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For the Establishment of Fundamental Informatics on the Basis of Autopoiesis: Consideration on the Concept of Hierarchical Autonomous Systems*

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I. The Structural Outline of Fundamental Informatics

1. Informatics and Socio-informatics

The term “informatics” or “information studies”, which has been in use since the 1990s, connotes a branch of learning on and about information that encompasses a wide range of disciplines. “Fundamental informatics” is a branch of learning that sheds light on the common basis for, and looks into the relationships among, the disciplines constituting informatics.

A majority of the constituent disciplines of informatics have been developed in the past half a century or so, and new constituent disciplines are still being established one after another. For the time being, however, the disciplines constituting informatics may be divided into two broad groups: those which are oriented toward natural sciences or engineering, and which may be collectively called “information science” or “information engineering”, on the one hand; and those which are oriented toward social sciences and the humanities, and which may be collectively called “socio-informatics”, on the other.

It was, needless to say, the growing widespread use of personal computers and the diffusion of the Internet since the 1990s that prompted these two fields to be bundled together under the term “informatics”. Unlike in the previous days when information technology (IT) had been handled exclusively by experts, in IT-oriented society all researchers, regardless of whether they are specialized in natural sciences, social sciences, or the humanities, deal squarely with information processing.

In the twenty-first century, therefore, there is a growing need for an academic discipline that comprehensively and systematically deals with information, information-related phenomena, and information-transmitting media. In other words, a body of academic knowledge that underlies both the first field, which carries out research and development of advanced and sophisticated forms of IT, and the second field which studies various phenomena of IT-oriented society, is in great demand.

Nonetheless, it is far from easy to bridge between these two fields. The most difficult question to be settled before bridging the two fields is that of how to deal with “significance” or “meaning” of a peace of information. (The “meaning” of a word is usually understood to connote an “ideal common denominator” that threads through various images evoked by the word, but in this paper it is used in a much broader sense to connote the “value” contained in information-bearing patterns.) Information is significant, and, as a matter of fact, one might even say that this is the essential feature of information; but information science/engineering focuses attention primarily on mechanical and formal processing of information, rather than on its significance or content. This is typically the case with the information theory proposed by an excellent engineer Claude Shannon, a theory which created a stir following its publication in 1948. In this mathematically-formulated theory, Shannon defines the "information quantity", and discusses a code system suitable for efficient transmission of information, while completely abstracting from the significance of information.[1]

In socio-informatics, on the other hand, it is taken for granted that information is significant. The objects of study for this discipline are social and human aspects of information-related phenomena. Inquiries are made into questions such as "What will become of the copyrights in IT-oriented society?" and "What sort of social phenomena is the Internet likely to give rise to?" Questions concerning mechanical or formal processing of information are outside the main focus of socioinformatic inquiries. Even when information in the sense of the object of mechanical or formal processing is included within the scope of socio-informatics, it is usually distinguished explicitly from significant information. (For example, in presenting his view of socio-informatics on the basis of an exquisitely defined concept of information, Toshiyuki Masamura makes a sharp distinction between significant and insignificant information.[2])

The two disciplines concerning information, one based on the disciplines of social sciences and the humanities, and the other on natural sciences, are very sharply divided over the question of how to deal with the significance of information. Over the years, however, various efforts have been made to bridge the gap between the two.[3] Of particular interest is an attempt to apply artificial intelligence to natural language processing. To put it plainly, this is an engineering attempt to let a computer understand natural languages and build a robot that can speak with a human being in English, Japanese, or any other natural language. This was pursued during the 1980s as part of the grandiose project for developing the fifth-generation computer, and with a lucrative financial backing from the government. It was in the process of implementation of this project, we might say, that theoretical and practical attempts were made for the first time to build a linkage between the two disciplines.

2. From Biological Phenomena to Information

A language consists to a considerable extent of formal and mechanical parts, including the grammar, that are certainly well adapted to high-speed processing by computers. As a matter of fact, a software program for machine translation that can be operated on a personal computer is effective in its own way. There is no denying that a number of research and development projects on the application of artificial intelligence to natural language processing are still being carried out, and the IT-related industries are still looking forward eagerly to wonderful fruits to be produced by these projects.

Nevertheless, it seems possible to learn good lessons from the failure of the project for developing the fifth-generation computers. The project's failure has made it crystal clear that it is virtually impossible, except under very limited circumstances, to bring a computer to properly comprehend the significance conveyed in a natural language.[4] Although the explanation in full detail is omitted in this paper, a series of difficult problems emerge one after another, making it difficult for a computer to comprehend the significance conveyed in natural language texts. Typical of such difficulties are known as the “frame problem”, which stems, for example, from the lack of common-sense knowledge on the part of computers, and the difficulties which computers face in figuring out the context in which a certain statement is made.[5]

We can name Terry Winograd as the researcher of information engineering who probed most deeply into this problem. Having once produced path-breaking significant research results in the late 1960s as a leading researcher of natural-language processing, Winograd stirred a controversy in the mind-1980s by publishing a book asserting that it is impossible for a computer to comprehend a human language.[6] These discussions about significance gradually made it clear that significance is inseparably related to biological phenomena.[7] Significance means “something that is important” and “something that is valuable” to a living thing, and an information-bearing sign points to the existence of “something that is valuable”. Pieces of information valuable for a human being are different from pieces of information valuable for a frog. The world, or what the biologist Jakob von Uexküll called the *Umwelt* (environment), in which the human being lives, and the one in which the frog lives, are completely different, and thus there is no guarantee that the pieces of information perceived by one have anything common with those perceived by the other. This is basically the case with any two human beings. If a piece of information is defined not as an object of formal processing, but rather as something like a signal or cue that prompts a living thing to make behavioral adjustments, then it stands to reason that a computer, not a living thing, cannot comprehend a natural language.

But if we feel contented with this perception and stop moving ahead, we can never bridge the gap between informatics and socio-informatics. This is where fundamental informatics comes in, proposing to take a fresh look into one question:

“What is a living thing, after all?”

Nobody denies that a biological phenomenon, taken at the level of molecules, is a physical-chemical phenomenon. If so, we might wonder (setting aside linguistic information of human beings, for the time being, because that is too complicated): Isn’t it possible at all that genetic information of bacteria in the process of proliferation is being processed in a mechanical way? Bacteria are certainly finding the mechanically processed genetic information significant. If, therefore, we can reproduce the processing mechanism on a computer, it will mean that the difficulty involved in the semantic processing of natural language by a computer is not of a theoretical nature, but is simply a matter of degree.

