Relationality Design toward Enriched Communications

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Abstract. We have been conducting research on how to design relationality in complex systems composed of intelligent tangible or intangible, artificial artifacts, by using evolutionary computation and network science as methodologies. This paper describes the research concept, methodologies, and issues of relationality design. As one of research on relationality, we investigate here significance of linkage between a real world and a virtual world in a learning system.

1 Introduction

In research on "Designing Relationaliy [1]", we intend to investigate the significance and meaning of creating relationality through grasping, expressing and operating relationality as networks in the field of system science. Especially we focus on complex systems with emergent mechanisms. In other words, we are aiming at understanding the significance and functions of such complex systems from a viewpoint of relationality.

1.1 Viewing System as Dynamics

Systems here denote collective systems that compose of elements and their interactions, and that have some mechanisms to autonomously maintain and regulate themselves. Assuming a football team as a system, players should be elements and teamwork or collaboration between players should be relationality. No matter how skillful and/or talented the player is, he cannot make games without a collaborated teamwork with other players. There should be no meaning if a team could not work as a system, and the performance of the team depends on collaborations between players. The opponent team is a system as well, and those systems should interact with each other. Collaborations and teamwork of both teams form interactions between those systems, and in turn such interactions influence collaborations between players. Collaboration between players, therefore, should be closely related with interactions between systems.

System behaviors and its property should be dynamically generated not by simple summation of individual elements but by relationality between elements. In addition, the change of relationality over the time could be grasped as an evolutionary process of the system. It is very important to view the dynamics of systems from a viewpoint of relationality.

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1.2 Communications as "Relationality with Others"

Communications typically between people are activities related to information. There should be two kinds of information related to communications; one as an object of processing and/or operating such as transfer, accumulation, conversion, processing, edition, expression, and so forth. Another is as media working for adding/creating values, giving influences, and controlling some flow and/or mechanisms. On the basis of human beings' information-related activities, there should be a human fundamental desire to seek for relationality with others. Postulating communications as "relationality with others", we intend to create some mechanism through which people can find diverse relationality.

This paper describes the research concept on relationality, and introduces the way of thinking and methodologies for relationality design, research directions and possibilities of relationality design.

2 Research on Relationality Design

The concept of *relationality* here denotes *interactions* through which two entities mutually influence each other, *linkage* over time and space, and *context* as a result of accumulated *interactions* and *linkage*. Interactions and linkage form context with the passing of time, and in turn the context and linkage affect the upcoming interactions. Thus interactions, linkage and context are mutually related. Relationality is not limited to physical and spatial one, or rather basically invisible and information-driven, and sometimes ecological and environmental. Social and economical systems, culture, region, and senses of value, therefore, are included in the relationality.

We human beings should be entities that wish for relationality or relationships with others and hope to find meaning in these relationships. Human beings, in other words, might live in relationality and be alive with relationality.

2.1 "Dependence and Governance" in Relationality

Relationality should work to form some structure of "dependence and governance", as shown in Figure 1.

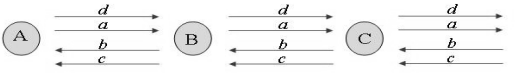

Fig. 1. Dependence and governance in relationality

Nodes, A, B, and C in Figure 1 are elements of a system, and directed links represent relationality between such elements. We may think that nodes represent human beings typically, but also objects and/or entities with which human beings have some relationality, such as social rules, economical systems, culture, religion, thoughts, senses of value, and so forth.

For example, assuming that A represents a baby, B does its mother, and C does its father, the baby depends on the mother, and the mother depends on the father, as shown as *a* in Figure 1. Or assuming that A represents a man, B does his company, and C does some social system, the man depends on the company, and the company depends on the social system. Or cars depend on road traffic signals, road traffic signals depend on the traffic signal system or some traffic regulations.

As you can see in the figure, dependence should be accompanied by the governance as the inverse, as shown as *b* in Figure 1. That is, the mother governs the baby, and the father governs the mother. The mother, however, should be responsible for the baby, and the father should be responsible for the mother, as shown as *c* in Figure 1. Moreover, the mother might often have something to live for from the baby's dependence to the mother, and the father might be the same, as shown as *d* in Figure 1.

Thus, such duplicated relationality eventually foster some sort of trust between entities, and finally human beings sometimes become unconscious of such relationality.

