Emergence and Evolution of Meaning: The GDI Revisiting Programme

Part I: The Progressive Perspective: Top-Down

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Abstract

In this first part of the paper, the category of meaning is traced forward starting from the origin of the Universe itself as well as its very grounding in pre-geometry. (The second part will be published as Díaz Nafría, Zimmermann 2011, dealing with an appropriate bottom-up approach.) Different from many former approaches in the theories of information and also in biosemiotics, we will show that the forms of meaning emerge simultaneously (alongside) with information and energy. Hence, information is always meaningful (in a sense to be explicated) rather than meaning showing up as a later specification of information within social systems only. This perspective taken has two immediate consequences: 1. We follow the GDI as defined by Floridi, though we modify it somehow as to the aspect of truthfulness. 2. We can conceptually solve Capurro's trilemma. Hence, what we actually do is to follow the strict (i.e. optimistic) line of UTI in the sense of Hofkirchner's. While doing this, we treat energy and information as two different categorial aspects of one and the same underlying primordial structure. We thus demonstrate the presently developing convergence of physics, biology, and computer science (as well as the various theories of information) in some detail and draft out a line of argument eventually leading up to the further unification of UTI and biosemiotics.

Introduction

After roughly 35 years of development in the theories of self-organization and related variants (chaos, self-organized criticality and so forth), it is somewhat of a surprise that physics proper has not yet sufficiently found its entry into the ongoing quest for a precise concept of information. Hence, even the most optimistic volume of collected essays on what is usually called UTI (edited by Hofkirchner in 1999) is introduced by Haefner with the remark that "… at the physical level, we encounter a set of physical theories that have never considered information as an appropriate term to understand physical phenomena … Quantum theories are not using the term information at all; instead, they are fixed to formulations of field theory." (Haefner, 1999, xv)
In fact, although the Vienna conference meeting took place in 1996 rather than 1999, this remark (and similar remarks as to that) do(es) not actually refer to the reality of ongoing research: As Seth Llyod points out in his book from 2006 (ibid., 52), already as early as in the sixties of the last century Fredkin and Zuse visualized the universe as a digital computer, a line of argument that Wolfram has followed more recently in his work on cellular automata published in 2002. Not to speak of the more recent theories on quantum information (Benenti et al. 2004, 2007, see also: Berman et al. 1998) which generically couple to theories of quantum gravity: One of the leading protagonists is David Deutsch here for whom "… [b]its, Boolean variables, and classical computation are all emergent or approximate properties of qubits, manifested mainly when they undergo decoherence." (Deutsch 2004b, 93) In other words: "The world is made of qubits … What we perceive to some degree of approximation as a world of single-valued variables is actually part of a larger reality in which the full answer to a yes-no question is not just yes or no, nor even both yes and no in parallel,

but a quantum-observable – something that can be represented as a large Hermitian matrix." (Ibid., 100)

This line of argument goes actually back as far as to John Wheeler in 1977 for whom "… [a] true observation of the physical world … must not only produce an indelible record, [but] somehow in part *meaningful information*." (Davies 2004, 8 – my emphasis) For him, "… [m]easurement implies a transition from the realm of mindless material stuff to the realm of knowledge. So it [is] not enough … that a measurement should record a bit of information, that lowly bit had *to mean* something." (Ibid. – my emphasis) This perspective led at the time to the famous "it-from-bit" thesis proposing that "the universe be fundamentally an information processing system from which the appearance of matter emerges at a higher level of reality." (Ibid., 10) In fact, it is Seth Lloyd himself who after all has developed the cosmological implications in most detail when presenting his work on the computational universe. (Lloyd 2006, 2010) For him, *the big bang was also a bit bang* (2010, 96).

