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Typ-Ken (an Amalgam of Type and Token) Drives Infosphere

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Floridi's Infosphere consisting of informational reality is estimated and delineated by introducing the new notion of Typ-Ken, an undifferentiated amalgam of type and token that can be expressed as either type or token dependent on contingent ontological commitment. First, we elaborate Floridi's SLMS (System, Level of Abstraction (LoA), Model, and Structure) scheme, which is proposed to reconcile ontic with epistemic structural reality, and obtain the duality of type and token inherited in the relationship between LoA and Model. While we focus on the ontological commitment that can negotiate and emphasize the discrepancy between type and token, we show that most research focusing on different hierarchical layers (type and token) has converged onto the flattened perspective of type and token to clarify the role of ontological commitment. We propose the idea of Typ-Ken to avoid this flattening. In addition, we elaborate Taddeo and Floridi's criticism of approaches to the symbol grounding problem and show that their criticism based on the zero semantical commitment condition is specific to the agents affected by the flattening. We then take bird flocks as a metaphor for the *living* Infosphere as if it had one mind. The knowledge recently yielded by image analysis indicates that it is difficult for previous flock models based on agents equipped with the flattening of local (token) and global (type) to show the special feature of a flock of the scale-free proportion (SFP). We show here that agents based on the Typ-Ken can reveal the SFP, which is the essential characteristic of the living Infosphere. In other words, Typ-Ken is an expression for informational reality (LoA and Model with ontological commitment) that can reveal seamless local and global interactions in the functioning of a flock or Infosphere.

Keywords: Infosphere, Level of Abstraction, Type and token, Symbol grounding problem,

1. Introduction

The naïve problem of whether an object exists independent of an observer illustrates the conflict between epistemic and ontic realism. This is replaced by the problem of which contributes to reality, the inside or the outside of an observer (Matsuno, 1989;Rössler, 1998; Gunji and Toyoda, 1997; Gunji et al., 1997). In particular, when reality is replaced by intelligence, the issue can be analyzed in the context of the origin of intelligence. If one commits to the stance of intelligence having its origins outside of the individual, one may think that intelligence can be evaluated based on external behavior and may accept the Turing test (Turing 1950). Such a stance is reminiscent of Searle's Chinese room, in which one has to look for the internally localized intelligence and is destined to fail (Searle, 1980). Commitment to the outside turns out the inside and vice versa. While the inside and outside provide a dualism by which to comprehend intelligence, they cannot be independently separated. The symbol grounding problem (SGP; Harnad, 1990) is a revised version of the Chinese room issue. One has to bridge the inside and outside in SGP while explicitly distinguishing the inside from the outside.

The issue in bridging the inside and outside repeatedly appears in computer science. A computer is not a computer without an energy supply, and computing itself generates side-effects such as heat. The notion of computing can be extended to include this kind of interaction between the inside and outside (Smith, 2002; Gunji & Kamiura, 2004a, b). The inside and outside can be compared to the type and token, respectively, according to the terminologies of Peirce (1931-1958). They can also be thought of as the operand and operator, respectively, in the discourse of programming language. One of the solutions for bridging the gap between the operand and operator is given by a solution to a domain equation or denotational semantics (Scott, 1971; 1982). This is analogous to negative teleology. We call this kind of solution the flattening of the inside and outside or of type and token. Flattening has recently appeared in various fields under the names of autopoiesis (Letelier et al., 2003; 2006) and affordance (Chemero, 2003; Chemero and Truvey, 2007, 2008), which are also strongly relevant to SGP.

Luciano Floridi proposes the new concept of Infosphere (Floridi, 2007) based on the extended notion of computing and the philosophy of computing (Floridi, 1999). Computing with seamless integration of the local and global interaction is implemented in the Infosphere. He proposes an informational structural reality that reconciles epistemic with ontic structural reality (Floridi, 2004a; 2008, Floridi and Jeff, 2004). Informational structural reality is a basic component of the Infosphere. We think informational reality has to be different from the reality derived by the flattening of the Infosphere, in which computing with seamless integration of the local and the global is implemented in a "living space" as if controlled by one mind. Floridi, however, also says, "There is no longer any substantial difference between the processor and the processed (in Infosphere) (Floridi, 2007)". Although this seems close to the stance of flattening, if so, this stance may not be inconsistent with Taddeo and Floridi's (2005) stance on the criticism of the symbol grounding problem. The difference between the Infospace and collective intelligence based on the subsumption architecture is unclear. Thus, it is necessary to spell out the nature of the informational reality to reveal the agents in Infosphere and computing with seamless integration of the local and global.

Recent new knowledge about flocks, schools and herds of animals (Buhl et al., 2006; Ballerini et al., 2008a,b; Cavagna et al. 2009) may be a key to comprehending informational reality. A flock was previously regarded as a community of flockmates, each of which can match its velocity with its neighbors' in the neighborhood by the constant radii (Reynolds, 1987, Vicsek et al., 1995, Czirok et al., 2006). These models are based on agents equipped with flattening of local interactions (tokens) and global flock movement (type). Thus, it was confirmed that a flock, as if it were one living individual, can be explained by only a local interaction rule. It appears as if information is propagated more quickly than local information propagation, which requires the seamless unity of the information society.

It has recently been found through image analysis that each flockmate uses a dynamically changing neighborhood (Ballerini et al., 2008a, b) and that the bird flock forms a large sub-domain that scales with the linear size of the flock (Cavagna et al. 2009). This means that a flock behaves as if it were one united organism, independent of size, because of both local and non-local rules. In other words, inconsistency between the token (local) and type (non-local) that is not resolved at all contributes to collective behavior. Inconsistency in opposition to flattening may be an essential property of informational reality. We present a flock model based on agents with inconsistency between type and token, elaborating on the scale-free proportion in a flock. In particular, we refer to the amalgam of type and token as Typ-Ken and elaborate on the idea that Typ-Ken is an informational reality that can constitute the Infosphere.

In this paper, we first outline Floridi's informational structural reality based on the System-Level of Abstraction (LoA)-Model-Structure (SLMS) scheme, determine the dynamic inconsistency between type and token as an LoA-Model pair featuring ontological commitment, and discuss its role related to computing and the Infosphere. Second, we review some concepts based on flattening of type and token in the fields of computer science and system theory and compare them with informational reality. Third, we examine Taddeo and Floridi's criticism of approaches to the symbol grounding problem (SGP) and confirm that their criticism is directed toward the notion of an agent that engages in the flattening of type and token. We show that the inconsistent amalgam of type and token, the Typ-Ken, can avoid Taddeo and Floridi's condition for the SGP. Fourth, we illustrate the Typ-Ken as the dynamic neighborhood in real flocks and show that agents such as the

Typ-Ken can contribute to collective mind and/or seamless computing at the local and global levels. Finally, we show how inconsistency between the type and token can contribute to the informational reality.

2. Informational Structural Reality

The conflict between ontic and epistemic reality is a problem typical of the inside-outside issue. Floridi proposes the SLMS scheme to construct structural reality (Floridi, 2004a; 2008, Floridi and Jeff, 2004). Roughly speaking, matters external to an observer (i.e., recognized as the outside by the observer) consist of a pair <Structure, System>, and representations inside an observer consist of a pair <Level of abstraction (LoA), Model>. Pairs of <Structure, System> and <LoA, Model> can be compared to a <type, token> pair using Peirce's terms. Because type corresponds to the class, rule, or attribute being abstractly represented and token corresponds to the individual or object found in the external world, type and token also can be thought of as the inside and outside, respectively. The duality of the inside and outside is doubly embedded (Figure 1A-C).