We human beings behave and communicate with others, sometimes based on the past memories and sometimes on anticipation for the future, as shown in Figure 2. For example, the young works hard in school for their future. Religious people pray for their ancestors, and sometimes devote their lives to the pursuit of their faith, believing in the life after death. That is, current humans' information processing is influenced by the past and the future. Thus, it is crucial to consider *linkage* over time and space as well as direct interactions especially in such systems where humans as entities or elements are involved. In that sense, *context* as a result of accumulated interactions and linkage is also very important.

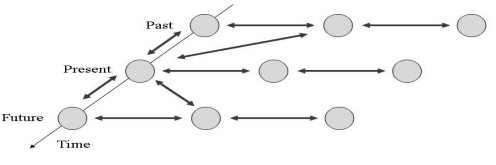

Fig. 2. Relationality over time

2.2 Relationality Design

Relationality design shall be aware of the invisible relationality behind the phenomena and affairs, to find a new value and/or implications of such relationality, and to utilize it, for example, in order to enrich the communications and/or human societies.

From a viewpoint of informatics, relationality inherits two aspects of information as media, as follows:

- Aspect to promote efficiency of information processing and operations by unifying the meaning of information and senses of value of people,
- Aspect to extend and allow the freedom of interpretations of information by esteeming diversity and plurality of the meaning of information.

The second aspect of information as media should be essential in communications. The meaning and value of information and/or behavior in communications depends on the receiver's interpretation. That is, information should be given to its meaning in a dynamical process where a communicating entity interprets and operates it. In other words, human beings coordinate their own behaviors seeking for specific information that identifies the meaning and value of their behaviors and the information they generated. In the sense that the meaning of information is originated from context, situations and/or environment in communications, information has an aspect of pragmatics.

Thus, relationality that should be invisible in nature has structural properties which enable to be visualized as a network, semantic ones to be handled semantically, and pragmatic ones mentioned above. We need, therefore, a methodology to understand such semantic and pragmatic features of relationality as dynamic behaviors of a system in terms of structural features of relationality — relationality networks.

3 Methodologies for Relationality Design

The idea to envisage systems as relationality networks could be applied to complex systems. The topics of research include analysis of relationality between entities and the resulting emergent properties of complex systems and societies at various levels of hierarchy, from the lowest, molecular level (interactions between molecules in the cells)[2] through the DNA (genetic regulatory networks)[3][4], cells (interactions between cells during the growth, differentiation and specializations of tissues and organs in multi-cellular organisms) to the highest level — artificial (interactions and collaboration between agents in multi-agent systems) and human societies (human communications and interactions).

We intend to grasp the information processing mechanisms of such complex systems as a process in which the relationality networks emerge, grow, develop, split and/or collapse, to understand the functions of relationality through systems' performance, and eventually to clarify the significance and meaning of relationality.

Methodologies we have employed for relationality design are evolutionary computation[5]-[7], especially genetic programming, to imitate the mechanism of biological evolution on computers, and network science to visualize and analyze relationality as networks. In genetic programming, the candidate solutions (represented as genetic programs) to the design problem undergo alterations through genetic operations (such as selection and reproduction) and their survival depends on the fitness (i.e. quality of achieved quality of the solution to the problem) tested in the environment, which allows the population of solutions to evolve automatically in a way much similar to the evolution of species in the nature.

As a holistic algorithmic paradigm, evolutionary algorithms are consonant with the holistic approach to the design and analysis of complex systems and societies, based on the belief that any complex system or society is more than the sum of its individual entities, more than the sum of the parts that compose it. And due to their heuristic nature, evolutionary algorithms offer the opportunity to explore various problems in the considered problem domains where the lack of exact analytical solutions or the

extreme computational expensiveness of such solutions hinders the efficiency of traditionally applied analytical approaches.

In network science, a system is modeled as a network in which elements of the system are represented by nodes and interactions between elements - by edges. The idea to envisage a system as a network can be applied to complex systems at various levels of hierarchy, from molecules, genes and cells, to human organization and society, and economical and social systems.

As a matter of fact, recent studies on network analysis of complex systems have revealed the common characteristics for them. For example, properties represented by Small World networks and/or Scale Free networks have given us a new view to grasp and understand such complex systems as network dynamics. In other words, those systems are supposed to share some common mechanisms to gather, edit and represent information, and to achieve some dynamical functions.