Within the theories of quantum gravity, these aspects have gained even more pertinence. This is because the quantum viewpoint itself typically tends to conceptualize information (contrary to what we learned in the beginning). As Carlo Rovelli has concluded: "… what precisely quantum mechanics is about is the information that physical systems have about one another." (2004, 219). The quantum aspect itself however, turns out to be somewhat more involved than expected, as Roger Penrose has pointed out in his more recent works when he talks e.g. of what he calls *quanglement* in demonstrating his reluctance to utilize the concept of quantum information. As he says: "Quantum is not information, but [it] can be used in conjunction with ordinary information channels, to enable these to achieve things that ordinary signaling alone cannot achieve." (2005, 603, 607)

It is especially in *loop quantum gravity* that these features are most prominent: The idea is that "[j]ust as a polymer … the fundamental 1-dimensional excitation of geometry can be packed appropriately to provide a geometry which, when coarse-grained on scales much larger than the Planck length, resembles continuous geometries." (Ashtekar 1998, 181) The theory is named after the Wilson-type loops which are essentially closed curves carrying quantized electric flux and being organized into hexagonal networks called *spin networks*. (Smolin 2000, 135; 2004, 504) To be more precise, the significant objects are not just the loops, but their holonomies: They represent a generalized kind of parallel transport that can be described in terms of a Lie group element in the fibre bundle attached to the chosen base manifold. Hence, holonomies can be visualized as homomorphisms from some group structure defined in terms of equivalence classes of closed curves onto a Lie group. We can see then that essentially, "the result of evaluating a Wilson loop about a very small planar circle around a point x is proportional to the area enclosed by this circle times the corresponding value of the curvature tensor of the gauge field evaluated at x." (L. Kauffman 1994, 79, cf. Baez, Muniain 1994) Hence, the holonomy has the same information as the curvature at this point. (Cf. Gambini, Pullin, 1996, 1 sq.) A spin network then, is a linear combination of products of holonomies of closed curves that wrap along the graph. (Rovelli 2004, 237) Louis Kauffman who dealt with a representation of loops and knots in terms of (mathematical) category theory, has shown that in principle, the binor identity characterizing spin networks, the skein identity of the bracket polynomial in knot theory, and the trace identity are really all the same. Hence, space altogether shows up then as one of the possible targets of the many functors that extract information from the network. (1998, 277 sq.) (For general networks see e.g. Barabási 2002, for categories see in particular Lawvere et al. 2003, for an alternative approach in terms of strings see Susskind et al. 2005. As to the relationship between functors and knots see also Yetter 2001 and Zimmermann 2000, 2002b.)

As a preliminary conclusion of all of this we can note the following: 1. The physicist's quest for a unified theory from the outset (an enterprise in fact that already starts at the end of the 19th century) is the reason for the fact that the concept of information is always present in the sense that comparatively early it became necessary to map the physical processes involved by means of thermodynamical (and statistical) techniques. From the beginning on therefore, for Penrose, the entropy of a state is described as a measure of the volume of that compartment which contains the phase-space point which actually represents this very state. (1989, 313)

Hence, if a theory of cosmology must, as Smolin puts forward (1997, 291), in order to be self-consistent, be a theory of the self-organization of the universe, the very aspect of organization entails a concept of information on an equal footing with the concept of energy. (A point, in fact, also Floridi would agree to: 2011d, 135. See also Jantsch 1982.) This idea has become popular back in the late seventies of the last century following the international reception of the theories of René Thom and Ilya Prigogine. (Thom 1973, 1975, 1983; Prigogine 1979, 1993, 1996; cf. Zimmermann 1974, 1978, 1982, 1984, 1990, 2001b) As one can clearly recognize from this development, the problem of organization is closely related to the problem of a unified theory of physical interactions. Although significant progress has been achieved here, starting with Maxwell's theory of electromagnetism and with Einstein's theories of relativity, leading forward to a further unification including weak interactions (Salam-Weinberg-Glashow) and even to a GUT, gravitation (completing a true TOE) has not yet been successfully integrated into this enterprise. And the reason for this may be a deficiency in the proper co-ordination of energy and information within the theories of the cosmological beginnings. Looking particularly for characteristic differences in the entropy of the universe, in 1979, Roger Penrose has claimed a principle of time-asymmetry which shows up as a direct consequence of this evolution of entropy and can be formulated as an explicit energy condition (called the Weyl curvature hypothesis). (Cf. Halliwell et al. (eds.), 1994, Hawking, Penrose, 1996) In fact, this is why recent approaches to quantum gravity try to explicitly reconcile energy and information. This is particularly apparent when dealing with black holes.