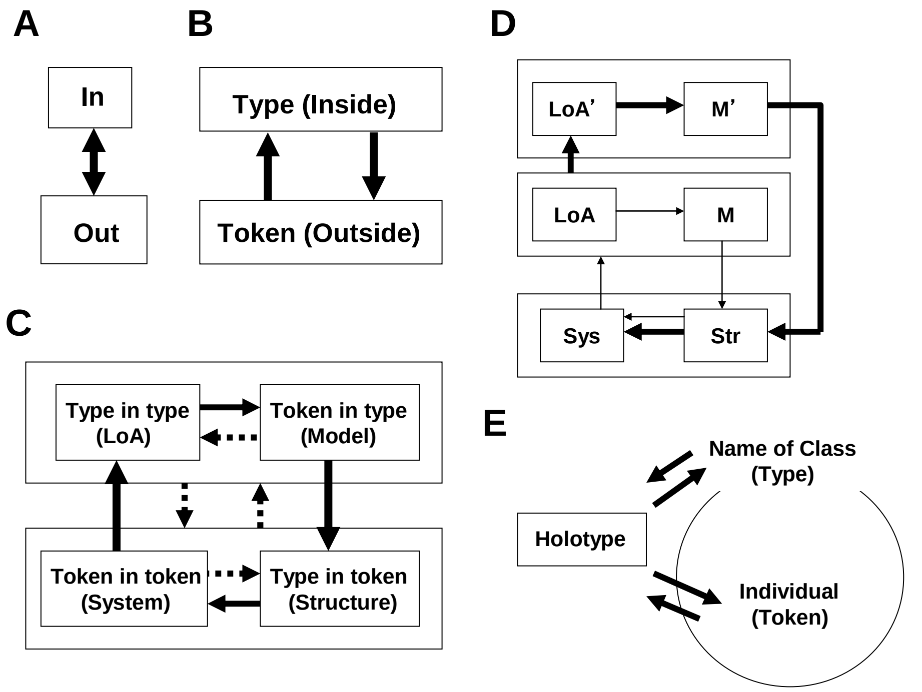

Figure 1. Comparison between type-token scheme and Floridi's SLMS scheme. A. Choice (double arrow) in the inside and outside. B. Duality between type and token. C. SLMS scheme viewed from the duality between type and token. D. The first (in thin arrows) and second (in thick arrows) ontological commitments in the SLMS scheme. The second ontological commitment reveals the broken arrow from the token in type to the type in type in C. The Symbols M, Str and Sys are abbreviations of Model, Structure and System, respectively. E. A holotype is both type and token in systematic biology.

The SLMS scheme works as follows: The system in the external world is regarded as a collection of (token-like) data, and it is represented at the level of abstraction. In other words, data are determined as a class in terms of range. This is type-like representation. Type always generates a model based on concrete and individual examples. This model is, therefore, token in its representation and works as the machinery to realize the class designated by LoA. When the generated model is applied to the external world, it identifies a particular structure. Finally, a collection of data that can possess such a structure is regarded as a system again (Floridi, 2004a; 2008, Floridi and Jeff, 2004)

Here, we view the SLMS scheme from the perspective of the type-token scheme. In an empirical world, the inside and outside are not differentiated, and either the inside or the outside is chosen from the amalgam of them (Figure 1A). When a pair of the inside and outside of an observer is implanted in an epistemological symbol world, it is transformed into a pair of type and token. Because type is distinguished from token by definition, ambiguity of type and token is superficially lost (Figure 1B). Ambiguous choice is replaced by a pair of dual opposite operations. The ambiguity, however, remains in principle, and a token-like property can be found in type and vice versa. Implanting of the inside and outside, therefore leads to differentiation of type- and token-like properties in type and token, respectively. Four components in doubly embedded type-token schemes are LoA, Model, Structure and System (Figure 1C). If dual opposite operations, shown as broken arrows in Figure 1C, are omitted, Floridi's SLMS scheme results. A pair of type in type and token in type corresponds to the theorem in the SLMS scheme (Floridi, 2004a, Floridi & Jeff, 2004) where the theorem is redefined by adding the structure (Floridi, 2008).

The opposite arrow from Model to LoA in Figure 1C is interpreted as an ontological commitment in the SLMS scheme. The opposite arrow originating from token-in-type (Model) works to compensate for the property of token in type-in-type (LoA). In other words, what is lost in the epistemological world (i.e., the property of token in LoA) is compensated by ontological commitment. Because the process proceeds only in one direction in the SLMS scheme, ontological commitment can work via Structure and System. This is the first-order ontological commitment (in LoA) that is shown as thin arrows in Figure 1D. The first-order ontological commitment affects a whole SLMS scheme leading to revision of the theory (i.e., a pair of LoA and Model). Thus, the thin arrow originating from System affects the outer rectangle that contains LoA and Model. Finally, it results in revision of LoA to LoA'(Floridi, 2008). The second-order ontological commitment is shown as thick arrows in Figure 1D.

Ontological commitment is always required because type cannot be clearly separated from token in an epistemological world. The holotype in systematic zoology yields a typical example. When a new species of animal is discovered, an article with a description of the morphological characteristics of the species is published in a technical journal, and a specimen representing the species, called a holotype, is preserved in a museum. By definition, a holotype is a type specimen representing most individuals in a species. Simultaneously, a holotype is a particular individual specimen chosen from a species (Figure 1E). Thus, a holotype is not only a type but also a token.

Actually, a holotype is expected to show an averaged morphology of its species. One can expect a particular distribution (e.g., Gaussian) for a species that is expanded from the holotype as the average. The holotype implicitly reveals the range of the morphological characteristics among all individuals of a species. If the range is not clear for one holotype specimen, several specimens are chosen and described as a paratype to capture the variation within the species. Paratype and holotype constitute an inclusion relation with respect to refinement. Holotype is therefore regarded as a LoA in the sense of Floridi (2004b, 2008). Because a holotype is always chosen from a population of collected specimens, the very population can be interpreted as a concrete example of a species represented by holotype. This population is therefore regarded as a Model in Floridi's sense and identifies a species as a virtual (but natural) concept. The notion of the species is nothing but Structure. The concrete population of collected specimens that is a token for the species as a type is attributed to the very species. Strictly speaking, collected specimens are first regarded only as data (System). If a researcher systematically finds a new species in a collection, he selects one specimen as its holotype (LoA), and a collection of specimens is redefined as a biological population (Model) representing the species (Structure).

Collection-Holotype-Population-Species can be interpreted as an SLMS scheme. Indeed, a pair <holotype, population> is regarded as <type, token> in type (as representations on the Inside), and a pair <species, collection> is regarded as <type, token> in token (as individuals on the Outside). Ambiguity of type and token is found in all components of SLMS schemes. As mentioned before, a holotype is a type as the name of a class representing all individuals of the species. A holotype is also a particular individual that has particular concrete characteristics. Imagine a species of bivalve. The holotype of this species is now assumed to be a specimen whose right valve is slightly undulated. The researcher who gave it a new species name and described its holotype did not notice this undulation. Subsequent researchers may notice that most of the collected specimens have no undulation and that the holotype is an unusual specimen. Alternatively, they may find that the species shows a bimodal distribution in terms of undulation morphology, with each individual being undulated or not. In both cases, the holotype is re-estimated, and LoA is replaced by LoA'. A holotype is not a pure symbol independent from the real world; it is connected with the real world and is opened to "non-finite" numbers of individual specimens. Because LoA has potentiality, it is opened to ontological commitment.

If all components in an SLMS scheme are restricted in a formal world, there is no ontological commitment. Even if the circulation S→L→M→S→… proceeds, it can be converged into a fixed point with respect to this circulation. In a sense of a fixed point, the difference and inconsistency between type and token is lost. This is flattening of type and token. Informational structural reality in an SLMS scheme is different from the reality derived from flattening because of the presence of ontological commitment.

3. Flattening by Infinity or Elimination

In systemic thinking, one can find duality between operand and operator, function and structure, and type and token. They take after the Cartesian issue of cogito: uniting “I” and “thinking I” or just connecting (or synthesizing) them. The way to unify them is flattening. In this section, we spell out flattening in various fields to make the significance of ontological commitment clearer. We employ the examples of a metabolic repair system, autopoiesis and affordance.

The metabolic repair (MR) system is proposed by Rosen to model the ambiguity of state and function (Rosen, 1958, 1972, 1991). Because a living system is essentially dynamic, it is not consistent with the notion of state that is defined by an element of a set. A living system is, however, defined by a dynamical system in which behavior is described as a series of states transformed by a particular map. In other words, a living system is defined by a pair of states and a map that are independent from each other (Rosen, 2000). There is a conflict between a real living system and its mathematical model. Rosen focuses on the property of homeostatic metabolism. The living system maintains its own behavior, which constitutes a homeostatic property. If metabolic states are defined by the elements of a particular set, the real metabolic state must carry a particular function that is nothing but a map transforming states. In this sense, the metabolic system reveals the ambiguity of state and function.

This ambiguity is mathematically implemented by one-to-one correspondence between states and maps. This construction involves one-to-one correspondence between a partitioning of possible maps and given states. If both states and maps are perpetually changed under this constraint of the one-to-one correspondence, the system can reveal a homeostatic metabolic system. Even if a metabolic state is altered by a huge perturbation, the system is repaired and maintained due to the adequate one-to-one correspondence between states and maps. This mechanism constitutes the metabolic repair system.

It is generally impossible to implement one-to-one correspondence between states and maps. Imagine a set of states whose number of elements is n. If a map of a metabolic system is defined on this set, the number of possible maps is n^n because each element can be mapped to n elements. One-to-one correspondence is not possible because n^n is much larger than n. If one attempts to acquire one-to-one correspondence between states and maps despite this asymmetry, one must take infinity as the size of the set or eliminate a subset of a set of all possible maps to reduce the number of elements to n (or partition a set of maps to reduce n). These two methods, using infinity or elimination, are flattening between states and maps. In particular, Rosen constructs a MR system by using flattening by a corresponding subset of maps to a state in a directed graph (Rosen, 1958, 1972, 1991). Because the state can correspond to a map and/or a function, the state can contain evaluation for its own state. This is anticipation (Rosen, 1985).

