Peter Fleissner, Wolfgang Hofkirchner

Emergent information

Towards a unified information theory

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Abstract

This paper proposes the restoration of information theory by means of a philosophy of evolutionary systems. What this philosophy implies for the conception of information may be called a multi-stage model, comprising both the history and the ordering of information processing by real-world systems. Such a unifying information concept may assist suitable research in the coming field of information science.

Keywords: Emergentist philosophy; Evolutionary systems; Theory of information; Semiosis

1. Information science

So far, no common information-concept has been agreed upon which might serve as a crystallisation nucleus for those sciences dealing with certain aspects of real-world information-processing manifestations; such a crystallisation nucleus would unify them and turn them into a single, though transdisciplinary information science. However, working out such a definition for the term information", thus promoting a general theory of information as distinct from the well-known information theory we have had so far, is an idea whose time has come (Hofkirchner, 1995). This work is actually part of an overall paradigm shift in science's world view, headed by the various theories of complex, non-linear, self-organising systems, and aimed at transcending the narrow boundaries of partialised disciplines towards unified theories which give an understanding of the world, while not giving up the expertise of specialised knowledge. The philosophical interpretation of the self-organisation theories is a proper background theory capable of restoring information theory as a theory of evolutionary systems exhibiting information processing. Something which may be called a multi-stage model of information can be derived from it. We try to sketch the boundary markers of such a model in brief.

In the first step we deal with the philosophical essence of the background theory; in the second step with the implications of the background theory for system-theoretical considerations; in the third step with the implications of the refashioned system-thinking for semiotic theory and the theory of cognition and human communication; and in a final step with the implications of all that for a general theory of information.

2. Emergence

The philosophical core of the background theory, though still to be elaborated, is an emergentist scheme of how the evolution of our world has taken place and how things are ordered according to that (cf. Blitz, 1992). Thus the theory of evolutionary systems is both historic and systematic:

The dynamic side of reality is expressed in a dialectic of old and new , the static in a dialectic of whole and part , which together constitute the evolutionary context: the new originates as part of the old whole and continues up to a specific point, at which the dominance of the old over the new changes into the dominance of the new over the old and the parts of the old become dominated by the new whole (Holzkamp, 1983). The particular element which constitutes the difference between old and new is no longer a part of the old, but rather the essence of the new. Thus reality is ordered.

Such a concept of stages for the universal evolutionary context is simultaneously a phase-theoretical and level-theoretical concept (cf. Hastedt, 1988). As a phase concept it concerns itself horizontally with the emergence of new qualities in the evolution process; as a level concept it deals vertically with the dominance of wholes in results of the same evolution process. As a stage concept it describes how the development of an entity can give rise to something new, which may eventually gain autonomy and reverse the situation by shaping the old entity. The stage concept combines the phase and level concepts: what for one is the starting point, is the result for the other, and so on.

It is thus anti-reductionist and anti-holistic:

Reductionism fails to qualify the emergence of the new from the old as such, for the following reasons: either the new is not new, because it was contained in the old, and only needed to be unrolled", or the old is not old (as suggested by the reductionist projection of new qualities onto the old). Reductionism fails to recognise the whole as macrodetermination for the parts, because it reduces qualities of a higher level down to a lower level, or projects the first onto the second, in order to derive the latter from the former.

The anti-reductionism known as holism " is a philosophical dualism/pluralism inasmuch as any connection between old and new or whole and part is disputed. It is seen as a question of incommensurable areas of varying qualities.

The multi-stage concept proposed here does not reduce new to old or whole to part, nor does it tear the qualities of different stages and levels of development away from each other. Reductionism is right to see the higher qualities as arising from the lower ones, and holism is right to stress the independent qualities of higher levels. The jump in quality is thus continuous and discontinuous simultaneously. However, it exists on a particular level only as a potential and not as a certainty. And only when the potential is realised does it become independent. The new entities can thus be seen as realising a subgroup of potentialities provided by the old entities, and building pyramids contained within each other (Ebeling et al., 1994); but every realisation is a whole that enriches the content of reality which otherwise would be composed of those entities forming the parts only.

The actual interactions open up an area of possibility from which one possibility must be realised (determinism!) but which has enough freedom of movement to allow evolution in the most varied directions (indeterminism!) (Hörz, 1994).

3. System dynamics

An emergentist philosophy of evolving systems has implications for system-theoretical terminology. Evolution in the context of system theory means the following: a phase of relatively stable development of a system can be followed by a phase of amplified fluctuations in parameter values, due to internal or external changes in conditions, until a bifurcation is reached. The system may organise itself and thus return to a path of stable development on a higher level, but it may also collapse (e.g. Laszlo, 1991). A jump can be interpreted as the emergence either of a new system state, or of a new system.

