Relational-Metric Based New-Generation Network Application

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The background, the proposed concept and design, and the result of the research and development work on the "relational-metric based new generation network" will be presented. The relational metric technique enables numerically modeling social distance between people, things and places from various types of life-log and sensor data. The integration of this and network virtualization enables us to control 'social distance of information for people' as people desire, which has been validated from experiment results.

1 Introduction

In society, there exists an "appropriate sense of distance" between people, places and things (tangible and intangible)[1]. For example, human beings seem to have a feeling of closeness towards their close friends, their daily commute route, and favorite foods and music, and they want to keep away from unknown people, places, foods and music. This sense of distance is called social distance. Social distance is not just between humans, it can exist between two places, or between people and places, and between various other objects. We can also apply social distance to relations between information and humans[2]. Accessibility of information should conform to the social distance. In other words, socially close (related) information should be quickly accessible. Until now, information communication network technology was developed for the sake of "communicating anytime, anywhere at a high speed", so the accessibility of information does not always conform to the social distance. The state when accessibility of information matches the social distance is defined as "appropriate sense of distance", and the target of our entire agenda was to achieve this.

"Appropriate sense of distance" is also important in information communication work such as content delivery and life log utilization. Content delivery work is the distribution of content generated by business entities or individuals. Currently, it is difficult for content providers to actually deliver to their targets what they want to provide, as there is an excessively huge volume of other content. On the contrary, it has become difficult for content acquirers to select what they really need from the vast array of content. Life log utilization work is the business of marketing using individual life logs such as logs on movements, purchases and usage histories. When a life log is utilized, from the viewpoint of privacy, it is necessary for the life log providers to control them so their own life logs are used within the desired scope. Conversely, for the life log acquirer, it is inefficient to collect all life logs from the point of the cost of analysis or management.

Based on the above background, the following points were set as the goals in this R&D.

1. Mathematically quantify social distance
2. Define the logical network with reference to social distance
3. Control the physical network based on social distance

In the course of the research and development, we achieved goal 1. with the help of the relational metric technology, and goals 2. and 3. with relational metric and network virtualization technology. Then, we embodied them into a practically usable application, which was named "New-Generation Network Application Based on Relationships."

This paper's contents are organized as follows. The elemental technology is described in Section **2**. The New Generation Network Application Based on Relationships is explained in Section **3**. The summary is written at the end.

2 Elemental technology

2.1 Relational metric

"Relational metric technology" we conceived is technology through which the social distance between people, objects and places is quantified from people's life logs, such

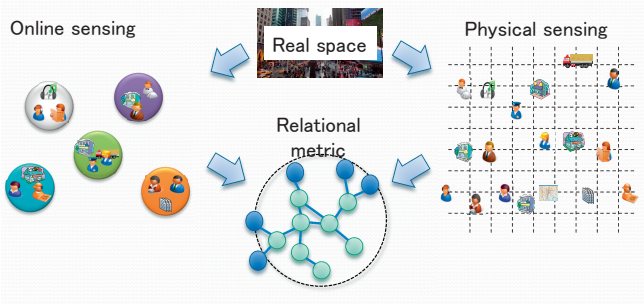

Fig. 1 Relational metric

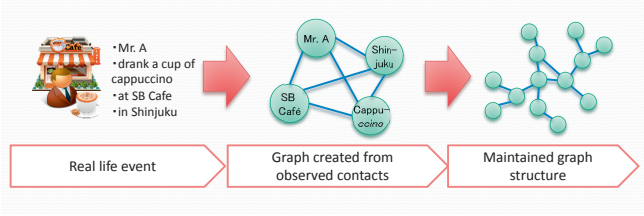

Fig. 2 Quantification of social distance by relational metric technology

as movement logs, facilities usage logs, product purchase logs, and online services usage logs[3]. As shown in Fig. 1, quantification is done from data collected through online sensing such as analysis of web crawling or social networking services, and through physical sensing by mobile devices or other means. Relational metric is graphically represented with objects as nodes and social distance between the nodes as the weights of the links. The objects are people, places and things. The advantage of using graphs is that they help quantify social distance between all the objects.