However, even if a living thing is a physical-chemical (or mechanical) phenomenon at the molecular level, perhaps there is a possibility that when taken as a “system” it may have its own characteristics. As a matter of fact, this is exactly the contention of the theory of autopoiesis that was proposed by the neurophysiologists Humberto R. Maturana and Francisco J. Varela.[8] More precisely, the theory asserts that “there are distinct, systems-theoretic differences between a living thing and a machine.”

“Autopoiesis” means “self (auto) creation (poiesis)”. According to this theory, a living thing is an entity that creates itself recursively. That is to say, it is an autopoietic system, and as such is very different from a machine of human creation, like an automobile or a computer, that is an allopoietic system.

Thus, the theory of autopoiesis will provide fundamental informatics with an important basis for its investigation about the significance (semantic aspect) of information.[9] In other words, a conceptual framework that will be built around the concept of autopoiesis will be sought after -- a framework that will prove effective in analyzing the semantic information within living things in general, to begin with, then analyzing those within a mental system of a human being, and finally analyzing those within a social system. Carrying out inquiries in this manner will be to follow the path of intellectual inquiry that starts from the concept of information employed in biology and other natural sciences, and leads to the concept of information employed in social sciences that pertain to human beings and society.

To add in passing, it is sociologist Niklas Luhmann who has played the pivotal role in disseminating the theory of autopoiesis, and his theory of social system will be one of the main pillars of fundamental informatics. It should be kept in mind, however, that even though Luhmann makes use of the concept of autopoiesis in his sociological discussions, there is, as is well known, a theoretical gap between his arguments and Maturana and Valera's biological discussions. In order to discuss information by overcoming this gap, fundamental informatics introduces a concept of "hierarchical autonomous system", which will be the main focus of the following discussion.

II. Autopoiesis

1. The Third-Generation Life System

How is a biological phenomenon different from a material or mechanical phenomenon? The argument that an inexplicable mystical entity resides inside the body of a living thing became a thing of the past long ago. It is an accepted practice of biology today to explain a biological phenomenon from a systems-theoretic standpoint. A living thing, when looked at from this perspective, is not a mere assemblage of elements, but a composite made up of elements, namely, a "system", which means that a phenomenon taking place in the composite or the system cannot be explained by reducing it to an algebraic sum of the physical-chemical properties of the constituent elements. Consequently, the answer to the question of "what is a living thing" must be sought in the domain of the "life-systems theory" which studies the way composites made up of elements are organized.

Life systems have been studied intensively since the mid-twentieth century, and it seems safe to say that the theory of autopoiesis is at the cutting edge of this new theoretical development. Hideo Kawamoto, a philosopher of science, who has not only translated Maturana and Varela's book on the theory of autopoiesis into Japanese, but has also been playing an active role in further developing the theory, calls an autopoietic system a "third-generation (life) system."[10]

The first-generation life system is an open "dynamic equilibrium system", which maintains itself by exchanging substances and energy with the external world. A living thing adroitly maintains itself in a homeostatic state, even if a variety of perturbations take place in the external world. As a matter of fact, it is the first-generation life system that has a characteristic of realizing a homeostasis. (A homeostasis is attained primarily and typically by a nervous system. Cybernetics that was first proposed in the 1940s took note of similarities between nervous systems of animals and electric-mechanical communications systems, and developed an automatic controller with a built-in feedback mechanism.)

However, a living thing is characterized not simply by its capability to maintain a homeostasis. It is equipped not only with a self-sustaining mechanism, but also with a mechanism for forming or organizing itself. A phenomenon wherein simple elements get together and form a complex dynamic order is often called a phenomenon of “emergence”; and a system that is equipped with a mechanism of emergence is a “self-organizing system”. This is an open dynamic non-equilibrium system, and constitutes the second-generation life system.

Since the 1960s intensive theoretical inquiries have been made into phenomena involving the formation of dynamic orders in a situation characterized by continuous inflows and outflows of substances and energy, and one of the well-known accomplishments of these research efforts is Ilya Prigogine’s theory of dissipative structure. Assuming that the initial state in such a situation is macroscopically chaotic, if microscopic “entrainment” is touched off by accidental perturbations, it leads to the emergence of a macroscopic dynamic order. A mechanism like this is at work in many biological phenomena, including the working of brain waves and movements of muscles, and it is now widely recognized that dynamic non-equilibrium systems constitute the basis for the formation of a physiological order within a living system.

Nonetheless, the second-generation life system is not yet a satisfactory model of a living thing. A phenomenon whereby a dynamic order like a dissipative structure is formed can certainly be regarded as one of “emergence”, but such a phenomenon is nothing but an ephemeral one that can take place only under a given condition prepared by a human being (for instance, only within a mixed solvent inside a beaker), and that will vanish if left alone. Such a system does not involve continuing, autonomous occurrence of diverse forms of emergence. Moreover, its boundary is fixed beforehand. The history of living things has continued for approximately 3.8 billion years. A living thing is exactly a system of such a type that can continuously give rise to diverse phenomena of emergence, while creating and defining its own boundary by itself. And a model that satisfactorily emulates this feature constitutes the third-generation, "autopoietic system".

The third-generation life system is conceptualized by taking into account and expanding on the concepts of the first- and the second-generation life systems, and is defined as "a network of processes of production of components that produce the components". Components of an autopoietic system continuously regenerate and realize the network of processes that produced them. Moreover, components constitute an actual system as a "concrete unity" in the space in which they exist.[11]

What is important in this recursive definition of an autopoietic system is that this system is essentially defined as an abstract and topological network of processes of production of components, and that a concrete unity that takes shape in the space is but a byproduct. In other words, the domain of an autopoietic system is topological, not spatial. Take, for instance, a cell, which is an autopoietic system; but, accurately speaking, a concrete cell that can be observed by a microscope is not a cell in the sense of an autopoietic system. A concrete cell existing in a space is a lump of high molecular protein, which may be regarded as an open system in the sense that it has inputs and outputs of substances and energy. Nonetheless, a cell, when viewed as an autopoietic system, or as a network of processes of production of components, is a closed, autonomous system that does not have inputs or outputs.