These kinds of flattening are found in various fields, where the pair of <states, maps> can be replaced by <data, program>, <set, power set> or <lattice, logic>. Scott introduces flattening between data and program (Scott, 1971). Given data, the flow diagram of data is regarded as a program. Because a program itself exhibits a data structure, one can construct a flow diagram of a program that is itself a program. The operation of constructing a flow diagram can be regarded as a particular map, and infinite numbers of compositions of this map are possible. Over an infinite operation of this map, one can assume a particular structure in which there is no difference between data and program. Applying the infinite operation to this particular structure can be equal to this structure because of infinity of the operation. This equation is called a domain equation, and a particular structureis obtained as a solution to this equation (Scott, 1982). This is a way of flattening using infinity. Because an infinite operation can be replaced by a loop, the difference between a set and a power set can be flattened by a loop. This yields a hyper set, as proposed by Aczel (1988). Barwise and Etchemendy (1987) also introduce a hyper set to express the Austin statement in which description cannot be separated from act.

A pair of <lattice, logic> is flattened by elimination. This method is found in generalizing topology via logic (Vickers, 1989). Given a set, one can obtain a particular collection of subsets called an open set. Topology is defined by a pair of this set and a collection of open sets. Topology yields a kind of filter by which an observer can see a given set. If a collection of open sets consists of a given set and an empty set, an observer can see either all or nothing. Because open sets are closed with respect to union and intersection, one can see the logical operations OR and AND in topology.

A pair of <set, topology> can be naïvely compared to <real world, epistemic world>. If an order is equipped with a set, one can see an algebraic structure like logic in an ordered set, especially in a lattice. Actually, a lattice is a specific ordered set (two elements can have an order) of which any two elements have both join (the smallest of the elements larger than a given two elements) and meet (the largest of the elements smaller than a given two elements). Join and meet are binary operations that are similar to OR and AND, respectively, in logic. Thus, the question arises of whether join and meet in a lattice can reconcile with OR and AND in a derived topology. If it is possible, roughly speaking, the real world can have one-to-one correspondence to the epistemic world.

The join is defined by using a universal quantifier because it is the smallest of the elements that are larger than a given two elements. The operation OR is defined by using an existential quantifier. Thus, join cannot be reconciled with OR. However, if join is defined only for two elements that are directed, join is consistent with OR. This is called directed join and is restricted with respect to its application. A lattice is consistent with topology by this elimination. In our sense, a pair <lattice, topology> is flattened by elimination.

When a pair of <states, maps>, <data, program>, <set, power set> or <lattice, logic> is depicted as a pair of <token, type>, flattening by infinity, loop and elimination are shown in Figure 2. Figure 2A shows flattening by infinity as demonstrated by the domain equation. In this procedure, the type (program) obtained by a particular map (*F*) is recursively regarded as a new token (data), which reveals the infinite composition of *F*. If this recursive process, represented by broken arrows in Figure 2A, is expressed as a loop, represented by the broken arrow in Figure 2B, flattening by loop takes place. This is implemented as a hyper set. Flattening by elimination is implemented in directed join as mentioned before.

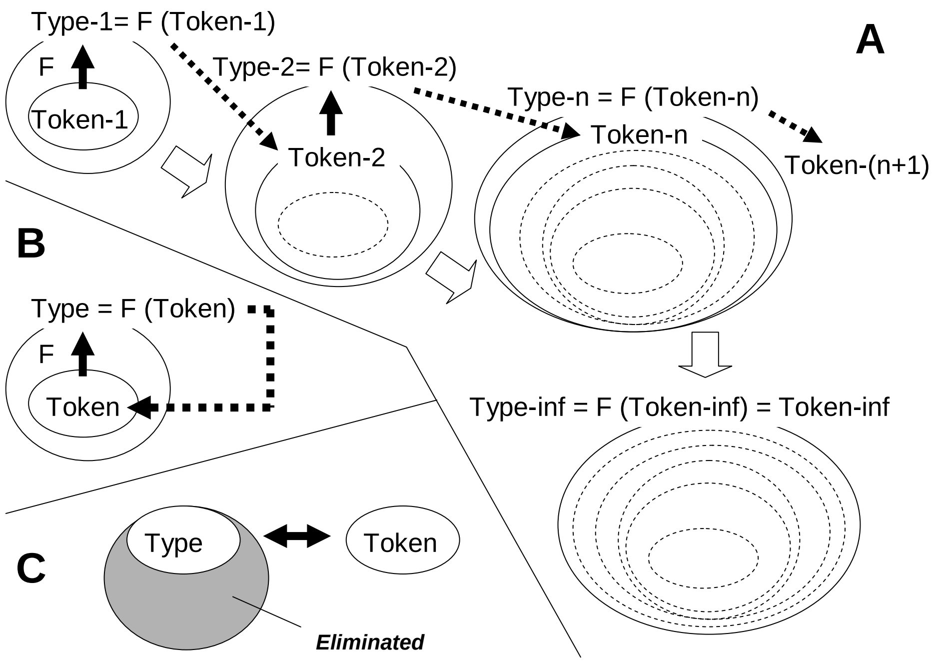

Figure 2. Two kinds of flattening between type and token: using infinity (A) and elimination (C), and the flattening derived by infinity, referred to as loop (B). A. Because type is regarded as a generalized token, the procedure of generalization is expressed as an operation, *F*. If a derived type is regarded as a new token, one can see the composition of generalization. The procedure of regarding is indicated by broken arrows. Infinite composition of *F* can lead to a particular structure, Type-inf = Token-inf. B. Flattening by infinity derives flattening by loop if the procedure of regarding type as token is recursively constructed. C. Flattening by elimination takes place if redundant parts of a type are omitted. The double-headed arrow represents equivalence between type and token.

In systemic thinking, the notion of autonomy is elaborated as an operational closure in which operations constitute a network web closed to others (Maturana and Varela, 1975, Varela, 1974; 1979). This is captured by the notion of autopoiesis, which means self-making. An autopoietic system is demonstrated by a system in which the chemical reactions creating the boundary components are encapsulated by the system's own boundary. On one hand, an autopoietic system is passively employed to the boundary. One the other hand, it actively makes and/or evaluates the boundary. Thus, an autopoietic system has double criteria. If there is inconsistency between these two criteria and the system perpetually adjusts the relationship between the boundary and creating the boundary, its ontological commitment can contribute to the autopoietic system. However, the autopoietic system seems to give up the ontological commitment. Varela and Maturana regard an autopoietic system as a unity in which two different criteria are consistently united. In autopoiesis, unity as existence is separated from evolution. An autopoietic system, thus, can evolve only through contingent encounters of different autopoietic systems called structure coupling.

Recently, Letelier (2003, 2006) elaborated on the similarity between autopoiesis and M-R systems. Given a set, we can imagine a hom set in which all possible maps of a given set are contained. Although a set never has one-to-one correspondence to a hom set, a subset of a hom set can be isomorphic to a given set. Letelier elaborates that this is the essence of autopoiesis as well as a formal model of the M-R system. This idea is also proposed by Ehresmann and Vanbremeersch (1987) in stressing the sense of category theory. These are nothing but flattening by elimination.

Affordance is also developed in the systemic thinking related to cognitive science (Gibson, 1979). Because it is immediately related to the critique of the representationism in artificial intelligence, affordance abandons the idea of representation. The theory of affordance consists of direct cognition and affordance. Direct cognition is a simple reaction triggered by an external stimulus without representation (Chemero, 2003). It never involves manipulating symbols, computing or logically thinking. According to Gibson, these hyper-processes are embedded in the environment itself and known as an affordance. A system operating in an environment behaves as what it is in a particular environment due to the affordance. This idea reveals that a system has harmonic consistency with its own environment. In other words, behaviors of the system have one-to-one correspondence between behaviors and evaluations of the behaviors. A pair of <behaviors, evaluations of behaviors> is also a pair of <token, type>. Affordance is simply implemented by flattening. Recently, Turvey and Chemero evoked flattening in the theory of affordance by elaborating on isomorphism between behaviors and evaluations and the hyper-set found in an affordance, which is equivalent to an MR system and an autopoietic system (Chemero and Turvey, 2007; 2008).

In sum, MR systems, autopoietic systems and affordance in systemic thinking converge into the idea of flattening in <token, type>. If <local rule, evaluation of local rule> is flattened, one can see that a system based on a local rule can harmonically adapt to its own environment. This idea was previously implemented by Brook's subsumption architecture (Brooks, 1991). There is no ontological commitment. This is erroneous. In the next section, we first see why the solution by flattening is erroneous through SGP, and next we propose an alternative in Infosphere in considering new knowledge about bird flocks.