As shown in Fig. 2, relational metric technology is used to quantify the social distance between objects by the following flow.

1. Considering 1 life log as 1 event, the objects included in each event are considered as different nodes. Nodes in the same event are regarded to have contact, for example between nodes i and j.
2. In time t, length l_{ij} (t) of the link between nodes ij is calculated based on the interval of contact until t. That is, the greater the intervals, the longer the links, while the denser the intervals, the shorter the links.
3. Nodes that are not directly connected are also connected via a common node and integrated in the graph.
4. The relation between nodes is maintained in the structure of the graph, so that the distance between 2 nodes which are indirectly connected through another node can also be quantified. For example, when nodes i and k are connected via j, the distance can be found by $l_{ik}(t) = l_{ij}(t) + l_{jk}(t)$.

In the above method, if there is a life log which can be considered an event, then it can be applied regardless of its format, and the social distance between 2 objects can be quantified based on the graph structure.

2.2 Network virtualization technology

If we consider the current network as the physical network infrastructure for achieving an "appropriate sense of distance" between people and information, it will give rise to the following intractable problems. As described earlier, in a content delivery business or life log utilization-centric industrial background, the content or life log data on the Internet is managed on an application. More specifically, one cannot know where the data is physically (or geographically) stored on the network, nor who owns the right to that data. For example, when a content or life log data is downloaded or uploaded by using a web server service, a copy of the data could remain on a web proxy on the way. From the view point of "appropriate sense of distance," unintentional physical or geographical movement or propagation of data is not desirable. From that point of view, intranet which is generally used by corporations may be more suitable than the Internet, as the physical network infrastructure for achieving "appropriate sense of distance." With network virtualization technology, it is possible to generate highly independent network spaces such as intranets, based on the concept of slices[4]. A major difference from Virtual Private Network (VPN) technology[5], which enables handling of networks of physically and geographically separated locations as one and the same network, is that slices can be dynamically generated and are flexibly programmable. In this R&D, we considered a network comprised of network devices configured with the network virtualization technology as the physical network infrastructure during the course of the research and development.

2.3 Network configuration

We proposed a network configuration for achieving "appropriate sense of distance," which would be using both the relational metric technology and network virtualization technology. Figure 3 shows the network configuration. Appropriate sense of distance can be achieved by the proposed network configuration, by the flow shown below.

1. An actual user defines the community based on the social distance. "User" implies the user of the "New-Generation Network Application Based on Relationships" which was developed in this R&D,

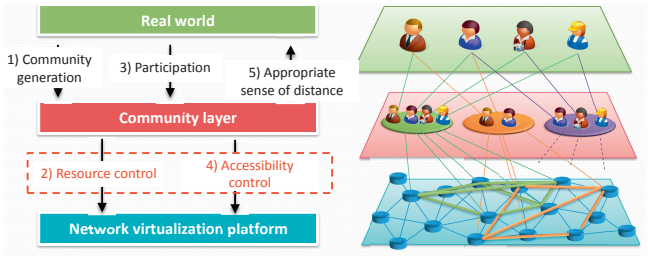

Fig. 3 Network configuration for achieving "appropriate sense of distance"

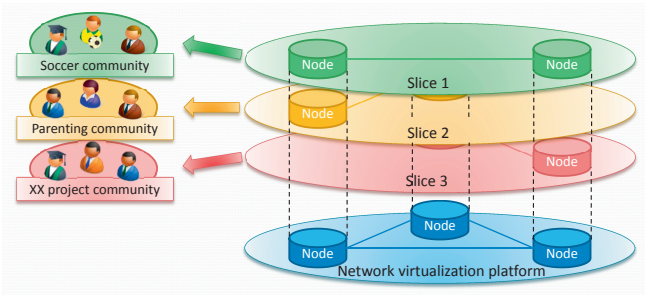

Fig. 4 Slices provided to the community

and the user could be an individual or an entity.

