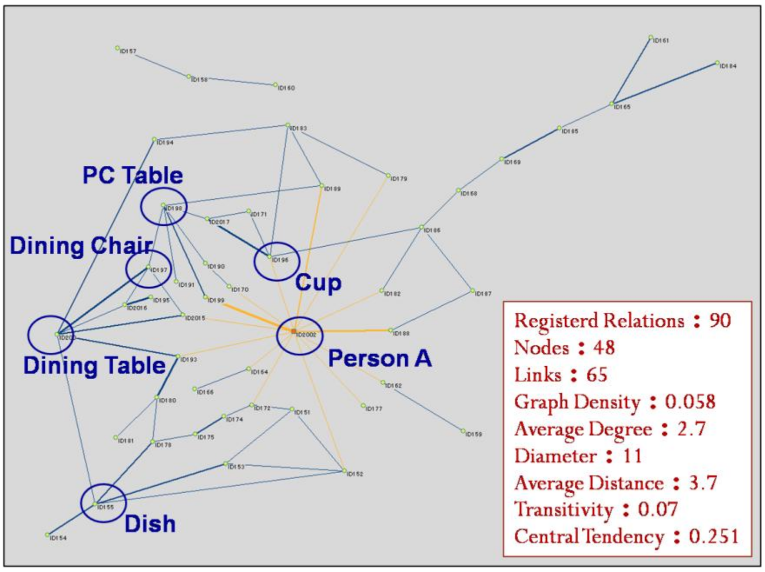

Figure 3.2 High ranking nodes on both binary and multiple value graphs.

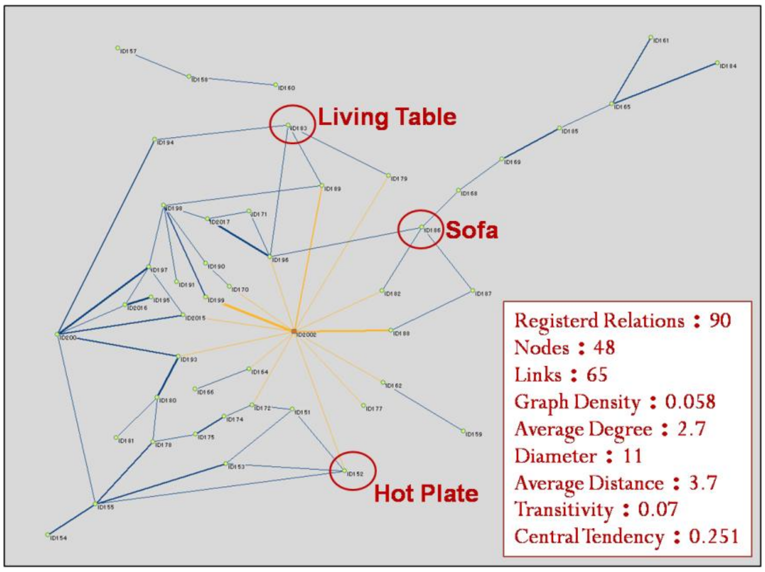

Figure 3.3 High ranking nodes on binary graph.

Then there were the questionnaire results. Before the experiment, Person A answered that their personal computer, dining chair, dining table, television, and washing machine are valuable to them. These objects are high ranking nodes on the binary and multiple value graphs, as shown in Figure 3.1. This means that we can find important objects in our daily lives by looking for nodes whose degree centrality is high. Moreover, we can find other important objects we could not anticipate before the experiment. For example, after the experiment, Person A says in the questionnaire that he recognized the importance of the TV remote control. The TV remote control is a node whose degree centrality is high only on the multiple value graph. We found that Person A gradually found the importance of the TV remote control through repetitive usage.