4. Infosphere Driven by an Inconsistent Agent, Typ-Ken

4-1. Agent equipped with inconsistency in a symbol grounding problem

MR systems, autopoiesis and affordance originated from the notion of adaptive and/or learning systems. In adaptation, attention must be given to both the behaviors of a given system and evaluation of those behaviors (i.e., selection by environment). In naïve thinking, adaptation seems to result from consistent reconciliation of the system's behaviors and the environment's evaluations of the behaviors. How is this reconciliation implemented? One of the solutions is flattening between them. It is reasonable that MR systems, autopoiesis and affordance are converged into the perspective by flattening.

A system equipped with flattening is, therefore, expected to be adaptable to environments. In other words, this system has enough intelligence to compute an optimal solution and is regarded as an agent equipped with intelligence. Because of flattening, there is no difference between behavior and evaluation (or interpretation), data and program. Only the machinery syntactical process proceeds while retaining adaptability to the environment. Adaptation leads to the consistent connection between a system and its environment. Thus, if this connection is formed as a symbol, we can see that a system uses a particular symbol matched to some property of the environment. This leads to the Symbol Grounding Problem (SGP) (Harnad, 1990).

The SGP can be well-defined not only for agents equipped with flattening but also those without flattening. We elaborate on the SGP here in two cases. If an agent is equipped with flattening, the behavior of an agent is regarded as either behaviors or evaluations of behaviors because no difference exists between them. The SGP is well-defined only if an agent is regarded as a system without evaluation. In this case, we can see that an agent has no semantical property, and then the SGP holds in the form of how the semantics originated from a purely syntactical process. On the other hand, in the case of an agent without flattening, one can see both behaviors and evaluations of behaviors in an agent. In this case, one can say that an agent has an ambivalent property of behaviors and evaluations of behaviors. Because behaviors and evaluations can be compared to syntactical and semantical properties, respectively, ambivalence entails ambivalence of the syntactical process and semantical property.

We elaborate on the critique of the approaches to the SGP proposed by Taddeo and Floridi (2005) in the context of flattening. In analyzing the SGP, they provide a zero semantical commitment condition in which (i) no semantical resources should be presupposed to be pre-installed in the agent, (ii) no semantical resources should be uploaded from "outside" of the agent, and these points do not exclude the possibility that the agent should have its own capacities and resources in which its symbols are grounded. The zero semantical commitment condition presumes that the syntactical process is independent from the semantical one. Taddeo and Floridi distinguish three kinds of approaches to SGP with respect to the degree of usage of representation, namely, non-representationism, semi-representationism and representationism, and conclude that none of them can provide a valid solution to the SGP.

Non-representationism is represented by Brooks' subsumption architecture (Brooks, 1991). Brooks emphasizes that the SGP is solved by a subsumption architecture in the sense that elaboration of explicit representations is entirely avoided. Taddeo and Floridi (2005) respond that semantics are externally prepared in advance. We agree with this criticism in the context of flattening. Imagine an ant-robot in which subsumption architecture is implemented. An ant-robot has an arm and an eye (CCD camera) and acts dependent on its own states and captured camera images. If the robot is carrying no baggage with its arm and sees a piece of baggage in front of it, it takes the baggage and walks randomly. If the robot is already carrying a piece of baggage and sees another piece of baggage, it abandons the baggage there and walks randomly with no baggage. Although no intelligent process is taking place, baggage is deposited and concentrated in particular places as if the ant-robots had nests. Now, imagine that a piece of baggage is so deeply embedded in the ground that the robot cannot pick it up. The robot would be stuck trying to take on the embedded baggage. Its actions never result in collective intelligence. Thus we can say that the ant-robots succeed in developing collective intelligence only when adequate situations are selected and prepared. Other inadequate situations are eliminated and avoided.

The ant-robots' adaptation to an environment in which baggage is distributed randomly can result in collective intelligence. As mentioned before, if one thinks that adaptation results from consistent reconciliation between a system and its environment or between the behaviors of the robots and evaluations of the behaviors, flattening is required for consistent reconciliation. The way in which inadequate situations are eliminated and avoided is nothing but flattening by elimination. In other words, users of robots have to prepare particular situations by eliminating other inadequate ones. Semantics are uploaded from the outside. This is inconsistent with the zero semantical commitment condition. In our context of flattening, subsumption architecture is destined to entail flattening by elimination. An agent has just a simple rule by which external stimuli triggers particular actions. There is no diversity of actions to be evaluated and chosen. If one attempts to reconcile behaviors based on this simple rule with evaluations of behaviors that lead to the adaptation, one has to eliminate evaluations of behaviors.

The flattening of <token, type> appears in other approaches argued for by Taddeo and Floridi. Cangelosi and Harnad's (2001) approach is regarded as a representationism approach. This approach is based on categorical perception that allows an agent to acquire new symbols from a combination of already-grounded symbols. They argue that categorical perception is implemented in neural networks. In fact, the neural network modifies its synaptic weights dependent on its trainer's (i.e., environment) evaluation of a pair of input and output. The modification of synaptic weights corresponds to a change to a map, while a pair of input and output is just a part of a map. A map can be expressed as a set of input-output pairs for all inputs. The neural network always generalizes an individual input-output pair, makes a whole from a part, and leads to a type from a token. This is, in principle, categorical perception: making a category from an individual case. Insofar as a map consists of many input-output pairs, one cannot deduce a map just from one input-output pair. Categorization is possible only if one deduction rule is uniquely given and other possible rules are eliminated. This is the flattening between part and whole by elimination. Even if categorization is implemented by flattening by elimination, learning for a given map is possible with a large number of neurons and layers. Many repetitions of training can be converged into the target map. The number of synapses and hierarchical structures like middle layers can reveal a realistic and adequate learning system. However, it is prepared in advance dependent on the target map and/or trainer. Inconsistency between type and token is completely reconciled by a theoretician making a neural net.

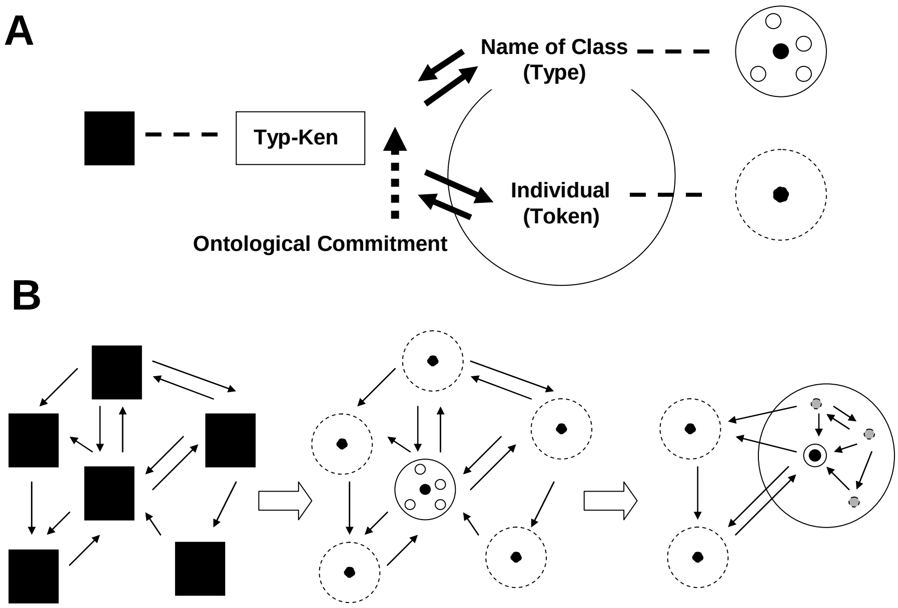

Figure 3. A. Typ-Ken carrying the ambiguity of type and token. Typ-Ken is always chosen to be type and token due to the ontological commitment. This implies transformation of two levels of abstraction (LoA). Token is here illustrated by an individual black dot that can be attributed to some class. Possible class is represented by a circle of broken lines. Type is illustrated by a black dot that can represent the set of individual white dots. B. The interaction of Typ-Kens can reveal the emergence of the symbol. A system consists of Typ-Kens interacting with each other (left). Depending on a local configuration, the Typ-Kens are changed to be either types or tokens (center). The commitment of the local configuration implies ontological commitment in the Typ-Ken. When possible members represented by type are actually determined by some tokens, the symbol (double circles) appears in a class (right).