2. As shown in Fig. 4, the resources of the network virtualization platform for the community are controlled, and slices are provided.
3. A user participating in the community shall provide or acquire content or life logs.
4. In the slices, accessibility of the information is controlled based on relational metric. Accessibility is the volume of information which is to be accessed and how quickly it is accessed.
5. The appropriate sense of distance is achieved in the actual world.

We conducted the R&D by following the above network configuration.

2.4 Data community space

The "community" used in this research and development is defined here. Although it is slightly different from the definition of a general community, a "community" is defined as the social scope in which a content must be transmitted when people are providing or acquiring content, and the social scope within which the life logs must be utilized when people are providing or acquiring life logs. To be specific, a family, local government or company, etc. are considered a community, and a project or hobby club can also be treated as a community.

Moreover, we have proposed a new concept of "data community space." Data community space is the ecosystem for generating and accumulating relational metrics by using the life logs created within the community, then calculating the social distance, and finally achieving "appropriate sense of distance." Only content with the closest social distance from each community is distributed in the data community space. Further, the slices provided by the network virtualization platform are used as the network platform of the data community space. Also, individuals can make multiple associations to multiple data community spaces.

Data community space is operated as shown below.

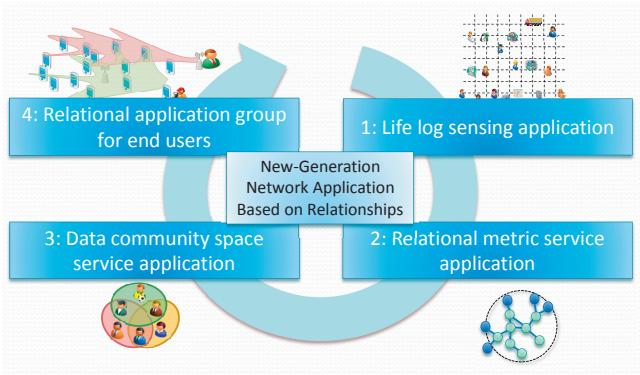

Fig. 5 The New-Generation Network application based on relationship

1. Data community is registered according to the community request. Logical registration is done without subjecting restrictions on the physical network resources.
2. Relational metric is formed from the life logs of the group of users belonging to the community to evaluate the social distance of the community.
3. The physical network resources of the slices allocated to the data community space are restricted based on the evaluation result of the social distance of the community.
4. When the community is not using the data community space, the slices disappear and the physical network resources are released.

In 2, the social distance of the community is evaluated, and the evaluation result is used in 3. To put it simply, the closer the social distance of the community, the more accessible its information (greater volume and speed of access), therefore many resources are allocated by the slices.

3 New-Generation Network application based on relationship

We developed the "New-Generation Network Application Based on Relationship" as shown in Fig. 5. The

following four applications work in tandem to provide their services.

1. Life log sensing application: Collects the life logs on which the relational metric will be based.
2. Relational metric service application: Quantifies the relational metric.
3. Data Community Space service application: Controls the physical network based on the relational metric.
4. Group of relational applications for end users: Provides the service for achieving the appropriate distance.

These applications are specifically described below.

3.1 Life log sensing application

This application is used to collect the life logs on which the relational metric will be based. The target life logs may be the movement history, facilities usage history, purchase history, online service usage history, etc. This application was used to do the test for verifying that the social distance of a community can be quantified by using life logs. The smart phone application shown in Fig. 6 was developed as the user interface of this application[5]. Test participants were recruited, and about 100 life logs were collected from approximately 50 participants. Life logs were purchase logs, comprised of the date and time, store, product and price. The test participants collected the information in a manual entry format. The relational metric formed from the collected life logs was graphically represented as shown in Fig. 7, in which the number of links of the nodes were plotted on the y axis and the orders on the x axis in a log-log graph, and the graph showed that the tested network does have the characteristics of power-law[3], which a social network should possess.