We assumed that there are several important nodes whose degree centrality is not high. We can find them by very carefully looking at the network visualization map. For example, as shown in Figure 3.5, we can see that the table pot is important for Person A's life because Person A could not water down the spirit *"Kyogetsu"* without table pot. The *Kyogetsu* and the cup are high-degree centrality nodes and these nodes that include table pot formed a triangular structure on the network. Similarly, beer, linked to dining table, dining chair, and Person A, is also important for Person A's life. These items are unexpectedly important. The pot would not be important in itself if Kyogetsu and the cup did not exist. Only when Person A drinks Kyogetsu out of the cup is the pot used. We assume, as a result, there are important objects in our daily lives that are only important when they are used with other things that have relation to them.

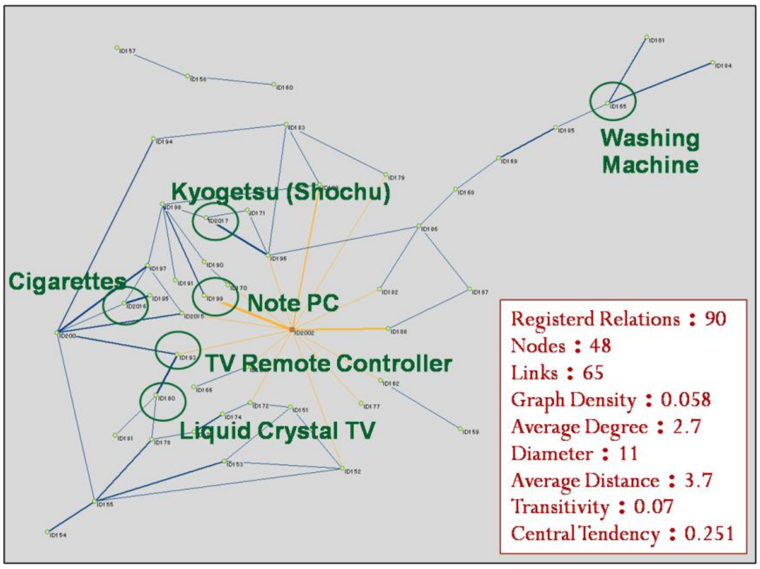

Figure 3.4 High ranking nodes on multiple value graph.

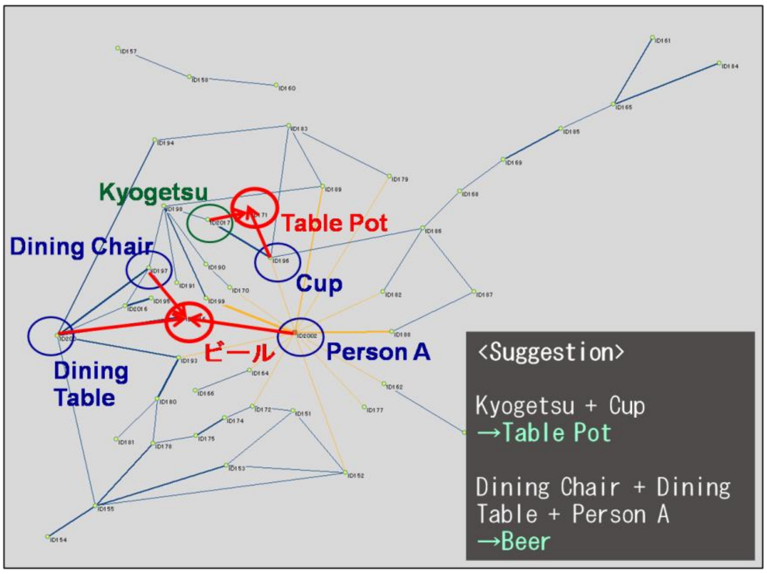

Figure 3.5 Important nodes whose degree centrality is not high.

3.2 TWO-PERSON NETWORK

We analyzed the networks of the Persons B and C concurrently. Persons B and C are a husband and wife. Figure 3.5 shows the change when we combine the graphs of these two people. When we define N as the overlapping nodes and L as the overlapping links, *N* and *L* are as follows.

$N = 40 + 29 - 60 = 9$ (3.1)
$L = 39 + 75 – 111 = 3$ (3.2)

The results of the *N* and *L* values indicate that there are few parallel nodes and links between Persons B and person C.