The neural network, equipped with many neurons, in which the flattening between input-output pairs and a map by elimination is implemented can lead to a particular partition of the data. This seems to be categorical perception. However, categorical perception is always exposed to the essential question of how the class of the data is put together in the first place without any semantic capacity to elaborate the general idea of the data (Taddeo and Floridi, 2006). The system operates a particular collection of data as a unit because the flattening between a class and a collection of the data is implemented. For the system, the notion of a class cannot be distinguished from the notion of a collection of the data. The equivalence between class and collection is ready-made, and one can see neither the emergence of the class nor symbol grounding.

The SGP appears to be solved if a pair of intent and extent is implemented. The agent categorizes the data (objects) and abstracts a collection of properties that are attributed to all members of a collection. The agent names a collection of properties, intent, and a collection of objects, extent. After that, whenever the agent encounters a new object, it can check whether the object satisfies all properties of intent. In other words, one can regard intent as a type (symbol) and a member of the extent as a token. However, the distinction between type and token and between intent and extent is uploaded in advance. This is inconsistent with the zero semantical commitment condition. Mayo's functional model (2003), which implements a continuum of sensory data, employs flattening by infinity.

Although it sounds paradoxical, we have to introduce an ambiguous concept opened to both types and tokens (Figure 3) to comprehend the origin of symbols. We call this Typ-Ken, and it is inspired by the concept of a holotype (Figure 1E). A holotype is used as a type or representative of a collection of individuals and is regarded as a token or a particular individual. Thus, systematic zoologists can use a holotype as a representative of a species to describe a new species and simultaneously examine a holotype as a particular specimen when a property of a holotype is called into question. Like a holotype, while a Typ-Ken seems to represent a collection of tokens, a Typ-Ken is an individual object and a particular token. Here, a type is an individual that is expected to be a special token to represent other possible tokens. Possible tokens represented by type are virtual ones. The virtual tokens are represented by open circles in the diagram of types in Figure 3A. Possible class is represented by a circle containing special and virtual tokens. Figure 3B shows the emergence of the symbol. Typ-Kens interact with each other. Depending on the ontological commitment (e.g., configurations of Typ-Kens), they become either type or token. When some tokens are employed to be tokens represented by type, possible virtual tokens assumed in type are determined, and type is represented by actual tokens. This is the emergence of the symbol.

One can choose a particular individual man as a representative of a particular population (e.g., Barack Obama as a representative of the United States). In contrast, when you encounter a particular Japanese person by chance, you can form an impression of Japanese people based on his character. If he is a nice guy, you form a good impression of all Japanese people; otherwise, bad. Any individual man (token) is expected to be a type. Additionally, a type is expected to be a particular token. This ambiguity is employed in Typ-Ken.

Introducing Typ-Ken avoids the zero semantical commitment condition because there is no clear distinction between syntax and semantics. It does not mean complete fusion of syntax and semantics that can be implemented by the flattening. Any approaches to SGP are based on the flattening between type and token if they are designed by bottom-up fashioned constructivism. The syntactical process implemented in the agent thus has no semantics, so the SGP has to be solved by semantical resources uploaded from the "outside" of the agent. On the other hand, Typ-Ken is both a type and a token in an undifferentiated manner. Because it is undifferentiated, one cannot find semantical resources pre-installed in the agent. Typ-Ken thus avoids zero semantical commitment condition (i). Also, because Typ-Ken contains undifferentiated semantical resources, it does not require semantical resources uploaded from the "outside" of the agent, so Typ-Ken avoids condition (ii).

As mentioned at the beginning of this section, SGP can be well-defined not only for agents equipped with flattening but also for those without flattening. Typ-Ken is the agent without flattening, while it is opened to both type and token. A pair of a type and a token corresponds to LoA and Model (or LoAs), so Typ-Ken with an ontological commitment can correspond to informational reality. In the next section, we spell out Typ-Ken more concretely by using a bird flock as a metaphor for a living Infosphere.

4-2. Typ-Ken as Informational Reality in a Flock

Bird flocks, swarms of insects and/or fish schools are typical forms of biological collective behavior (Sumpter, 2006, Goldstone and Gureckis, 2009). Each agent manages to adjust its local directive motion with global mass behavior. This kind of pair reveals <token, type>, so the agent seems to negotiate the difference of <local, global>. The classical model, called BOID, is based on the flattening between local and global properties (Reynolds, 1987). A local rule, which the agent follows, is defined to reconcile local interactions and global behavior, maintaining a flock. A local rule is expressed in three parts: (i) the agent avoids collisions in the inner neighborhood; (ii) the agent matches the velocity among nearby agents in the middle neighborhood; and (iii) the agent attempts to stay close to nearby agents in the outer neighborhood. If the neighborhoods in (i)-(iii) can be defined as concentric neighborhoods with different radii, various patterns of flocks and avoidance patterns from a predator are obtained (Parrich and Edelstein-Keshert, 1999, Couzin et al., 2002). The simple model called SPPs (self-propelled particle system) or active Brownian particles (Strefler et al., 2008) can also reveal flock and school patterns if the boundary condition is given periodically, where SPPs is based on a local rule equipped only with neighborhood (ii) (Vicsek et al., 1995, Czirok et al., 2006).

Although previous models for flocks and schools are equipped with the invariant local rule, constant radii of neighborhoods and invariant strengths of interactions, real birds seem to adjust the local rule dependent on their situation in keeping a flock. A bird seems to weaken the interaction to detect a magnetic stimulus when foraging and strengthen it during avoidance of a predator (Couzin, 2007). This behavior results in the flock itself behaving as if controlled by one mind. Recent progress of image analysis techniques reveals the dynamic structure of flocks. One finding is topological distance of the neighborhood (Ballerini et al., 2008a, b). Movies of starlings were analyzed with respect to the correlation function; namely, how correlated a bird is with its *k*-th nearest flockmate is estimated. It is obtained that each bird is strongly correlated with the first through sixth or seventh nearest flockmates independent of the distance between them. This is called topological distance. This means that the neighborhood in which the bird matches its velocity to its flockmates is dynamic. This phenomenon is consistent with birds' numerical ability (Hunt et al., 2008).

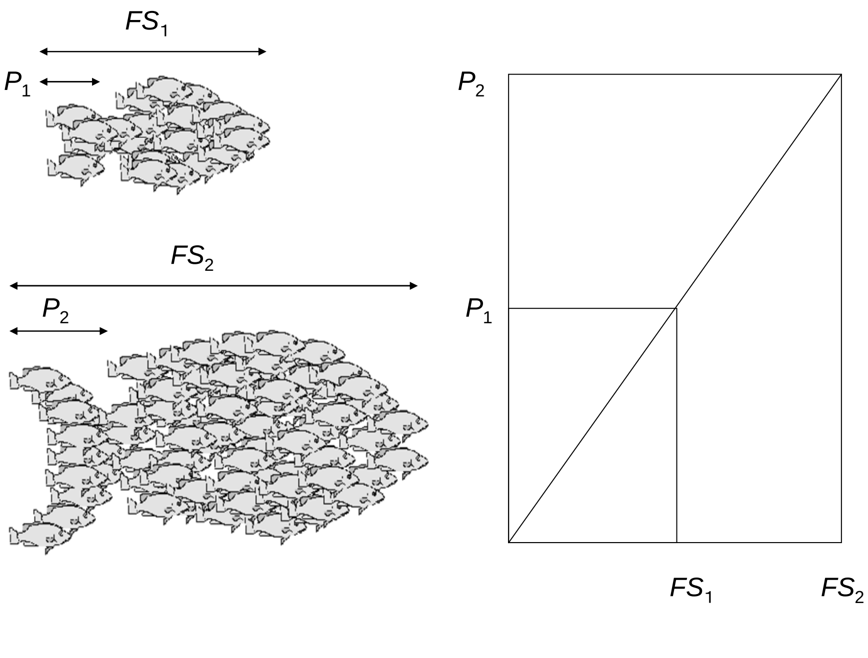

Figure 4. Scale-free sub-domain in a fish school. Diagram shows that fishes form a crowd-fish as if one individual. Independent of the size of the crowd-fish, the relative size of the tail is constant, as shown by $P_1/FS_1 = P_2/FS_2$. One can obtain a linear relationship between the tail and the crowd size.

A much more important phenomenon is the scale-free proportion in a flock (Cavagna et al., 2009). The bird flock forms a large sub-domain that scales with the linear size of the flock. Given a distribution of bird velocities, the fluctuation vector for each bird is defined by the difference between its own velocity and the mean velocity of the flock. If the fluctuation originated externally, it is expected that fluctuations are homogeneously and randomly distributed. However, one can see some sub-domains in which fluctuation vectors show the same direction in a real flock. Such sub-domains are synchronously updated as if agents were directly connected with each other. Additionally, the relative size of the sub-domain is constant, independent of the flock size.