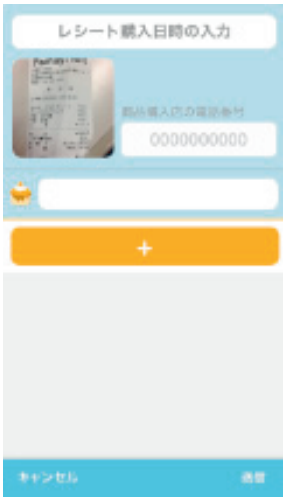

Fig. 6 User interface of the life log sensing application

3.2 Relational metric service application

This application is used to quantify relational metric. A relational metric was formed using the following dataset as the life logs, to verify this application.

1. Email data of Enron Corporation (from January 1998 to December 2002, approximately 240,000 logs)
2. Wireless LAN AP connection data collected by University of California, San Diego (USCD) (from September 2002 to August 2003, approximately

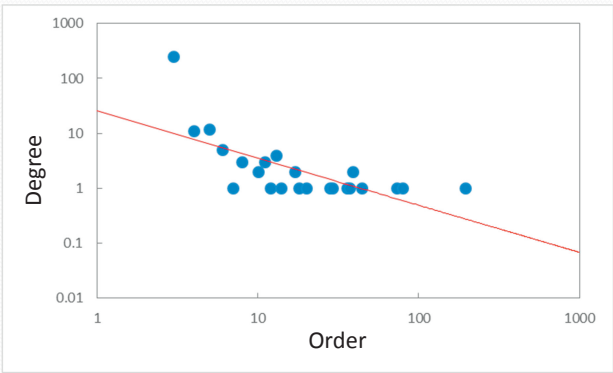

Fig. 7 Characteristics of graph plotted from life logs

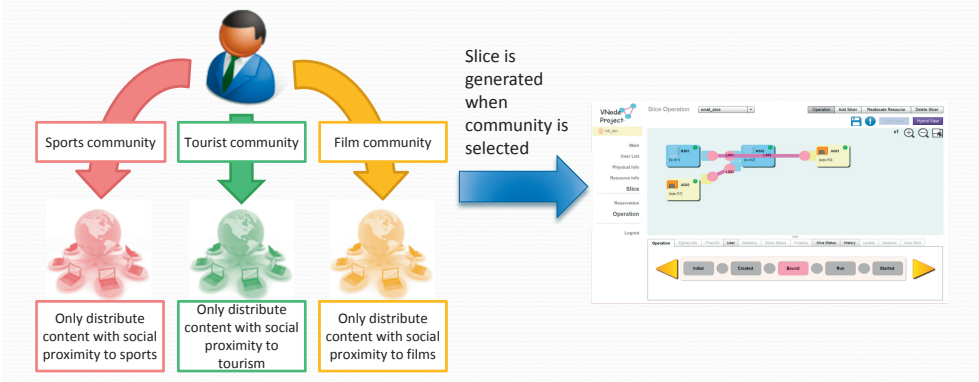

Fig. 8 Demonstration of data community space service application

820,000 logs)

3. Data on technical reports of the Institute of Electronics, Information and Communication Engineers (IEICE) (from April 2008 to March 2011, approximately 7,400 logs)

This showed that the social characteristics of each community can be exhibited by a relational metric[3].

3.3 Data community space service application

This application controls the physical network based on the relational metric. Using this application, network users can select and connect to the network linked to their communities, and get information with a sense of distance appropriate for each community. Furthermore, services such as content delivery, messaging and information search are provided on the network linked to each community. In particular, the customer to whom the content is delivered, people with whom messages can be exchanged, and results displayed by the search, differ depending on the connected network. In other words, the user experience of a dedicated Internet for each community is provided.