However, as shown in Figure 3.7, there are shifts in the nodes whose degree centrality is high, when looking at only Person B or C and when looking at both B and C. In the rightmost table in Figure 3.7, the red nodes are the high degree centrality nodes that can be seen only in Person B's network, the blue nodes are the high degree centrality nodes for only Person C's network, and the green nodes are the high degree centrality nodes for both Person B and Cs' networks. It is natural that the green nodes are high degree nodes in the rightmost table, because the degree of these nodes is counted by both people. The most significant thing, however, is the fact that important objects are different when we look from one and two person's viewpoint. We can find important shared objects by looking at the networks of B and C concurrently. Figure 3.8 shows the network visualization map of Persons B and C. We plotted the red, blue, and green nodes on the map. The red nodes often exist near the nodes of B and the blue nodes often exist near the nodes C. On the other hand, green nodes often exist between the node of person B and C. We can easily find some of the shared nodes by looking at the nodes that link to both people on the network visualization map.

ID：2003		ID：2036		ID：2003,2036
Registerd Relations：71		Registerd Relations：102		Registerd Relations：173
Nodes：29		Nodes：40		Nodes：60
Links：39		Links：75		Links：111
Graph Density：0.101	+	Graph Density：0.096	➡	Graph Density：0.063
Average Degree：2.7		Average Degree：3.8		Average Degree：3.7
Diameter：6		Diameter：5		Diameter：8
Average Distance：2.5		Average Distance：2.3		Average Distance：2.9
Transitivity：0.073		Transitivity：0.068		Transitivity：0.066
Central Tendency：0.659		Central Tendency：0.735		Central Tendency：0.478

Figure 3.6 Combination of Persons B and C (Characteristic value of graph).

ID	Name	Degree
ID2003	Person B	40
ID627	Yellow Table	11
ID640	Bed	7
ID637	Glass	6
ID638	Refrigerator	5
ID642	Makeup Bag	5
ID636	Ballpoint Pen	5
ID647	Lip Balm	5
ID626	TV	4
ID645	Black TV	4
ID643	Alarm Clock	4
ID646	Black PC	4
ID628	Brown Box of Tissues	3
ID631	White Chair	3
ID635	Halogen Stove	3
ID630	Red Sofa	3
ID639	Mirror	3
ID644	TV Stand	3
ID633	TV Remote Controller	3
ID648	Bookshelf	3
ID601	Notebook	3

ID	Name	Degree
ID2036	Person C	47
ID627	Yellow Table	15
ID2040	Coca-Cola	10
ID638	Refrigerator	9
ID609	PC Desk	8
ID607	Note PC	6
ID610	Desk Stand	6
ID633	TV Remote Controller	6
ID626	TV	6
ID2043	Ice Coffee	5
ID2044	Milk	5
ID611	Mouse	4
ID2041	Text	4
ID643	Alarm Clock	4
ID2045	Tea	4
ID2046	Ice Cream	4
ID634	Brown Table	4
ID2051	Rice Biscuit	4
ID2053	Cheese	4
ID2054	Low-malt Beer	4

ID	Name	Degree
ID2036	PersonC	47
ID2003	Person B	40
ID627	Yellow Table	26
ID638	Refrigerator	14
ID626	TV	10
ID640	Bed	10
ID2040	Coca-Cola	10
ID633	TV Remote Controller	9
ID643	Alarm Clock	8
ID609	PC Desk	8
ID637	Glass	6
ID634	Brown Table	6
ID607	Note PC	6
ID610	Desk Stand	6
ID630	Red Sofa	5
ID642	Makeup Bag	5
ID636	Ballpoint Pen	5
ID647	Lip Balm	5
ID2043	Ice Coffee	5
ID2044	Milk	5

Figure 3.7 Combination of Persons B and C (Degree centrality of graph).