So, evolving entities are dynamical elements , dynamical systems made up of elements and their relations, and dynamical nets made up of systems and their relations (cf. Bunge, 1979, 1981, and Rapoport, 1986).

In identifying a system, three different levels of the system's dynamics can be distinguished:

1. The level on which the elements of the system in question are interconnected. This is the level of the internal structure of the system (the micro-level).

2. The level on which the system itself is in one state or in another. Compared to the structural level, the meso-level is focused.

3. The level on which the system exhibits its external behaviour vis-a-vis its environment. The way the system interacts with its co-systems in the net is examined here (macro-level).

It seems useful to assign a certain function to each level, as follows:

1. To the first level the input function.
2. To the second level the state function of the system.
3. To the third level the output function.

The input function transforms the causes coming from outside the system into effects at the structural level. The state function transforms the effects at the micro-level into effects at the meso-state level. Finally, the output function transforms the effects at the state level of the system into macro-effects at the behavioural level in the net.

Each level is the base on which the next level is built; each level has progressively less space for possibilities than the below one. From one level to the next there is a leap of qualitative difference. So these levels give the prerequisites for understanding the emergence of new systems or the emergence of new system structures, system states, or system behaviour.

The emergence of systems: Our starting point is a network of precisely those entities whose existence is the essential condition for the coming into being of the system. In this network, the future elements and environment of the system must be contained as non-specific entities, just as nodes and links of the net. This net is thus identical to the potential in which the possible conception of the system is found, and so can be called the emergence field. Should some nodes start making stronger connections with each other than with the remaining nodes, thus forming a coherent relationship, converging, making links with other nodes only via each other and not directly, then they are building a system in which they are the system elements, and their interconnections are the elementary system relations. The remaining nodes and links become the system environment, which comes into contact with the element nodes only via the system. The emergence of the system causes all entities contained within the net to acquire a new character the net has changed.

The emergence of the structure, the state, or the behaviour of a system: Here we are dealing with a pre-existing system, complete with elements, relations and environment. Altered conditions on the level of the system (meso-level) can only be caused by changes on the level of the elements and relations (micro-level), i.e., the (internal) system structure. This means that either the arrangement of the elements has changed, or the characteristics of at least one element have changed (thus altering its relations within the system). But changes in the structure dimension are not sufficient to change the function of this structure in the system; another qualitative jump is missing here. Additionally, a change in the system state is not enough to change the action of the system or its relationship to the environment (macro-level); a jump in quality must also be assumed here.

4. Semiosis, cognition, communication

Emergentist system thinking has implications for the domain of human information-processing. Firstly, the terms of semiotic theory and of the theories of recognition and communication have to be adjusted according to the scheme of levels. Secondly, these levels have to be conceived simultaneously both as levels of reality and as phases of evolving reality.

According to semiotics, information (at least on the level of socio-cultural evolution) has syntactical , semantic , and pragmatic aspects. It seems advisable to relate these three aspects to one another in the same way the system levels are related, i.e., by modifying the semiotic pattern so that a nested hierarchy of individual aspects results (Fenzl et al., 1995).