In research on "relationaliy design", we are thinking of combining and integrating these methodologies and are conducting hypothesis-finding-based simulations in order to investigate a new value and significance of relationality and to utilize relationality [8][9].

4 Linkage between Real World and Virtual World

As one of the research topics on relationality, research on linkage between a user world and a virtual world in a learning system is introduced here.

Figure 3 shows schematic configuration of this research. A PC provides a user with a human-PC interactive learning game, i.e., a concentration card game for children to study the multiplication table by interacting with the PC. While the user and learning game compose the real world, a virtual world which consists of a few kinds of insect is also displayed on the same PC screen.

In this system, we introduce some linkage between the real world and virtual world. The purpose of this research is to investigate the meaning and significance of

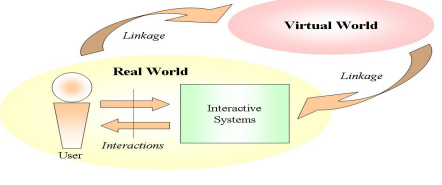

Fig. 3. Schematic Configuration of this Research

the linkage of the virtual world to the real world. The user's behavior, mental and/or physiological state, and performance in the learning game in the real world affect the virtual world, and cause some change in the virtual world. The change in the virtual world, in turn, would make some effect on the user's behavior, mental and/or physiological state and the learning game performance. That is, we are interested in how the existence of a virtual world with some linkage to the real world influences

users, what and how we should design the linkage to work it out, and how we could utilize such influence and how we could apply such mechanism to human-human and human-computer interactions.

4.1 Experimental System

We implemented a concentration card game on the multiplication table as human-PC interactive learning game in PC. The left side of PC screen shown in Figure 4 represents the card game environment. A user, or PC by turns, selects two cards, one for multiplication question, and another for answer. If the two cards match each other in multiplication, the user or PC gets a point.

The right side of PC screen in Figure 4 represents the virtual world with a few insects. These insects move around the world and the number of insects should be increased or decreased according to the user's performance in the learning game. In other words, the user's performance in the real world is evaluated, and the evaluation should be presented explicitly as a change of the virtual world, i.e. the increased or decreased number of insects.

A subject is directed to play the learning game, and is not aware of the linkage to the virtual world. Whether a subject would notice the linkage or not, and how its consciousness would influence his/her performance are interesting questions. Whether the subject gets conscious about the linkage or not, his or her physiological response might be caused unconsciously. In this experiment, we employed heartbeat measurement to investigate mental and physiological effect of the linkage.

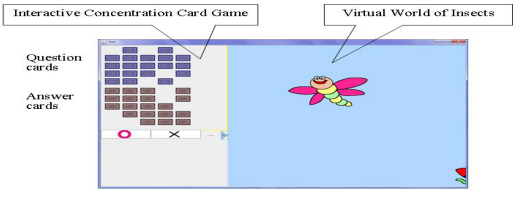

Fig. 4. A Snapshot of the PC screen

4.2 Results and Discussions

Figures 5 and 6 show the experimental data in two measurements of the heartbeat. As you can see from these figures, there is no significant change in the number of heartbeats. But we could find some change of RR interval which is measured interval of adjacent R waves in electrocardiogram, as indicated by arrows in Figures 5 and 6.

There should be always some fluctuation in heartbeat even if a human is in a rest. It is difficult in general to say that the heartbeat of the subject if actually affected by the virtual world[10]. Compared with the case where there is no change in the virtual world, however, we could find significant effect of change of the virtual world on RR interval. As the result, we conclude that the change of the virtual world causes some effect on human's state mentally and physiologically.

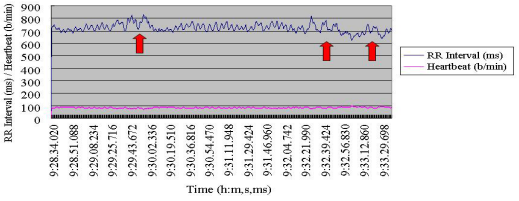

Fig. 5. Experimental Data (1)

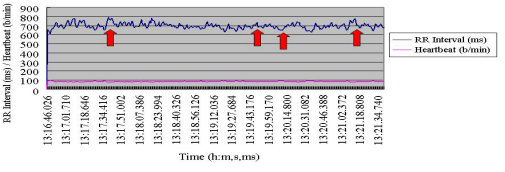

Fig. 6. Experimental Data (2)

5 Research Direction and Possibilities of Relationality Design

Relationality mediated by information, tangible and intangible, artificial artifacts influences human behaviors, thoughts and consciousness. Sooner or later intangible artifacts are formalized as social systems, tangible artifacts are embodied as objects, and then such social systems and objects work for generating new information. Such social systems, objects and new information, in turn, mediate new relationality to influence human behaviors, thoughts and consciousness. We believe that it should be essential to repeat such circulating generation and reciprocal interactions of human consciousness and senses of value with relationality.