3.3 MULTI-PERSON NETWORK

We analyzed a network that consists of several people by looking at the visualization map. Figure 3.9 shows a network obtained from the relations made by a family (Persons D, E, and F). Similar to the situation described in Section 3.2, we can find the objects that the three people share. In this graph, there are several nodes that are linked to both the nodes of D and E or the nodes of D and F. However, there are few nodes linked to both the nodes of E and F. This means that Persons E and F have less relation with each other than D and E or D and F in this family. Actually, D is the father, E is the mother, and F is the son. Therefore, in this family, we consider that the son and his mother have very little relation with each other. Thus, we can guess the human relationship by looking at a network of several people.

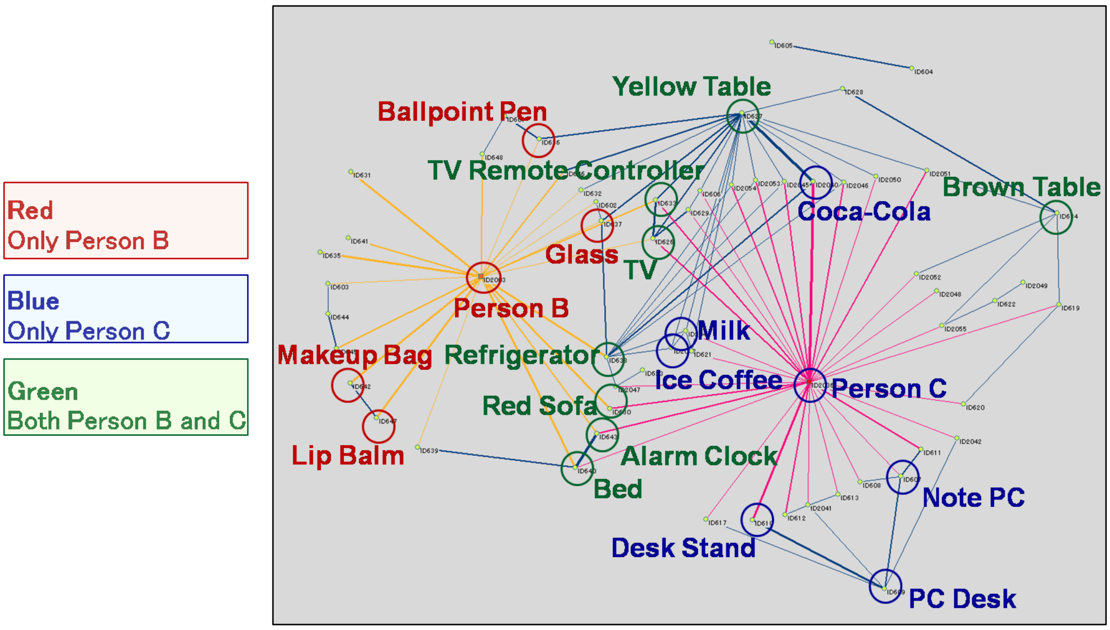

Figure 3.8 Network visualization map of people B and C.