Figure 4 is a cartoon emphasizing scale-free proportion. Fishes form a crowd fish dependent on the size of the population. If a crowd-fish swims as if one individual, fishes involved in the tail of the crowd-fish move synchronously. In this case, one can see a sub-domain in the tail in which fluctuation vectors have the same directions. As shown in the right graph in Figure 4, the proportion of the sub-domain and the domain size are constant. The proportions of a large-scale crowd-fish are the same as those of a small-scale crowd-fish.

Actually, the size of the sub-domain synchronously updated in a flock is temporally changed with respect to size, number and shape. Thus, the size of the sub-domain is statistically estimated by the mean size that is obtained as the distance at which the correlation function is zero. The scale-free proportion suggests that a flock can adjust its own body image. A flock seems to have a collective mind. A man can change his or her body to adapt to an operational environment. When a driver is used to driving a particular vehicle, he or she can perceive the location of the vehicle as if it were an extension of his or her body, even if it is a very large vehicle like a bus. A scale-free proportion suggests the same phenomenon.

How can we explain the scale-free proportion found in a flock? A flock is a population of agents, a huge computing space and Infosphere. Can this phenomenon by explained in terms of agents equipped with flattening? The agents of SPPs equipped with flattening of <local interaction, global flock> cannot explain this phenomenon (Niizato and Gunji, 2010a). A phenomenon like scale-free proportion in a flock is obtained if the correlation function is dumped with the power law (i.e., scale-free correlation). This reveals a critical relation between the order (a united flock) and perturbation. If such a critical perturbation is chosen in SPPs and the environment inhibiting the breaking up of a flock is prepared for SPPs, scale-free correlation is obtained. However, a flock is situated between order and chaos in this critical phenomenon. Various sized flocks appear in time development, and no internal structure like a sub-domain appears. In a flock revealing a sub-domain, perturbation is autonomously controlled and is internally originated. Different from SPPs, perturbation does not seem to be opposite to the mechanism making a flock. Different from critical phenomena, coherent patterns coexist with scale invariant correlation (or autonomous perturbation). We thus have to search for an alternative way to explain scale-free proportion.

Recently, we applied the concept of Typ-Ken to the neighborhoods of individual animals. Although we previously proposed a continuous state model (Niizato and Gunji, 2010a, b), we here show the discrete state and space model. The neighborhood of an individual in a flock, school or herd is also regarded as a type and a token. The neighborhood is sometimes a kind of extended body of the individual. If a mesh size of a fish net is large enough for a sardine to go through the net, a solitary sardine can escape from the net. However, sardines forming a school cannot go through the same fish net. It seems that the neighborhood of the individual sardine plays a role in extending its body, and then the neighborhood becomes stuck in the net (Nakajima in personal communication). In this case, the neighborhood is employed to the extended body. The neighborhood of the individual is not a local space in which its flockmates are located but a body equipped with intentionality. In the sense of the extended body, the neighborhood is a type.

On the other hand, even if a school or flock is maintained and the density of the neighborhood is low, each individual manages to follow the flockmate in the neighborhood (Niizato and Gunji 2010a, b). In this case, the neighborhood is used as a local space in which the individual and its flockmate (other individuals) are located. The case reveals that the neighborhood is used as a token. The ambiguity of type and token neighborhoods is implemented by the switches between metric and topological distances in the previous model (Niizato and Gunji, 2010a, b). Here, we implement the ambiguity by using Typ-Ken as either type or token.

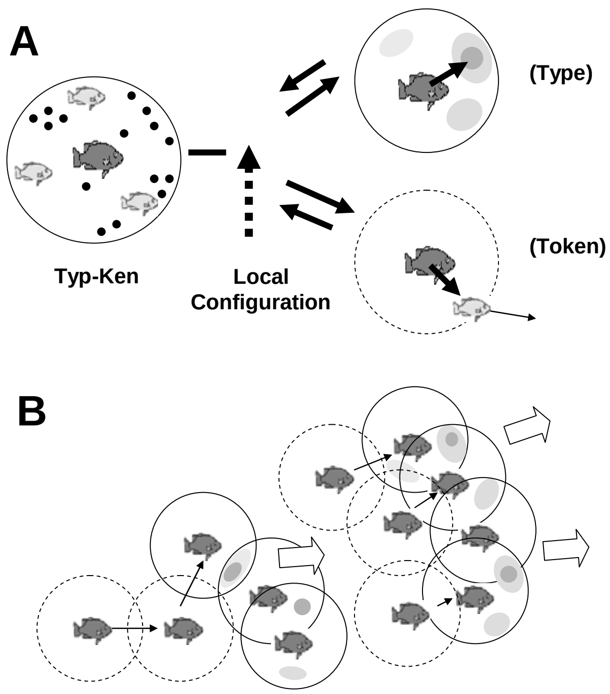

Figure 5. A model for a flock and school based on the Typ-Ken. A. Triadic system consisting of Type, Token and Typ-Ken. Typ-Ken is a basic neighborhood of the individual. Type and Token correspond to the extended body of the individual and a local space with flockmates, respectively. B. Movement of a flock or a school. The neighborhood is used as the type-neighborhood (solid circle) or token-neighborhood (broken circle) dependent on the local configuration. See text for detailed discussion.

The neighborhood as Typ-Ken is expressed as shown in Figure 5A. Space is defined by two-dimensional lattice space, and time is defined by discrete steps. The Typ-Ken is the neighborhood of an individual (dark fish at the center) equipped with possible next positions of the individual (black dots in the circle) and its flockmates (pale fishes). The individual has its own velocity (direction and constant scalar, omitted in Figure 5A) and possible next positions (dots mentioned above) are given from this velocity with constant deviation. The neighborhood is expressed as a circle with constant radius. If the individual is isolated from other flockmates, there is no flockmate in the neighborhood. In that case, the individual at the center can move to one of the possible next positions. If the Typ-Ken is used as a type-neighborhood, flockmates in the neighborhood are ignored, but possible next positions of both the centered individuals and its flockmates are superimposed in an additive way. Each site is enumerated by counting the number of possibilities, which is represented by contours with respect to density. The centered individual can move to sites favored by many flockmates. If the Typ-Ken is used as a token neighborhood, all dots representing possible next positions are ignored, and one based on a moving flockmate in the neighborhood is chosen. In other words, the individual follows one of the moving flockmates in the neighborhood.

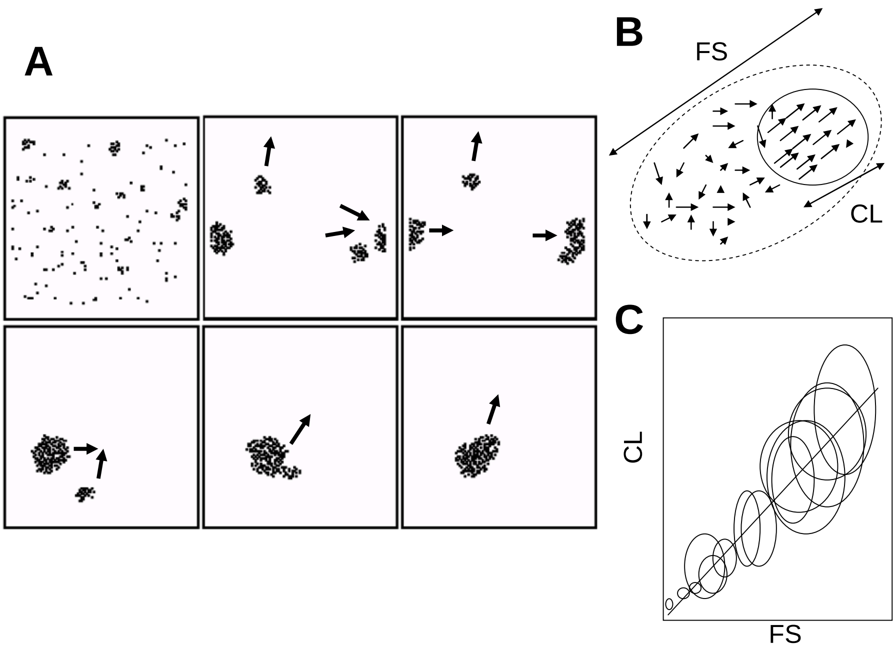

Figure 6. A. Snapshots of our model based on Type-Ken. For an initial random distribution of agents, some aggregations occur after 1000 time steps (upper left). After 10,000 steps, three moving flocks are encountered and are fused into one flock (upper to lower, left to right). Arrows represents the movement of the nearby flock. Simulation is executed for 200 agents given a periodic boundary condition. B. Schematic diagram representing sub-domains of a flock. FS: flock size, CL: correlated length. C. Linear relation between FS and CL obtained from simulation results. An ellipse represents the population of the data originating from the population of the same number of agents. The center of the ellipse represents the mean value, and the radius represents the standard deviation.