When a user defines the network linked to his/her community, the corresponding slice is logically generated on the network virtualization platform. When this slice is actually used as a data community space, the zone and physical resources such as computational resources are secured for that slice.

We conducted a social test in conjunction with companies who were potential users of the service application with the data community spaced described above. This result of the test was as follows. The result of the questionnaire implemented for evaluating the usefulness of the "Service application by a data community space" showed that of the 29 persons who replied to the questionnaire in 24 participating companies, 70% replied "It is useful," showing the usefulness of this application.

3.4 Group of relational applications for end users

Relational applications for end users are those applications providing the appropriate social distance from information using relational metric, as a service. We developed two applications as examples: i) Content delivery application, and ii) In-network messaging application.

The content delivery application shown in Fig. 9 achieves the appropriate sense of distance between users and information in a community, by controlling the accessibility of information in the data community space. Accessibility of information is controlled based on the social distance quantified by relational metric. Accessibility of information is the speed of access and volume of information to be accessed. The zone and computation resources of the physical network are controlled according to the relational metric, and information with a large relational metric is accessed with higher capacity at low latency. Figure 9 shows the user interface for visualizing the access scope of information that changes dynamically. This application achieves an appropriate sense of distance in that it delivers content to the user requiring it, while ensuring that content which is not needed by the user is not accessed.

We developed the in-network messaging application shown in Fig. 10. Messaging services such as email, SMS, social networking service (SNS) and microblog are some of the important means of communication for people today. However, it is difficult to automatically select the optimum destinations according to the message to be sent. For example, with a mailing list (ML), the message is delivered to all the addressees registered beforehand, so it is difficult to flexibly set the addressees depending on the message content. And so, we developed a messaging system for flexibly controlling the addressees according to the message content. This system has the following functions in particular. 1) It calculates the relational metric based on the sender and message contents (= context). 2) Using the relational metric as the index, it automatically infers the addressees of the message based on the social distance. Figure 10 shows the user interface of the implemented system, and it was confirmed that by using the sender and message contents as the context, the message addressees can be inferred automatically. This application can be used to achieve an appropriate sense of distance by delivering the messages to desired targets while ensuring that unneeded messages are not accessed.

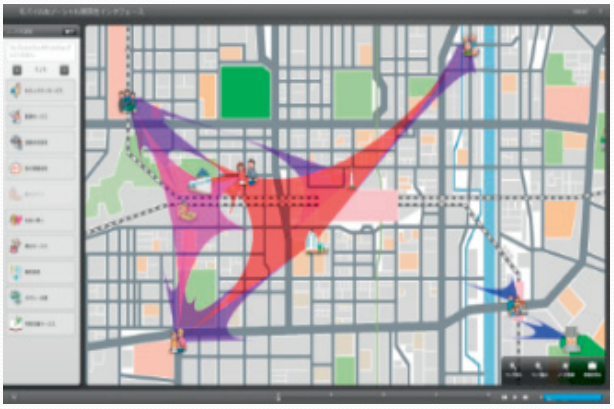

Fig. 9 Relational application 1: Content delivery

Fig. 10 Relational application 2: Messaging

4 Conclusion

This paper proposed a concept of a new generation network application based on relationships, and described its background, architecture, developed applications, and results obtained from the tests. Relational metric technology quantifies the social distance between people, places and things, etc., from various life logs and sensor data; network virtualization technology virtually makes multiple networks exist on physical network infrastructure; using these two technologies, we successfully created data community spaces for achieving an appropriate sense of distance between people and information. The usefulness of the New Generation Network Application Based on Relationships was shown through implementation tests, by developing a group of four relationship applications: life log sensing application, relational metric service application, data community space service application, and relational application for end users, as applications which can be actually used by users.

Acknowledgment

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