This corresponds to the fact that there is "no inside or outside" in an autopoietic system, which is the most important feature of such a system. A living thing, when looked at from its own standpoint, can neither distinguish between the inside and the outside, nor between an illusion and a reality. When a frog, upon receiving a stimulus from a dark spot floating in the air, jumps at it, only an observer watching the frog's behavior from the side can tell whether the dark spot is a fly which the frog can prey upon or a mere fleck of dirt or soot. The frog itself has no inside or outside, but is single-mindedly performing an action. By way of performing an action, the fly defines its "self" and draws the "boundary" that separates itself from the environment.

It is thus possible to say that "a shift in perspective (viewpoint)" constitutes the most salient feature of the theory of autopoiesis. The theories of the first- and the second-generation life systems held fast to the approach of describing biological phenomena as observed from the outside of the living thing. However, the unique features of a living thing that continues to exist and undergoes a process of evolution while endlessly changing its shape and configuration in a constant motion, can only be seen and grasped from the perspective of looking at a system from within it.

2. The Theory's Aporia over the Question of How to Deal with a "Composite System"

The most serious aporia for the theory of autopoiesis seems to be the question of how to deal with a "composite system". The concept of a composite system consisting of a set of autopoietic systems as its components was considered mainly by Maturana. Take, for instance, a multi-cellular organism. It is an assemblage of many cells, where each of the constituent cells is itself an autopoietic system, too. But is it at all possible for a number of autopoietic systems to get together and form a composite autopoietic system?

Kawamoto points out that the concept of a relationship between components and a composite system has led to the aporia, over which a conflict has developed between Maturana and Varela. He observes as follows:

"Suppose that component systems have got together to form a composite system, which has become a new autopoiesis unity. If such were the case, it would mean that an autopoietic system of a higher order has been formed. But Varela objects as follows: If component systems continue to be autopoietic systems, these systems should be sustaining themselves all along, and therefore will never become components of a system of a higher order; Component systems must also be self-producing through their own productive operations, and will never be produced by the autopoietic system of a higher order; And if the composite system is an autopoietic system of a higher order, then a relationship of the kind that is defined to hold in an autopoietic system does not hold between the system of a higher order and the component systems. On the other hand, if it is assumed that, when the composite systems have joined together to form the system of a higher order, the composite systems have ceased to be autopoietic and the system of a higher order alone has become autopoietic, then it follows that the component systems have lost their very autonomy. If such were the case, it would mean that the component systems would be unilaterally subordinate to the system of a higher order. Maratuna could never bring himself to accept this reasoning, especially as it pertains to a relationship between individuals and society, because of his belief that in such a relationship the autonomy of individuals must be upheld."[12]

In short, according to the definition of an autopoietic system, it seems impossible for both component systems and a composite system to remain autonomous. The very fact that autonomy is the defining feature of an autopoietic system would dictate that there could be no such a thing as a composite autopoietic system.

The possibility of overcoming the aporia was first proposed by Luhmann from a limited perspective of a relationship between individuals and society. Kawamoto followed by presenting a more general solution.

According to Luhmann, a social system is an autopoietic system that has “communication”, not individuals, as its components. In other words, a social system is organized as communication recursively produces communication.[13] There is no denying that a society cannot be formed unless a plural number of individuals get together. However, once a social system begins to operate stably, communication, a new component belonging to a dimension different from that of individuals, begins to be produced recursively. Here, individuals constitute an “environment” for the social system.

Kawamoto asserts that much the same thing is also at work in multi-cellular organisms. To be more specific, when a multi-cellular organism is operating as an autopoietic system, Kawamoto reasons that the system’s constituent components are new components such as “intercellular mediating substances”, but not cells, which now constitute an “environment” for the multi-cellular organism.

What is noteworthy here is that there is no longer a relationship between component systems and a composite system. Individuals constitute an environment for a society, but at the same time the society, for its part, also constitutes an environment for the individuals, mutually pervading into each other. A similar relationship holds between a multi-cellular organism and its cells. This sort of relationship in which “multiple systems through their operations manifest themselves as an environment to each other”[14] is called a relationship of “interpenetration”. What is crucially important to note here is that when such a relationship holds between two systems, “an operation of one system is synchronized with an operation of the other system, mutually intersecting with and pervading into each other”.[15] A situation in which autopoietic systems come to have some relationship with each other in the course of their operations is expressed by Maturana as “structural coupling” between the systems. And interpenetration seems to be a very remarkable example of synchronous relationship among various forms of structural coupling. To add in passing, an autopoietic system that interpenetrates a social system is not an individual in the sense of a physical living system, but in the sense of a mental or psychological system. A mental system is an autopoietic system that has “thinking” as its component, and it is regarded as being in a typical relationship of interpenetration with a social system.

The most crucial thing that must be kept in mind here is that a hierarchical relationship is totally absent from the foregoing discussion. It has been conventional to develop a theory of living systems on the basis of hierarchical relationships within an organism. However, as pointed out already, the salient feature of a biological phenomenon is that a characteristic of what is taking place within the body of a living thing cannot be explained by reducing it to an algebraic sum of the physical-chemical properties of the constituent components. This means, in other words, that there emerge in the composite system of a higher hierarchical order unique features that are not found in the component systems of a lower hierarchical order. However, an attempt to deal with this kind of relationship between systems within the theoretical framework of autopoiesis proves difficult because the idea of hierarchically ordered relationship between systems is incompatible with the theory of autopoiesis. To be more specific, a relationship between all sorts of autopoietic systems is bound to take the form of a system-environment relationship, including a relationship of interpenetration.

To speak in terms of the history of evolution, a living thing that first began as a unicellular prokaryote eventually evolved into a eukaryote, and then into a multi-cellular organism, which is an assemblage of eukaryotes. If living things are essentially autopoietic systems, all these life forms must be autopoietic systems as a matter of course. Furthermore, various systems that a multi-cellular organism has within its body, such as a nervous system and an immune system, can also be regarded as autopoietic systems. When a multi-cellular organism is considered in a commonsensical manner, therefore, its body cells, nervous system, and its entirety appear to have a hierarchically ordered relationship of physical nesting among them. Then, why is it that such a hierarchical relationship has to be negated?