The type-neighborhood is a bundle of possibilities that is the extended body of the individual. The type-neighborhood results in resonance of individuals, which determines the motion of individuals. In contrast, a token-neighborhood is a *naked* individual, and the individual in a token-neighborhood can follow a flockmate because the neighborhood consists of tokens. The next question that arises is what determines the presence of either a type- or token-neighborhood for the Typ-Ken. Indeed, how is the local rule adapted to the individual and dependent on the neighborhood? In our flock model, local rule is updated to individuals in an asynchronous manner.

The algorithm is summarized as follows. First, velocity matching occurs among the nearest neighbors. Second, the next possibilities for all individuals are enumerated at each site. We call this number the popularity. The higher the popularity is, the more individuals can move to the site. If there is a site in which this popularity is beyond a given threshold value in the neighborhood, the Typ-Ken is used as a type-neighborhood. Otherwise, it is used as a token-neighborhood. Updating is divided into three phases. First, the individuals in a type-neighborhood are updated. The individual moves to the site with the highest popularity in the neighborhood. If the site with the highest popularity is common for multiple individuals, only one randomly chosen individual can move to the site. Other individuals move to the second highest popularity site. After all individuals in the type-neighborhood are updated, individuals in the token-neighborhood are updated. If the vacant site appears in the token-neighborhood because of the movement of the individual in the type-neighborhood, the individual in the token-neighborhood can move to this vacant site. If one vacant site is common to multiple individuals, one individual is randomly chosen. If there are multiple vacant places in the token-neighborhood, the individual moves to a randomly chosen vacant site. If there is no vacant place in the token-neighborhood, one of the possible sites is randomly chosen, and the individual moves to that site. At most, one individual is at one site.

Asynchronous updating with local configuration is an expression of ontological commitment. In our model, asynchronous updating prohibits conflict between individuals with respect to reaching the new site in a lattice space. If synchronous updating is implemented, individuals going to the same site encounter a conflict entailing a dead end. In this sense, asynchronous updating is an essential part of ontological commitment in a non-mechanical manner.

This model mimics the behavior of flocks and schools very well (Figure 6). Once some individuals are gathered at some places, the Typ-Ken is employed to the type-neighborhood, and the extended body can be interacted with itself. As a result, some agents are matched with respect to the velocity and move in similar directions. If flockmates in the neighborhood suddenly move or disappear in the token-neighborhood, the agent follows them, creating a moving flock. When a flock encounters another flock, it sometimes has a repulsive reaction and sometimes is fused. Thus, finally, the flock is united as one moving flock. While a flock always consists of agents in both type neighborhoods and token neighborhoods, internal structure in a flock occurs and dynamically changes. Our model has some parameters: the radii of the neighborhoods, the number of possible states in the neighborhood of Typ-Ken, and the deviation angle from the velocity allowing the distribution of the possible states. While the behavior of flocks is dependent on parameters in terms of the number of flocks, stability of flocks, and polarities (similarities of velocity) in a flock, the dynamic internal structure (not random) in a flock can be found independent of the parameter setting. This is an important characteristic different from SPPs or the agent system equipped with flattening. The dynamic internal structure shows the existence of sub-domains in a flock, as mentioned before. Mean size of the sub-domain is statistically estimated by the correlated length, which can be defined as the zero of the correlation function. Figure 6B shows the schematic diagram revealing the sub-domain with the correlated length. The arrow represents the fluctuation vector of the individual in a flock. The length of the sub-domain surrounded by a broken circle is nearly equal to the correlated length. For a flock, one can obtain a pair of flock size and correlated length (size of the sub-domain). Depending on the number of agents in a flock (population size), one can obtain various pairs of flock size and correlated length. Figure 6C shows the relationship between flock size and correlated length over various population sizes in our Typ-Ken model. It shows a linear relation, and the sub-domain occurs in a constant proportion independent of the population size. This is nothing but scale-free proportion (SFP) in a flock. SFP is also obtained in our previous flock model based on the ambiguity of type and token (Niizato and Gunji, 2010a, b).

The generation of scale-free proportion results from ambiguity of type and token in Typ-Ken. If the local density is high in a flock, the Typ-Ken is employed as a type, and the agents move to one of possible next states available in the neighborhood. Because possible states deviate from the agent's own velocity and the velocity is matched with nearby flockmates, the agents that are close to each other and are part of a type neighborhood maintain similar velocities. By contrast, if the local density is low, the agents only follow the front runner due to the presence of a token neighborhood, and similarities among agents are very low. As a result, a dense region shows correlated fluctuation vectors. Partition of type and token neighborhoods in a flock can generate dynamic sub-domains in a flock. A flock can move and behave as if controlled by one mind.

4-3. Typ-Ken in Infosphere

Compared to agents equipped with flattening, a flock based on the Typ-Ken reveals self-organizing autonomous fluctuation. In SPPs and various flock models, fluctuation contributes to all agents homogeneously, like thermal noise. There is no internal local structure in a term of thermal distribution. In our flock model, fluctuation is stored in the type neighborhood and is released in the token neighborhood. In the type neighborhood, the agents have similar velocities to their flockmates, and the local adjustments between individuals are weakened because the movement of the agent in a type neighborhood is consistent with matched velocity. In a token neighborhood, the agent moves independent of its own velocity. It follows nearby flockmates, reflecting contingent local configurations of agents. The movement contributed by the token neighborhood generates various velocities in a local region in a flock, so it releases the fluctuation. Locally storing and releasing fluctuation reveals self-organizing autonomous perturbation. This is the main engine of a flock's behavior as if it were controlled by one mind.

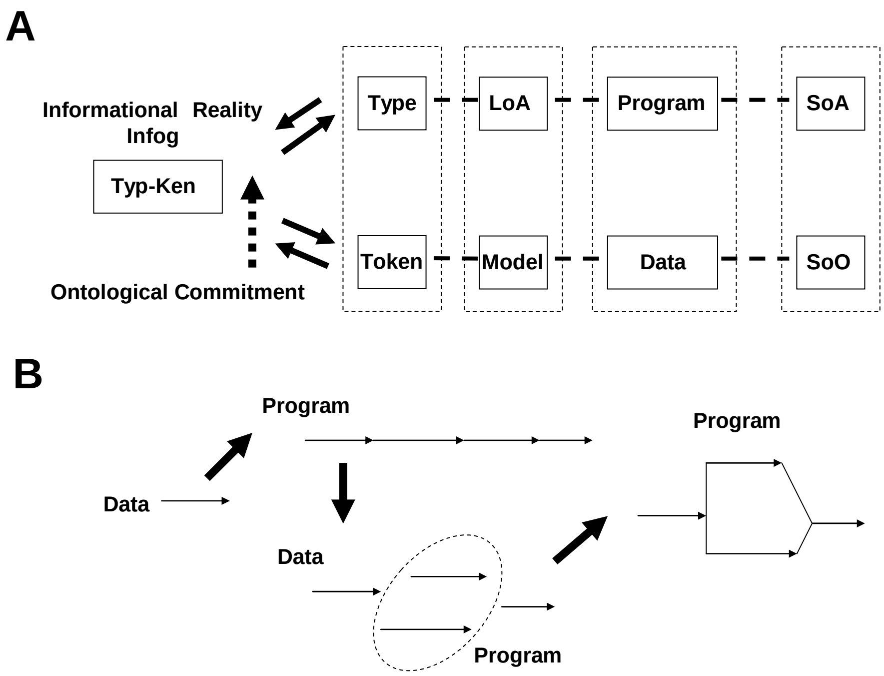

Figure 7. A. Comparison among pairs of <token, type>, <Model, LoA>, <data, program> and <SoA, SoO>, where SoO and SoA represents sense of ownership and sense of agency in body image, respectively. They can be regarded as being based on Typ-Ken. The Typ-Ken is an informational reality or an Inforg, the agent in Infosphere equipped with ontological commitment. B. Schematic diagram revealing the origin of a distributed process based on Typ-Ken. The data are regarded as a program via Typ-Ken and vice versa. Redundancy leads to distributed processes.

We here recall the notion of Infosphere and informational reality proposed by Floridi (2004a; 2008). In our context, a pair of <Model, LoA> can compare to a pair of <token, type> (Figure 7A). Level of abstraction reveals the type of data involved, and abstracted individuals refer to various concrete matters. Floridi illustrates LoA using a series of coin tosses (Floridi, 2004c). When you toss a coin six times, you can obtain a series of the property of heads (1) or tails (0) like 101010. You may consider the model generating this 1-0 series as the repetition of 10 three times. The more you toss, the more complex is the model obtained. A finite length series of coin tosses is regarded as a level of abstraction. One of the expected models for the series of coin tosses is a Model Floridi mentions. A Model is, thus, regarded as a token. According to Floridi, LoA is arbitrarily chosen and can be modified through ontological commitment. Even for a coin toss, various features of tossing can be chosen as LoA, such as manner of toss, number of rotations, and so on. When you model 101010 as the repetition of 10 three times, you may record tossing by video camera and find that the manner of tossing is the same in all odd-numbered tosses. At that time, you may revise LoA based on the manner of the toss. In this context, ontological commitment is not separated from interactions between LoA and Model or between type and token.