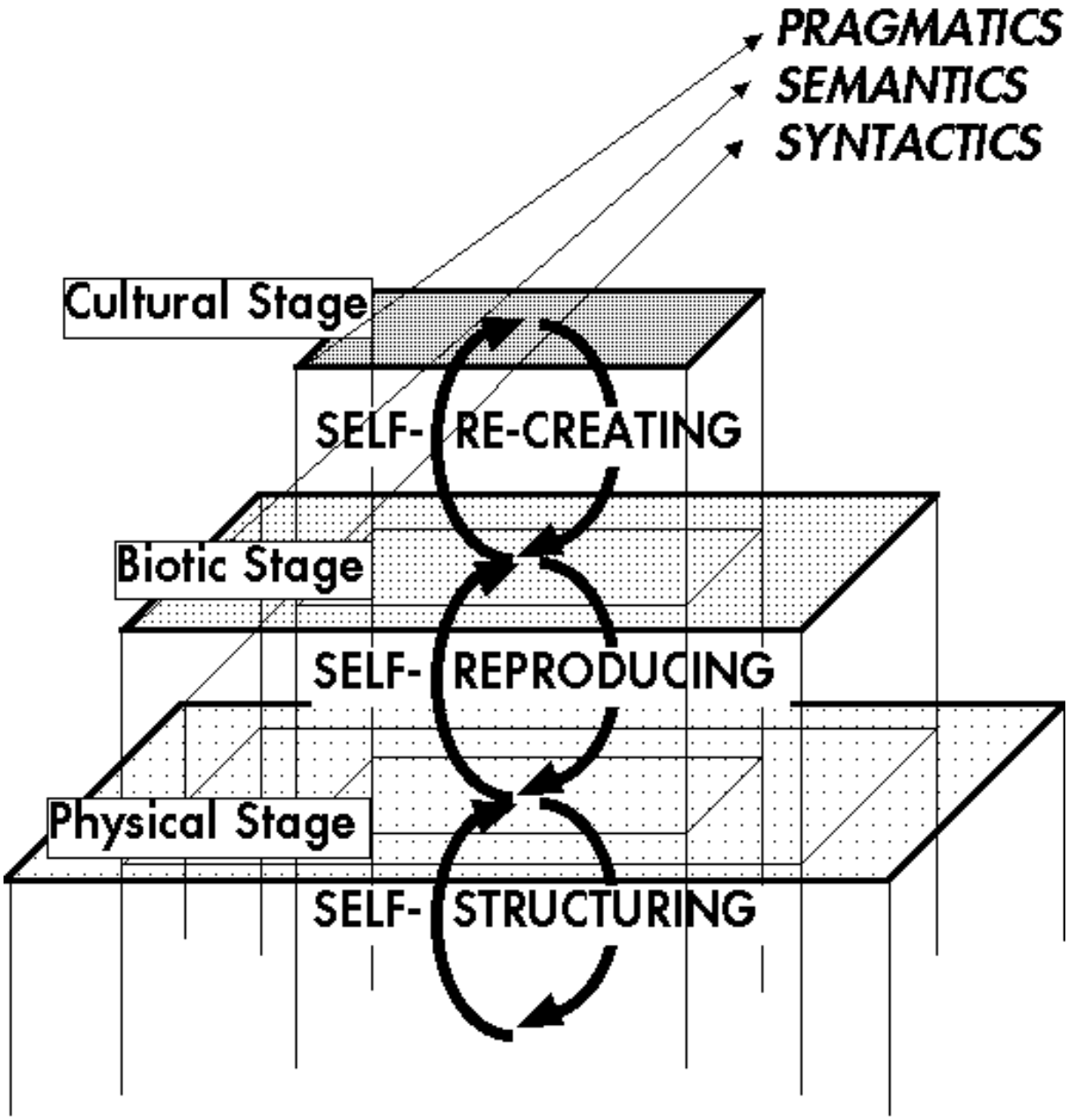

Figure. Levels of information processing within evolutionary systems. (1) At the stage of physical-systems evolution only one level of information processing makes an appearance. (2) At the stage of biotic-systems evolution information processing unfolds into two levels (sensing and effecting). (3) Only at the stage of cultural-systems evolution there is a three-step information processing according to semiotics (perceiving – interpreting – decision-making).

The following conclusions can thus be made: For an information processing system:

1. syntactics refers to the micro-state level;
2. semantics refers to the meso-state level;
3. pragmatics refers to the macro-state level of a system.

That is to say, the information process may result in structural changes in the interior of a system, it may result in changes of the actual state of the system, or it may result in changed external behaviour . We must notice that changes in the interior structure need not lead to changes in the system's state, and that changed states need not necessarily entail changes in the behaviour. But a difference in the output of a system must be based upon a different state, and a different state must take as a basis elements and relations that differ from former structures.

It is not only semiosis which is to be seen in a new light, but also the domain of human cognition and communication. Therefore, the terms of recognition theory and of the theory of human communication also have to be refashioned (Fenzl et al., 1995).

Cognition (the case of informational relations between cultural subjects and some objects) can thus be imagined as a process of self-organisation cycles, leading from one to another:

The first, perceiving , makes data from signals;
the second, interpreting , the assignment of meaning, makes knowledge out of data;
the third, decision-making, makes practical applications from knowledge, and forms wisdom.

In the jump up from one level to the next, a new moment appears. The existence of data is an essential condition for the existence of knowledge, but is not sufficient by itself; similarly, the existence of knowledge is an essential condition for the existence of practical wisdom, but is not sufficient on its own.

Last but not least, a brief mention of communication (the case of informational relations between several cultural subjects) should be made. This is a process which includes the horizontal dimension.

Taking into consideration the history of the formation of the levels which build layers in information processing systems, we suggest the following:

The appearance of information in modern human society (cognitive and communicative processes in social systems, mediated by the best available technology) is the most highly developed appearance of information which is known to us at present. That is to say, it forms the current end point of a developmental sequence in which various evolutionary systems, all linked to each other, show stages of differing information-processing (cf. Haefner, 1992, Stonier, 1990, 1992).