The answer is closely related to the definition of autopoiesis. The most salient feature of the theory of autopoiesis, as pointed out already, is that it has shifted the perspective, from that of observing and describing a biological phenomenon from outside, to that of observing the system from within and in accordance with its own logic. That is, it has made it a rule to adopt the standpoint of the actor or operator, not of an observer or describer. This feature of the theory of autopoiesis leads to the characteristics peculiar to an autopoietic system, that are manifested by expressions such as “it has no inputs or outputs”, and “it has no inside or outside”. And taking the standpoint of the system itself, not of an outside observer, will make it impossible to talk about relationships among multiple systems. Needless to say, if a theory totally gives up observation and description, it cannot be a theory any longer, but it is characteristic of the theory of autopoiesis to try to understand a system in close reference to its operations, by restraining the standpoint of an observer as much as possible.

It follows from the observation above that the theory of autopoiesis, when pushed to its logical end, has no room for hierarchical relationships. In the theory of autopoiesis, as Kawamoto observes, “a variety of systems, without being characterized by any superior-subordinate relationships among themselves, simply continue to operate while intersecting with each other”.[16]

At this juncture, however, fundamental informatics must part company with the theory of autopoiesis, because upholding this theoretical standpoint means that it will become impossible to analyze the flow of information, namely the phenomena concerning the transmission of information.

From the outset, the theory of autopoiesis has not been formulated on the assumption that information is exchanged between plural living systems. According to this theory, autopoietic systems are only supposed to give each other stimulus and perturbations, but not to exchange pieces of significant information. At the most, they become structurally coupled with each other through their operations. Assume, for instance, that two persons are talking with each other. Then a linguistic domain that emerges here is characterized, according to the theory of autopoiesis, merely as a sort of “consensual domain” that emerge in actions, but not as one for the dissemination of information.[17]

Consequently, fundamental informatics will have to open a new terrain while paying due attention to the autopoietic characteristics of living things. Now, hierarchical relationships among various systems will have to be reconsidered in a fresh light.

III. Hierarchical Autonomous Systems

1. An Observer and Autonomy

Information is inseparably related to biological phenomena. It seems, therefore, natural for fundamental informatics to base itself upon the theory of autopoiesis. It should be kept in mind, however, that fundamental informatics is not primarily concerned with analyzing biological phenomena themselves, but rather with information-related phenomena among human beings or in society. Thus, fundamental informatics attaches great importance to autonomy, among various features of an autopoietic system.

A living thing is an essentially autonomous entity, but when it performs operations to transmit information and interpret its significance, are there any "restrictions (restraints)" or "bindings (constraints)" at work that affect its performance? Is not it precisely because a living system is restrained at least in some sense, that it is capable of transmitting information? Typical examples of such restraints are the vocabulary and grammar of a language, that enable us to talk with other people without being conscious of their effects.

An effort to make out the relationship between autonomy and restraint indispensably calls for the perspective not only of an actor, but also of an observer. There is no denying that the theory of autopoiesis pays greater attention to actions than to observation. However, Varela presents the concept of "autonomy", independently from Maturana, conceptualizing autonomy premised on the existence of an "observer."[18] Let us sort out the relationships between various systems by paying attention to each system's autonomy and an observer.

If systems, when looked at by an observer, continue to exist as continuous unities, and if they are “organizationally closed”, then the systems are termed “autonomous”. Here systems are defined to be organizationally closed if “their organization is characterized by processes such that the processes are related as a network, so that they recursively depend on each other in the generation and realization of the processes themselves; and they constitute the system as a unity recognizable in the space (domain) in which the processes exist”.[19] In other words, an organizationally closed system is one that is recursive and self-referring, and that forms its boundary by its own action and operation, but it is an observer who recognizes it as a unity. It should be pointed out, furthermore, that the act of observation is performed not from “outside” the system, but from “within” it and in close resonance with its operation.

Now, in case when a component process in an organizationally closed system is also characterized as a “process that produces its components”, it coincides with an autopoietic system. To put differently, compared with an autonomous system that can come into existence if its “components are brought into connection with each other” by a recursive process, the conditionality required for the existence of an autopoietic system is more strict, because its “components must be produced” by a recursive process. To put it more plainly, an autopoietic system is nothing but an “autonomous system that is characterized by a relationship of production”.

Moreover, among various autopoietic systems, a living system is characterized as one that only produces “physical components”. In this case, the components make their appearance in the space as substances.[20] It must be kept in mind here that a mental system which is composed of thinking as its component is not a living system.

It follows from the foregoing observations that living systems are included in autopoietic systems, which in turn are included in autonomous systems. It is thus safe to say that autonomous systems are self-recursive systems in the broadest sense, and as such are the exact opposite of allopoietic systems, or ordinary machines, which have inputs and outputs. (Conceptually, it is possible to regard organizationally closed systems as self-recursive systems in the broadest sense, but if an observer who can witness the closed nature of such systems is absent, their closed nature cannot but remain hypothetical.)

In coming to grips with the essential features of living systems, it may be effective to pay attention to actions and operations of the systems, but in discussing these systems from the standpoint of fundamental informatics, it is impossible to neglect the acts of observation and description. This is because, only by observing a system and describing it with the use of our system of representation, can we say that we have socially recognized the object.

Now it is well to say a few words about an observer. In fundamental informatics an observer is defined as a "mental system" (or its functional equivalent). And what is described by the mental system with the use of a human being's system of representation, including language, is defined as "information" (in the narrow sense). In contrast, information in the broad sense is a sort of a pattern by means of which a living thing generates patterns inside its body, and which is significant or valuable not only for human beings but for living things in general.[21] Let us call this primordial form of information "raw-information." The mechanism by which various patterns or pieces of raw-information are generated can be explained by means of a model representing the second-generation dynamic non-equilibrium systems.[22]

When, for instance, a word is addressed to a human being, a physical pattern corresponding to the word is generated in the person's brain. This pattern is a piece of raw-information. Then the mind system of the person, who is an observer, gets structurally coupled with his/her nervous system, extracts from there the meaning of the piece of information (in the narrow sense), and describes it in word. Social communication takes place, with the described meaning serving as the material of communication.

The "content" carried by a piece of raw-information is "significance" or "value" to a living thing, but when the observer extracts the piece of information in the narrow sense from the nervous system, its content is now characterized more as a "meaning" for social communication rather than as a significance or value. In other words, it is only through intermediation by an observer that pieces of information begin to carry meaning that can be communicated and comprehended at the social level.[23]

2. Hierarchical Relationships among Autopoietic Systems

The theory of fundamental informatics holds that any autonomous system, including an autopoietic system, can come into existence only when it is accompanied by an observer who witnesses its autonomy. And under a situation where this prerequisite is satisfied, if an observer watching systems A and B, which are structurally coupled with each other, obtains results (1) and (2) mentioned below, the theory holds that "hierarchically autonomous systems" are in existence here, with system A ranking higher than system B in hierarchy:

(1) The observer observes system A, making sure that it is autonomous and making a note to that effect. Then he/she changes the perspective, observes

system B, making sure that it is autonomous and making a note to that effect. Then, he/she goes back to system A, repeating the same procedure, and then goes back to system B again, and so on. As a result of this repetitive observation and description, the two systems are found to continue performing their operations stably, and to continue preserving their autonomy.