Different from direct interactions which we experience their effects, however in reality, we sometimes become unaware such intangible relationality as social systems and linkage, in spite of that the effects of such relationality are preserved.

The ultimate goal of relationality design is to create some mechanisms that enable to reform people's consciousness, and it should be very important to be aware of such possibilities of relationality design. In other words, we are aiming to create new senses of value through relationality design. Or we are working on proposing new concepts as possibilities or choices which human beings and human societies could select in the future. For that purpose, it should be useful for us not to take the way as extension of the present time but to take the way to think from an extreme, and/or to look back the present from the future.

Based on such motivation mentioned above, some ideas are described below toward to possible research directions of relationality design.

5.1 From "Give and Take" to "Gift and Free-Ride/Use"

In the modern societies driven mainly by market economy, equivalent exchange, e.g., **give & take** policy is one of the most powerful senses of value. It is also obvious that **give & take** is one of relationality.

People ask a sort of return in exchange for giving information. This policy seems to be the basis for almost all social and economical activities, and most people think it natural. The enclosure of information has been approved and promoted by the protection law of property rights and individuals' information typically as privacy. Thus, the **give & take** policy as a sense of value has been reinforced by such social situations. Short term reckoning on borrowing and lending has been spread as a common sense, and people make it sure by contract. Social systems supporting to make contracts and to impose penalty to the break of contract have been established so far. In a sense, however, it might be true that social costs people have to pay have been increased.

Let's assume **Gift & Free-Ride/Use** instead of **Give & Take**. Let's take a position to disclose personal information as much as possible instead of enclosing information. Let's imagine the following situations: While no one asks a sort of return and/or right in exchange for giving information, people can utilize, change and edit it free and without notice.

There should be no merit in a short term to people who disclose information. However, assuming that the policy of **Gift & Free-Ride/Use** takes root in society, people might be able to enjoy the benefits generated by the circulation of **Gift & Free-Ride/Use**. Also not a little decrease of social costs might be expected.

An example of relationality design based on the **Gift & Free-Ride/Use** policy is discussed below.

5.2 Possibility of Effective Operation of City Infrastructure Based on Information Disclosure

Let's assume that all people living in a city and its environment disclose their personal information, for example, when they depart home and where they go by car, to a public center. Technologically it should be possible in the near future to collect such information by M2M (Machine-to-Machine) communications through network without labors by people.

As an application of utilizing information collected to the center, road traffic in all cross sections in the city could be estimated, and all road traffic signals could be controlled according to the estimations. As the results, we could find some significant merits to the environment, for example, the decrease of fuel and exhaust gas of cars as well as saving time compared to the current road traffic system. Thus, people would be willing to disclose their information and their consciousness would be gradually turned to the direction.

If we could clarify such effects as possibilities or options in the future even through simulations, we should focus on technologies and systems design to achieve the goal. When and how to collect information disclosed by people, how to edit such information into some scenarios to control road traffic, and how to execute them adaptively should be interesting research issues to be solved technologically.

Road traffic control is just an example. If dynamical demands for city infrastructure could be estimated according to information disclosed by people, we believe it possible to result in effective operations of city infrastructure.

6 Conclusion

In this paper, we have proposed the concept of relationality that denotes interactions, linkage over time and space, and context as a result of accumulated interactions and linkage. Also we discussed research direction and issues on how to design relationality in complex systems composed of intelligent tangible or intangible, artificial artifacts, by using evolutionary algorithms and network science as methodologies.

As one of research on relationality, we introduced research on linkage between a user world and a virtual world in an interactive learning system. We investigated the effect of the existence of the virtual world on the user world through subject experiment with heartbeat measurement. And we confirmed that the linkage with the virtual world, especially the change of the virtual world, affects the users' state mentally and physiologically. There should be still research issues, for example, what of and how a real world should be related to what of a virtual world in time and space, a user's physiological states would be related to the virtual world directly and/or the linkage between the real world and the virtual world, and so forth.

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