We may also agree on the assumption that the development of the cosmos is a unique process, in which the various evolutionary branches have their roots. This means that today's state of development in society has historical precursors from which it arose, that the social development of humanity is a continuation of natural history by different means, and that the ramifications in living and non-living nature reach back to a state of development of our cosmos which is generally known as the Big Bang".

We can then pose the question: what are the intermediate stages of this highly developed state of information which we know today? What are the forerunners of the advanced information-processing typically found in the so-called information society? What are the predecessors of information processing on pre-societal levels?

5. Information

Seen from the view of evolutionary information-processing systems, we finally arrive at the multi-stage model (see figure) in which we can handle the fact that there have been, and still are, systems in the overall evolutionary process which are not complex enough to show levels as differentiated as those in human information-processing systems (cf. Swenson, forthcoming).

At least three major quality jumps in information-processing performance, which can themselves be subdivided, make an appearance (cf. Haefner, 1992):

(1) This is the stage of physical-systems evolution. At this stage there is no differentiation between the three levels/aspects. That is to say, these systems exhibit self-organisation by self-structuring in a dissipative thermodynamic way only. There is only one transformation function. The new structure is identical to the new state of the system and also to its new behaviour (cf. Atmanspacher et al., 1990, Atmanspacher et al. 1992, Haken, 1988). The syntactical, semantic and pragmatic sides of information coincide.

(2) This is the stage of biotic-systems evolution. Living systems have an aim: they try to survive by organising flows of energy and matter. Because they produce the elements and relations of which they consist, they are self-reproducing (autopoietic) rather than merely dissipatively self-structuring. Therefore they must be able to analyse signals from the environment and establish significance for the maintenance of their metabolism (Ayres, 1988 and 1994). Signals which are involved in changes to the structure thus gain meaning for the systems. We can distinguish between two functions, the first at a structural level (sensing), and the second at a combined state/behaviour level (effecting).

(3) This is the stage of cultural-systems evolution. Cultural systems are self-structuring, self-reproducing systems that exhibit an additional property not found at lower levels of evolution: they produce not only the interior conditions of their existence, but also those of the exterior. They are free to restructure their

environment, and with these alloplastic characteristics are capable of restructuring themselves. Hence they are self-re-creating (cf. the ideas of Jantsch in Schmidt, 1987, and Holzkamp, 1983). Because of this characteristic, these systems exhibit a mature distinction between the state function and the output function. Meaning becomes a guide for action, knowledge is established and serves as a foundation for decisions.

Summing up, we can characterise information in the following way:

Every system acts and reacts in a network of systems, elements and networks, and is exposed to influences mediated by matter and/or energy relations. If the effects on the system are fully derivable from, and fully reducible to, the causes outside the system, no informational aspects can be separated from matter/energy cause-effect relations. However, as soon as the effects become dependent on the system as well (because the system itself contributes to them), as soon as the influences play the role of mere triggers for effects being self-organized by the system, as soon as degrees of freedom intervene and the reaction of the system is unequal to the action it undergoes, the system produces information (cf. Haken, 1988). Information is created, if there is a surplus of effects exceeding causes in a system. Information occurs during the process in which the system exhibits changes in its structure, or in its state, or in its output, i.e., changes which are due to the system. Information is created by a system, if it is organising itself at any level. Information is that part of the process of self-organisation that is responsible for generating new features in the system's structure, state, or output. In a figurative sense, information can be looked upon as the result of this process, as what is new in the structure, state, or output. And insofar as this new feature in system A may serve to stimulate self-organising (and therefore informational) processes to produce new features in system B, we can speak of information in a metaphoric sense only, as if it were something to be sent from one system to another.

Elaborating on an information concept along the lines given here will help we hope to contribute to the formation of a general theory of information as the foundation of information science.

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Peter Fleissner , born in 1944, is Professor of Technology Assessment and Design at the Informatics Department (working group for Social Cybernetics) at the Vienna University of Technology. He was educated (in electronics) at the same university. He was an assistant professor at the Economics Department of the Institute for Advanced Studies, Vienna, a research fellow at the International Institute for Systems Analysis (IIASA) in Laxenburg, Austria, and Deputy Director of the Institute of Socio-economic Development Research at the Austrian Academy of Sciences, Vienna. He has published extensively on social cybernetics, systems dynamics, and the social and economic impacts of technological change.

Wolfgang Hofkirchner , born in 1953, is a lecturer and researcher at the Informatics Department (working group for Social Cybernetics) at the Vienna University of Technology. He graduated in political science at the University of Salzburg. He was a research fellow at the Institute of Socio-economic Development Research at the Austrian Academy of Sciences, Vienna. His main area of interest is the combined field of science technology society.