(2) While system A is observed, it is found that in system A's operation system B is performing certain functions as an allopoietic system. And the observer can recognize that the operation of system B is restricted by system A as a result of the structural coupling between the two systems. However, while observing system B, the observer cannot recognize any restriction on system B's operation being imposed by system A.

In this situation, system A emerges as a composite system, and system B as a component system constituting system A. What is important here is that even though system B's operation is partly embedded in the organization of system A, so to speak, this fact does not affect system B's organization. The constraint imposed on system B can only be recognized through observation of system A, with the result that from the standpoint of an observer of system B, system A remains a tacit or implicit entity (the environment), and system B's autonomy is kept intact.

To add in passing, this sort of relationship between a component system and a composite system has, in a certain sense, been envisaged by the theory of autopoiesis from early on. Maturana and Varela point out as follows:

"An observer can describe an autopoietic component of a composite system as playing an allopoietic role in the realization of the larger system which it contributes to realize through its autopoiesis. In other words, the autopoietic unity functions in the context of the composite system in a manner that the observer would describe as allopoietic."[24]

It should be pointed out, however, that the passage quoted above seems to assert that a component system itself can constitute a component of a composite system, but such an assertion is theoretically unjustifiable because an autopoietic system, by definition, is a self-productive system that cannot be produced by a composite system. Given this fact, it is indispensable to base our inquiry about the hierarchical relationships among autopoietic systems upon the arguments of Luhmann and Kawamoto that communications, not human beings themselves, are the components of social systems.

The "hierarchical relationships" here, therefore, mean "restricting" or "binding" relationships in the operations of systems, and as such, are not necessarily the same as physical or spatial relationships of inclusion.[25]

To put it plainly, a subordinate system in hierarchical autonomous systems performs a kind of a "role". In a self-producing process of a nervous system a particular nerve cell contributes to the operation of the nervous system by performing a specific function. To put it the other way around, the nerve cell is constrained by the nervous system to perform that specific function. On the other hand, however, when the nerve cell is in a stable state, its self-producing process itself is operated autonomously. In a transitional state, it is of course not impossible for the nerve cell to operate in a way contradictory to its assigned role, but in such a situation, the stable state is no longer maintained, and the nerve cell will be eventually eliminated from the nervous system so long as it keeps on this “false operation”.

Generally speaking, inside the body of a living thing there exist very complicated binding relationships, which constitute intricate, hierarchical networks. An individual human being, for instance, is made up of approximately 60 trillion cells, which perform a total of more than 200 different functions. In analyzing a complicated system like this, the idea of hierarchical autonomous system or hierarchical autopoietic system seems to be very effective. If system A hierarchically stands above system B, and if system B hierarchically stands above system C, then it can be automatically concluded that the operation of system C is indirectly restrained by system A. However, if the idea of hierarchical relationships is rejected, then it will become necessary to analyze each and every mutual relationship for any possible combination among all the autopoietic systems involved, with the result that the objects of analysis will run into an astronomical number.

A similar discussion holds true also with regard to the relationship between a society and an individual. If the two are taken to stand in a completely equal relationship with each other, the essential mechanism in information transmission becomes concealed. As a matter of fact, although it is intrinsically impossible for two autopoietic living things to literally transmit information with each other, there actually takes place between them a “fiction” as though pieces of significant information were being transmitted in their entirety between them. Here the fiction is sustained by various restrictions or bindings, including a language. And given the fact that in many cases communication takes place not on the basis of a one-to-one relationship of equality, but on the basis of collective or social power relationships in the broad sense, it is impossible to talk about the functions of information in disregard of the restrictions or bindings imposed by society on the behaviors of individuals.[26]

To repeat the point made earlier, even under such hierarchy, it is not an individual who becomes a component of a social system. It is words uttered by an individual that serve as the “material” of communication, which in turn serves as a component of a social system, and this is analogous to the way that a pulse signal generated by a nerve cell becomes a component of a nervous system. It is the system that chooses from among various materials, and thus there is no chance for the materials to impose restraints on the system.

Let us assume, for example, that a person who has taken a drug is making reckless remarks, unable to differentiate between an illusion and reality. He might be able to utter whatever reckless remarks he likes to, but such remarks are rejected in social life. If he continues to behave in the same way, he would eventually be eliminated from the society. In a stable social system, therefore, individual members are operating in ways corresponding to their respective roles as allopoietic systems, and in this sense they are embedded in the social system.

3. A Super-social System

Let us use the concept of a hierarchical autonomous system and try to capture the mechanism by which social information is transmitted. It should be kept in mind that “transmission” here does not connote momentous and piecemeal transmission of messages as dealt with by Claude Shannon, but refers to a mechanism by which the meaning (significance) of information becomes socially “shared” and gains social currency.

To put the conclusion first, in fundamental informatics the transmission and sharing of the meaning of information are attained through three-stage autopoietic hierarchical systems, consisting of, from bottom up, mental systems, functionally differentiated systems, and the mass-media system.

A mental system is constituted by thoughts of an individual belonging to a society as its components, and generates descriptions that serve as the materials of communication. These descriptions are based on raw-information inside the individual, as pointed out already. The functionally differentiated systems that stand above the mental systems are a collection of functionally differentiated social systems that stand in parallel with each other, including the economic system, the academic system, the legal system, and the family system, etc., each of which continues to generate as its components communications relevant to its functions (for instance, the economic system generates communications concerning business transactions). For the time being, these functionally differentiated systems may be equated to what Luhmann calls *funktionale Differenzierung system.*[27]

Since these functionally differentiated systems are autopoietic systems which recursively produce communications, it follows from the definition of an autopoietic system that there exists for each of the systems an observer who is structurally coupled with the system concerned, and who is called a “social observer” here. A social observer is a mental system, but is deemed to observe and describe by rejecting personal subjectivity as much as possible. (In the case of the economic system, for example, the social observer is more reminiscent of an economic reporter for a newspaper than a corporate manager or a worker.) Descriptions about the functionally differentiated system as observed by the social observer become the materials that are woven into "mass communication", which is a component of the autopoietic system called the mass-media system. Mass communication means a "communication about communications", and as such, is nothing but a sort of meta-communication.