The interactive LoA and Token opened to ontological commitment is expressed as Typ-Ken. For the same reason, the interaction between data (processed) and program (processor) can be based on Typ-Ken (or Dat-Ram (an amalgam of the data and program) opened to ontological commitment. Floridi illustrates Infosphere by comparing the post-cybernetic metropolis of *Ghost in the Shell* with a *Matrix*-like scenario (2007). He emphasizes that there is no longer any substantial difference between the processor and the processed and that there is a gradual disappearance of ontological friction. This means there is no difference between the real thing and a representation, which is consistent with structural reality. It is easy to compare before and after structural reality to the scenarios of *Matrix* and *Ghost in the Shell*, respectively. However, even if one introduces structural reality, one is faced with the opposition between epistemic and ontic structural reality. Although it leads to the reconciliation of epistemic and ontic structural reality, the inconsistency between epistemic and ontic reality is replaced by the conflict between type and token and never disappears. In this sense, an Infosphere consisting of informational reality and/or inforgs should not be equipped with flattening.

Ontological commitment never disappears and essentially contributes to Infosphere. The scenario of *Ghost in the Shell* is a little bit naïve. Floridi compares the interface connecting users with objects in a real world with a digital interface (Floridi, 2007). The former is represented by a dishwasher. He says, "…whilst a dishwater interface is a panel through which the machine enters into the user's world, a digital interface is a gate through which a user can be presented in the Infosphere". The iPhone provides a good example. Images captured by the iPhone's camera can be equipped with tags containing some information on the iPhone's display. If you see a hotel, you can view a tag presenting information such as its room charges and restaurant menu. You certainly see the building in front of you as a hotel at which you can stay, which means that the hotel with the tag is the informational reality brought out from both the user and the real world. It is easy to imagine that wearable computers could evolve from the iPhone such that informational reality is always present through a head-mounted display and headphones equipped with a camera and microphone. In addition, if artificial tactile processes and artificial odors are made available and visual and audio images are replaced by virtual ones, one can perceive informational reality independent of real things. Although there is no longer a difference between the real and the virtual, the informational reality is opened to ontological commitment. The sense of discomfort between different sensory modes extends to the inconsistency hidden in informational reality. This corresponds to inconsistency between LoA and Model, or type and token, as when the manner of tossing is discovered as a new LoA when observing a series of {heads, tails} coin tosses. Evolvability of informational reality suggests ontological commitment.

Ontological commitment in informational reality is present not only in Infosphere but in everyday life. Although we naïvely believe that our body really exists as what we see, our body image is also regarded as informational reality. Phantom limb (Ramachandran, and Rogers-Ramachandran, 1996, Ramachandran and Hirstein, 1998) shows a typical example, but flexible body image can be found in ordinary people. Imagine that you see an artificial rubber hand in front of you while your real hand is hidden beside the screen (Botvinick and Cohen, 1998, Ehrsson et al. 2004). If your real hand and the rubber hand are synchronously touched by a paint brush, you perceive that the rubber hand is yours. Similarly, synchronous operation of tactile and visual stimuli can bring about an out-of-body experience (Lenggenhager et al., 2007, Ehrsson, 2007). These phenomena show that our body image can easily be modified in sense of ownership (SoO). Recent results elaborate that body image results from dynamic negotiation between SoO and SoA (sense of agency: sense of operating body) (Tsakiris et al., 2006, Farrer and Frith, 2002), although it was previously thought that SoA was based on SoO (Gallagher, 2000). SoO and SoA can be compared to token and type, respectively, because SoA includes operation. The experimental fact that it is easy to modify body image reveals body image as informational reality involving an inconsistency between SoO and SoA. Even our body image is open to ontological commitment.

Although it sounds as if no ontological friction is much more effective for Infosphere, ontological commitment essentially contributes to the behavior of Infosphere as if it were a unified living entity. Although Luciano (2007) mentioned that there is no distinction between the local and global in Infosphere, this seamless feature is found not in dynamics or mechanism but in functional properties. Seamless mechanisms are implemented by the agent equipped with flattening, which shows no seamlessness of function, as illustrated in SPPs for flocks. The agents as the Typ-Ken with ontological commitment that never implement seamless structure between the local and global in dynamics can contribute to seamless function.

In the previous section, we suggested the role of the Typ-Ken for computing in Infosphere. An underlying important feature is ambiguity of type and token. One man is sometimes regarded as an individual and sometimes as a representative of all Japanese people. If a particular Typ-Ken is determined as an unnecessary (or necessary, respectively) computational resource in computing and is regarded as a type, all tokens that are interpreted as being attributed to the type are given up (or are taken up, respectively). One individual calculation leads to mass computing, which is very efficient. However, the ambiguity of type and token is arbitrary and contingent. A token is not always regarded as a type. Therefore, contingent and dynamic changes in the distributions of types and tokens bring out self-organizing autonomous fluctuations leading to a united crowd that behaves as if controlled by one mind. The contingent ambiguity contributes local storing and releasing fluctuations, leading to the *living* Infosphere.

The Typ-Ken may reveal the evolution of functional distributed processing (Figure 7B). Imagine that the Typ-Ken interpreted as data can be contingently regarded as a type and then regarded as a collection of tokens. This means generation of similar data, which implies simple repetition and redundancy (compositions of data (arrow) in Figure 7B). However, plural data are not independent of each other. Because they were attributed to the same type, they are employed in united computing. Indeed, imagine that some two tokens (surrounded by broken circles in Figure 7B) are typed and become tokens again. These two tokens get different characters in type but are employed by a synthesized behavior. This leads to parallel distributed processing (right circuit in Figure B). Via the Typ-Ken, redundant system is perpetually modified and finally becomes a parallel distributed system. Redundancy (or robustness) and high efficiency are dynamically bridged via the Typ-Ken equipped with ontological commitment. The Typ-Ken drives a *living* Infosphere.

5. Conclusion

Luciano Floridi extends the notion of computing in the context of philosophy of computing, proposes a way to reconcile epistemic with ontic reality, and evaluates approaches to solving the SGP. These studies are immediately connected with each other and converge onto the idea of the Infosphere. The Infosphere consists of inforgs and informational reality that is developed through arguments on the reconciliation of ontic and epistemic reality. Informational reality is regarded a pair of Level of Abstraction (LoA) and Model with ontological commitment. Because a pair of <LoA, Model> can be compared to a pair of <type, token>, informational reality can be defined as a pair of <type, token> with inherited inconsistency between them. Inconsistency is an intrinsic feature of informational reality derived from ontological commitment.

To spell out the role of ontological commitment in a pair of <type, token>, we introduce the term Typ-Ken to compare with the flattening of type and token. We show that systemic thinking in the form of MR system, autopoiesis and affordance can be converged into flattening. On the other hand, if a pair of <LoA, Model> is converged into flattening, there is no ontological commitment. Before we see the significance of ontological commitment, we discuss approaches to the SGP evaluated by Taddeo and Floridi in the context of flattening. Because the agent system of bottom-up fashion is essentially based on flattening, the flattened operation defined by the agent is regarded as a purely syntactical process. Thus, one can find semantics giving the agent a functional role outside of the agent. This is inconsistent with the zero semantical commitment condition proposed by Taddeo and Floridi. As a result, if flattening between type and token or syntax and semantics is introduced, the SGP cannot be solved because semantics are always found outside of the agent.

Without flattening, we have to accept the difference between type and token on one hand and undifferentiated ambiguity of type and token on the other hand. This is a pair of <type, token> relevant for ontological commitment.

We here propose the concept Typ-Ken, which is amalgam of type and token and appears as either a type or a token dependent on contingent ontological commitment. We confirm that Typ-Ken can solve the SGP while avoiding the zero semantical commitment condition. In particular, we review recent issues in modeling behavior of flocks and schools and show that scale-free proportion (SFP) found in a flock cannot be explained by the model equipped with flattening. We claim that our flock model based on the Typ-Ken can reveal SFP that achieves the body image of a flock with constant proportion. In other words, Typ-Ken with ontological commitment can contribute to the living flock's behaving as if controlled by one mind. Finally, we suggest that Typ-Ken opened to ontological commitment can balance robustness (or redundancy) and efficiency in a self-organizing manner. These systems can generate parallelism from redundancy. The Infosphere can be designed and constructed by using the Typ-Ken.

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