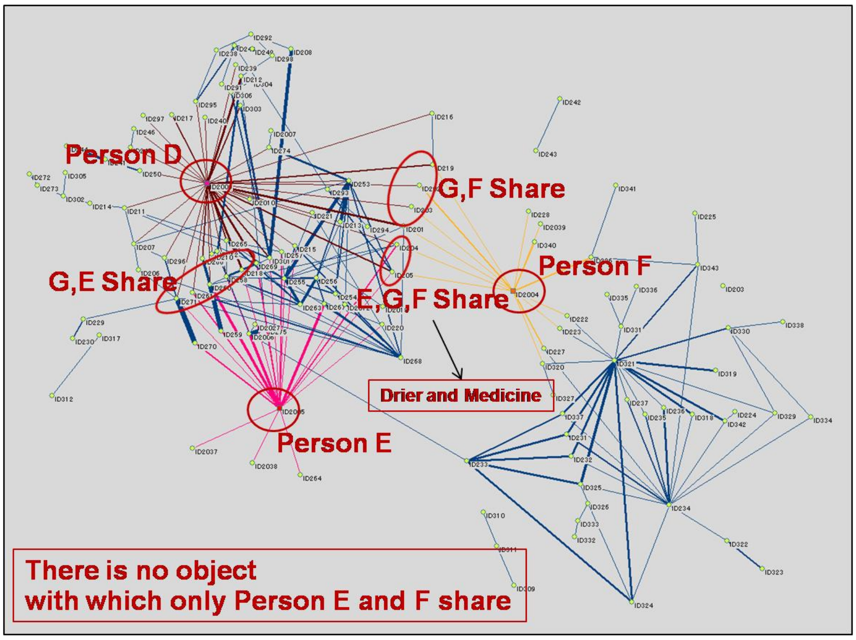

Figure 3.9 Network visualization map of people D, E, and F.

4 DISCUSSION

4.1 MERITS AND DEMERITS OF THE EXPERIMENT

The biggest merit of the experiment is the fact that we can get significant data actually from real homes. It is hard to set up RFID system which is efficient identification tool of objects [12] in the general household quickly. Furthermore, while RFID tags get cheaper, it takes a lot of money if we need to append many tags. In contrast, our experimental system depended on a cellular phone which is very familiar with the public. Therefore, we can get data not from testing site constructed only for the experiment but from general households.

However, there are some demerits and limitations of the experiment. First, it is difficult to collect all the relations from the subject's life. In our daily life, there are infinites numbers of actions and subjects. So we can't read barcode every time they act. Besides, it is impossible for subjects to experiment when they engaged in something. Therefore, there is a loss of precision when we analyzing the relation network. On the other hand, we consider that the experimental data is effective because subjects unconsciously enter relations which is particularly important in their lives despite they can't enter all relations. Second, it is troublesome to read barcodes because it takes time to launch both an application and a barcode reader. Most subjects said that it was troublesome to enter relations one by one manually in the questionnaire.

To solve this problem, for example, we can construct the much easier experimental system by using RFID tags in the future. RFID is much effective because we can enter relations automatically [12] and get every data when subjects are active. Moreover, RFID have advantage in giving ID numbers to objects. The future global use of RFID makes it pivotal to provide globally unique identification numbers such as EPC [13]. Besides, we can deal with not only sensor data but also user-specific data [14] using RFID systems. For these reasons, RFID is expected for extracting relations among humans and objects.

4.3 COLLECTING DATA VS. USER BENEFITS

We had an experiment for investigating relations among humans and objects by using the cellular phone system. As the number of entered relations grows, users receive some benefits. There are four considerable benefits as follows. The more relations users enter, the more accurate the outputs become.

(1) Users can recognize important objects in their daily lives by looking at the high degree centrality nodes. In this case, the important objects means the objects used repeatedly.

(2) Users can recognize something important in their daily lives when it is used with other closely-related things.

(3) Users can recognize the important shared objects by seeing the network of two persons concurrently.

(4) Users can guess human relationship by looking at a network visualization map of several people.

4.4 FUTURE WORK

Benefits we described in Section 4.3 are not everything. For example, there are two further researches we want to try to find the methods of understanding our lifestyles. First, we extrapolate our lifestyles by looking at attribute's names of the objects. For example, a banana, an orange and an apple have the same attribute's name "fruit". Therefore, if a subject eats them every day, we can suggest that the subject likes to eat fruits. We have to order attribute's names to make such a prediction. In this case, the attribute's names and the attribute value are base on the Ontology researches [15]. It is also possible to combine the attribute's names and web information through Semantic Web [16] technology. Second, we extrapolate our lifestyles by looking at time-line of entering the relations. It was difficult for us to looking at time-line because experimental data is not available when a subject is too busy to experiment. However, RFID system makes it possible. We can extrapolate life pattern [17].

5 CONCLUSION

We created and used a cellular phone application and succeeded in extracting the actual relations among humans and objects. Then we found some ways of understanding our lifestyles by using network analysis. This experiment is positioned as preliminary experiment and showed the fact that it is worthwhile to pay attention to the objects we uses in our lives. It is important to see how objects link to the other objects or humans. We can extrapolate much accurately when we construct automated system and get more data in the future research.

6 ACKNOWLEDGEMENT

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