The "super-social system" that is placed at the top of the hierarchy is the mass-media system. When looked at from the standpoint of an observer of this system, the subordinate collection of functionally differentiated systems such as the economic, the academic, the legal, and the family systems all appear to be functioning as allopoietic systems. In other words, they appear to be functioning as if they were news sources for a newspaper's economic, arts and literature, city news section, and homemaking pages, respectively

Now, given this hierarchy among the "mass-media system, functionally differentiated social systems, and mental systems," how restrictions are imposed, and how, under such restrictions, the meaning (significance) of information comes to be socially shared?

To begin with, the fact that the mass media is an autopoietic system means that mass-communications continue to be generated within the mass-media system. It is not true that the mass-media system "reports" the facts which exist outside it. Thus, a conventional assertion that "a distorted reporting by the mass-media produces harmful influences on the masses of people" is wide of the mark. The criterion by which to determine whether a reporting is distorted or not cannot but be always relative, with everything being created and annihilated inside the mass-media system. To be sure, in the process of the generation of each specific mass communication, the system is subjected to “stimuli and perturbations” coming from the environment, which take, for instance, the form of a description by an economic reporter who is observing the economic system. However, such stimuli and perturbations are no more than materials, and the mass-media system continuously generates mass communications by choosing materials through processes of its own (for example, a process of judgment based on factors such as popularity, the circulation of a paper, and the audience ratings).[28]

Thus, the mass-media system provides people with an “image of reality” which it makes up inside itself. The “image of reality” is an “integrative image of reality,” namely an “image of reality interpreted and edited by the mass media”, which is universally shared by all the members of a society. This very “image of reality” is imposed upon each mental system as a “restriction or binding”. It is thus within the framework of a given image of reality that we think.

Then what is “reality”? Needless to say, it is the state of things that surround the members constituting a society, or the state of the world as looked at from individual mental systems, but its substance is nothing but a “restriction or binding” that each functionally differentiated system imposes upon an individual mental system. In other words, an individual lives under various bindings imposed by a series of functionally differentiated systems, such as the economic, academic, legal, and family systems. A university professor, for example, writes an academic paper in his office (i.e., operates in the academic system), mails his paper by registered mail from a post office (i.e., operates in the economic system), goes home by observing traffic lights (i.e., operates in the legal system), and chats with his family (i.e., operates in the family system). And his mental system always remains under the bindings of these various functionally differentiated systems. When he writes his paper, he claims his thesis to be true, but will never say that he is writing it for his love of his wife, or as a repayment of his indebtedness to one of his senior colleagues. This is so because the continuation of communications in the academic system pivots around the question of whether a certain thesis is true or mistaken. Similarly, when he mails his paper, he might ask the clerk at the window: "How much does it cost to mail the paper by a registered mail?"; but he will never demand: "This academic paper contains great truths and is extremely important, so be sure never to let it get lost!" This is so because the economic system gets into or out of operation depending on whether the payment is made or not.[29] Each functionally differentiated system, therefore, operates on the basis of a process peculiar to itself, and as looked at from this system's observer, individual mental systems are performing certain roles as allopoietic systems. And "reality" is nothing but this sort of state of things as looked at from individual mental systems.

What is important to note here is that individual mental systems cannot objectify most of the "reality", and are not conscious of it. In other words, most part of the reality is "background and latent reality". A legal communication that "you must stop at a red light" is not something that comes to surface when one faces a traffic signal. It can be regarded more appropriately as a quasi-subconscious restraint on behavior.

A modern society is a highly specialized society, where an individual cannot bring reality outside his own field of specialty to light except on a fragmental, partial, and ephemeral basis. To be sure, official communications on the workplace have the effect of partially bringing reality to light, the reality thus revealed ends up not being shared by people at large. When, for example, a banker talks about investment dealing, he may be able to shed light on some aspects of the economic reality involved, but the academic value of the entire economic reality will be neglected. In other words, since individuals in a modern society can take part in official communications only in very limited and unbalanced ways, they are not able to grasp a logically coherent and socially holistic image of the reality.

It is the mass-media that bring the latent reality to surface, making it visible for these members of a modern society. Thanks to this function of the mass-media, people can form, for the time being, a logically coherent "image" of the reality, which is nothing but an "image of reality". An image of reality is not necessarily the same as the reality, and, as such, is merely an artificial image, namely, an interpreted and edited version of the reality that is uniformly presented to people; but, nonetheless, for people it is the only "tangible, and comprehensible shape of the reality".

This fact has a bearing upon the characteristic feature of mass communications. More specifically, mass communications are characterized by the fact that despite being generated recursively in a closed setting, they are uniformly presented to all the members participating in a society. On the basis of the commonly held and shared image of the reality, individuals perform their private communications.

To sum up the foregoing observations, the reality and the image of reality work as restrictions or bindings imposed on individual mental systems, and to put it in a nutshell, it is precisely these restrictions or bindings that facilitate the dissemination and sharing of social information. It is a mechanism like this that is deemed to be sustaining the fiction of information transmission.

IV. An Outlook from Information

In lieu of concluding remarks, the main contentions of this paper will be summed up below, followed by some words on with two of the many important issues that have been left untreated in the paper due to space limitations.

Informatics, a new field of academic intellect that is commanding much attention as being characteristic of the era of information technologies, encompasses both socio-informatics, which is based on social sciences and the humanities, and information science, which is based on natural sciences and engineering. And fundamental informatics is situated at the base of these two disciplines. The crucial issue to be dealt with by fundamental informatics is the question of how to deal with “meaning (significance)”. Given the fact that the meaning (significance) of information emerged together with the birth of organisms (living things) some 4 billion years ago, answering the question is the same as answering the question of what is a living thing from the perspective of the systems theory.

This paper has tried to understand a living system from the standpoint of the theory of autopoiesis, thereby looking into the foundations of mechanisms for transmission of information. The concept of autopoiesis captures the salient feature of the activities of living things, i.e., they continue operating while recursively creating themselves. A living thing is an autopoietic system, and, as such, is clearly distinguished from a machine of human creation, which is an allopoietic system.

Given, however, the fact that the theory of autopoiesis focuses its attention on the operations of a system individually, it cannot convincingly explain the relationships between systems, especially the relationships between a composite system and its constituent systems, such as between a multi-cellular organism and its constituent body cells. The theory cannot deal properly with the hierarchical nature involved in such relationships between systems. In this connection, the theory is also faced with difficulties in analyzing the transmission of the significance (meaning) of information.

This paper has, therefore, proposed the concept of a hierarchical autonomous system (or a hierarchical autopoietic system) on the basis of Varela's argument about an autonomous system. According to this conceptual framework, a hierarchical relationship between systems is defined not in terms of physical inclusion of one system in another, but rather in terms of restrictions or bindings imposed by one system on the operation of another. Thus defined, any system constituting a hierarchy of systems, regardless of its hierarchical level, remains autonomous when looked at from the standpoint of its observer; however, when looked at from the observer of a system of a higher hierarchical order, a system of lower hierarchical order appears to be without autonomy, functioning as an allopoietic system.

This conceptual framework has then been applied to an analysis of a three-stage hierarchy among autopoietic systems consisting of the "mass-media system, social systems, and mental systems". An individual person's mental system is under the restrictions or bindings of a set of social systems, namely, functionally differentiated social systems. Such restrictions or bindings are nothing but the "reality" that the functionally differentiated systems present to individual persons. From the standpoint of an individual person, much of the reality remains latent, fragmented, and invisible; but an integrative world image is provided by the mass-media in the form of an "image of reality". It is the reality and the images of reality that work as common and shared restrictions or bindings imposed on individuals. This, on the other hand, sustains the fiction of so-called information transmission.

Aside from the foregoing contentions that have been made in the paper, there are a number of important issues that remain to be addressed. Especially important among them are the following two.

First, the positioning of the mass-media system may be open to question. It may be possible to regard the positioning of the mass-media system above the various social systems (i.e., functionally differentiated systems) as raising a sort of objection to Luhmann's theory. In Luhmann's theory, the mass-media system is ranked in parallel to the economic system, the legal system, and the like. This treatment seems to be well in accord with the theoretical disposition of Luhmann's theory, which will never put not only the mass-media system, but also any one social system in general, in a transcendental position above the other social systems. The theory posits that neither a unitary perspective nor an absolute frame of reference capable of grasping a society in its entirety is in existence, and that observations are performed in a relative, not absolute, way by a group of functionally differentiated plural systems.

What must be emphasized here, however, is that even if the mass-media system is positioned above the functionally differentiated systems, this fact cannot immediately serve as the grounding for disproving the non-existence of an absolute frame of reference. Put differently, even though the mass-media system provides restrictions or bindings to the functionally differentiated systems, it cannot necessarily offer a universal perspective for looking at a society as a whole.

The most crucial reason for this is the instability of the mass-media system, which is far more unstable and susceptible to change than the other functionally differentiated systems. Moreover, even though the image of reality, which this system provides to people, may serve as an integrative image of reality for the time being, the image usually proves to be logically incoherent and full of contradictions. As such, the mass-media system cannot perform the function that "God's outlook" used to perform in pre-modern societies.

Second, there is the question of how to understand "media," the question which has a close bearing on the instability of the mass-media system discussed above, and the one which has not been taken up in this paper. Communications cannot work in the absence of media. Therefore, a discussion about the transmission of the meaning (significance) of information indispensably requires a discussion about media. However, the word media is used here in a sense much broader than what is connoted by the conventional concept of the word. More specifically, if defined by drawing insights from the theory of Luhmann, media mean "something that puts communications in order, and organizes materials into a form".[30]

Included among concrete forms of media are "Verbreitungsmedien (dissemination media)", such as television and telephone through which messages are transmitted, "syntagmatique (syntactic) media", which provide significant linkages among communications that are generated successively, and "paradigmatique (paradigmatic) media", which keep examples of meanings in stock for use in the generation of communications.[31]

Thanks to these media, social transmission, circulation, and sharing of the meaning (significance) of information become possible. In particular, syntagmatique media play an instrumental role in stably connecting the functions of signification, while paradigmatique media are active in the terrain of long-term functions of signification. Because of these media, the realities that are generated by the functionally differentiated systems are more stable than the image of reality generated by the mass-media system.

A further treatise about the ongoing discussions within the discipline of fundamental informatics, including those over the two questions mentioned above, must await a separate paper.

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[1] Claude E. Shannon "A Mathematical Theory of Communication", *The Bell Technical Journal*, Vol. 27, 1948, pp. 379-423, 623-656.

[2] Toshiyuki Masamura, *Jôhôkûkan-ron* (A Treatise on an Information Space), Tokyo: Keisô Shobô, 2000.

[3] Well known among them is an ambitious attempt which the semiologist Umberto Eco made in the 1960s to explain a poetic language by means of an information theory. See Umberto Eco, *Opera Aperta*, Milano: Bompiani, 1962; *Hirakareta Sakuhin* (Japanese translation by Shinohara Motoaki and Wada Tadahiko), Tokyo: Seidosha, 1984; and *The Open Work* (English translation by Anna Cancogni and with an introduction by David Robey), Cambridge, Mass.: Harvard University Press, 1989.

[4] The awareness about the difficulties involved in making a computer comprehend a natural language did by no means deny that a study in natural language processing itself can be of any use, but instead reoriented the study into a more practical direction. For example, the main focus of studies in machine translation has now shifted from the studies about how to make computers understand the significance of a natural language to the studies about translation procedures that make use of corpus-based pattern matching.

[5] Daniel Dennet, "Cognitive Wheels", in Christopher Hookway, ed., *Minds, Machines and Evolution: Philosophical Studies*, Cambridge and New York: Cambridge University Press, 1984.

[6] Terry Winograd and Fernando Flores, *Understanding Computers and Cognition: A New Foundation for Design*, Norwood, N.J.: Ablex Pub. Corp., 1986.

[7] Even at the beginning of the twentieth century when information began to attract attention as a basic concept distinct from substance and energy, physicists including Erwin Schrödinger already pointed out the inseparable relationship between information and a living thing. Subsequently, however, especially since the establishment of information science in the 1940s, there has been a continuing tendency to pay greater attention to the mechanical or formal facets of information.

[8] Humberto R. Maturana and Francisco J. Varela, *Autopoiesis and Cognition: The Realization of the Living*, Dordrecht (Holland), Boston, and London: D. Reidel

Publishing Co., 1980; *Ôtopoiêshisu* (Japanese translation by Kawamoto Hideo), Tokyo: Kokubunsha, 1991.

[9] Winograd also makes use of the theory of autopoiesis. See Winograd, *op. cit.*

[10] Hideo Kawamoto, *Ôtopoiêshisu* (Autopoiesis), Tokyo: Seidosha, 1995.

[11] H. R. Maturana and F. J. Varela, *op. cit*., pp. 79 and 135; the Japanese translated edition, *op. cit.*, pp. 71 and 242.

[12] Kawamoto, *op. cit*., p. 249.

[13] Niklas Luhmann, *Soziale Systeme: Grundriss einer allgemeinen Theorie*, Frankfurt am Main: Suhrkamp, 1984; *Social Systems* (English translation by John Bednarz, Jr., with Dirk Baecker, and with foreword by Eva M. Knodt), Stanford: Stanford University Press, 1995.

[14] Kawamoto, *op. cit.*, p. 253.

[15] *Ibid*., p. 254.

[16] *Ibid.*, p. 255.

[17] Francisco J. Varela, *Principles of Biological Autonomy*, New York: North Holland, 1979, p. 49. Maturana and Varela, *op. cit.*, pp. 32 and 120; the Japanese translated edition, *op .cit.*, pp. 138 and 203.

[18] Varela, *op. cit.*, p. 54. For a detailed analysis of Varela's discussion about the relationship between an autonomous system and an observer, see Takafumi Suzuki, "Seimei e no Kisojôhôgakuteki Kanten: Shoki Varela Kenkyû" (An Approach to Living Things from the Standpoint of Fundamental Informatics: A Study of Varela in His Early Years), an M. A. thesis submitted to the Graduate School of Interdisciplinary Information Studies, the University of Tokyo, 2003.

[19] Varela, *op. cit.*, p. 55.

[20] Varela equates an autopoietic system with a living system. See Varela, *op. cit.*, p. 17 and Suzuki, *op. cit.* Since a mental system and a social system do not produce physical components, the theoretical difference between Luhmann and Varela becomes clear here.

[21] In fundamental informatics, a piece of information is defined as "a pattern by which a living thing generates patterns". See Toru Nishigaki, *Kokoro no Jôhôgaku* (Informatics of the Mind), Tokyo: Chikuma Shobô, 1999, p. 32.

[22] With the use of a model of a nonlinear oscillator and a chaos model, Hiroshi Shimizu and Ichiro Tsuda have inquired into the mechanism by which pieces of primordial information are generated in the brain. See, for example, Hiroshi Shimizu, *Seimei to Basho: Imi o Sôshutsusuru Kannkei Kagaku* (Life and Place: Related Sciences Which Create Significance), Tokyo: NTT Shuppan, 1992; and Kunihiko Kaneko and Ichiro Tsuda, *Fukuzatsukei no Kaosuteki Shinario* (The Chaos Scenario of Complex Systems), Tokyo: Asakura Shoten, 1996; and Kaneko and Tsuda, *Complex Systems: Chaos and Beyond – A Constructive Approach with Applications in Life Sciences*, Berlin, Heidelberg and New York: Springer-Verlag, 2001.

[23] The concepts of observation and information used in fundamental informatics are quite different from those in Luhmann's theory. In Luhmann's theory, the operations of a social system themselves are closely related to the concept of observation. For further details, see Niklas Luhmann, *Boebachtungen der Moderne*, Opladen: Westdeutscher Verlag, 1992; and *Kindai no Kansatsu* (Japanese translation by Baba Yasuo), Tokyo: Hôsei University Press, 2003. Moreover, in Luhmann's understanding, the concept of "information" is closely connected with selective conduct, in the sense that information is supposed to combine with transmission and comprehension to form communication. This view of information seems to be in line with the traditional understanding of information, advocated typically by Claude Shannon.

[24] Maturana and Varela, *op. cit.*, p. 110.

[25] Hierarchical relationships based on restrictions or bindings are by no means special. It may be appropriate to regard a department or section of a private firm, for instance, not as a physical collection of employees, but rather as a sort of hierarchical system based on restrictions or bindings.

[26] Régis Debray, *Cours de médiologie générale*, Paris: Editions Gallimard, 1991; *Ippan Mediorojî Kôgi* (Japanese translation by Shimazaki Masaki, Tokyo: NTT Shuppan, 2001).

[27] Luhmann's theory of functionally differentiated society is a very ingenious one in that, on the premise that it is no longer possible to observe a modern society from a unitary perspective, it proposes to see the totality of the society as a confluence of its pictures as observed from functionally differentiated, plural perspectives. (For further details, see, for example, Yasuo Baba, *Rûman no Shakai Riron* [Luhmann's Theory of Society], Tokyo: Keisô Shobô, 2001.) Moreover, unlike the theory of fundamental informatics, Luhmann's theory defines the concept of meaning in relation with complexity. Despite these differences, Luhmann's concept of functionally differentiated system is adopted here in appreciation of its openness to admit of plural horizons of meaning to be derived from a variety of perspectives.

[28] The viewpoint that understands the mass-media system not as one that reports on facts outside it but as a closed system which continuously generate communications has been proposed by Luhmann. For further details, see Takehiko Daikoku, "Rûman no

Masumedia-ron" (Luhmann's Theory of Mass Media), *Shakai Jôhôgaku Kenkyû* (Journal of Socio-Information Studies, an official journal of Society for Socio-Information Studies), No.6 (March 2002), pp. 13-27.

[29] Luhmann calls the entities that keep communications going in each functionally differentiated system *Erfolgsmedien* (success-media) or *symbolisch generalisierte Medien* (symbolic generalized media). The success-medium in the economic system, for example, is the money. Each functionally differentiated system is led by the corresponding success-media to the horizon of meaning that is peculiar to the system.

[30] Takehiko Daikoku, " 'Media no Ippan Riron' e no Zenshô" (A Prelude to "A General Theory of Media"), M.A. thesis submitted to the Graruate School of Interdisciplinary Information Studies, the University of Tokyo, 2002, pp. 96-112.

[31] What Luhmann calls *Erfolgsmedien* (success-media) and *Semantik* (semantics) are characterized, in the theory of fundamental informatics, as conceptually corresponding to syntactic media and paradigmatic media, respectively.