But there is still another point to this: 2. As is obvious from the underlying intention of unified theories, they also refer to a kind of secularized grounding problem which in metaphysical philosophy is traditionally dealt with when talking about the concept of substance and its attributes. (Zimmermann 1991, 1998, 2004, 2010, 2011) From time to time this perspective is mentioned more or less at random, but altogether, the philosophical perspectives taken by physicists are very often far from being relevant and precise. This is mainly due to the terminology utilized according to somewhat arbitrary criteria and to the mixing up of ontological and epistemological problems: First of all, there are serious attempts to conceptualize the underlying physics with a view to basic principles which give a kind of philosophical grounding to physics normally absent when discussing physical details. Roger Penrose e.g., in his 1995 Tanner Lectures, is comparatively prudent in his formulations when stating that "[w]hat we need is a criterion to enable us to estimate when two space-times differ significantly and this will lead to a *time-scale* for Nature's choice between them. Thus, the viewpoint is that Nature chooses one or the other according to some rule we do not understand yet." (Penrose 1997, 86) In that case he points to the theory of consciousness which he has developed himself together with Stuart Hameroff. Therefore, for him the solution must be somewhere in the quantum domain: "It seems to me that consciousness is something global. Therefore, any physical process responsible for consciousness would have to be something with an essentially global character. Quantum coherence certainly fits the bill in this respect." (Ibid., 133) He thus concludes that "[m]entality … be ontologically fundamental in the Universe" and mentions some kind of "proto-mentality". (Ibid., 176) This is something we can subscribe to: If there is a choice for Nature, then Nature is acting in a sense, it is subjective rather than objective. This is indeed an idea that is present in philosophical theories from Schelling to Bloch. And in particular it is the idea of characteristic time-scales that fits nicely to Schelling's worldly epochs. (Zimmermann 1998a, 2004, 2010, 2011)

But unfortunately, letting aside that Penrose is known officially as a serious Platonist (which is somewhat out of date to say the least), Hameroff does not share his modesty and claims that their results would point towards a philosophy of some "… funda-mental panexperiential view in which primitive experience exists at the Planck scale of spacetime geometry." (Hameroff 1998, 154) And Lee Smolin adds that "[p]hysics should be more than a set of formulae that predict what we will observe in an experiment; it should give a picture of what reality *is*. … It cannot be that reality depends on our experience." (Smolin 2006, 7) As to the first statement we notice that the vagueness in formulation actually destroys the strong argument provided by Penrose, because automatically, we envision a world which is some sort of living creature and loose the aspect of "proto-entities". (We will come shortly back to this.)

On the other hand, the same vagueness in Smolin's statement renders the whole approach to end up with a false idea: This is mainly so because it is not quite the task of physics to say what there actually is. And it is a mere claim that reality cannot depend on our existence (because it is this very reality that produced us in the first place). But the main point is here that the concept of reality is far from clear: because traditionally, reality refers to what the world is like in absolute truth but to what we cannot actually perceive at all, because the cognitive capacity of human beings is limited. Hence, the world as we see it is its modality, the world as it really is we call reality. Obviously, the former can only be an approximation to the latter. And this is what in the physics of quantum gravity we would also like to call approximation or emergence. (Ashtekar 1998, 181; Johnson 2002, Davies 2004, 10; Deutsch 2004b, 93, 100; see also: Deutsch 2004a, Penrose 2005, 603) Hence, in the strict sense of the concept, Smolin would be right (but then, physics could not help). Or, if he has mistaken the concept and refers to modality instead, he is simply wrong, because the latter is indeed depending on our existence. A similar critique is adequate when referring to the recent book of Vedral's (2010) when the author struggles (unsuccessfully) with the concepts of nothingness and *creatio ex nihilo*. (Ibid., 2, 5) In fact, he does not actually answer the questions he is presenting in the beginning ("… why is there a reality at all and where does it come from?"), because on the one hand, he shares with Smolin the same difficulty referring to the correct meaning of "reality", and because on the other hand, he forgets that information (as well as energy) is a worldly concept which is utilized for human modeling, but not part of reality proper. (We leave aside here the astonishing point that the author is, as far as we can see, not referring to the works of Seth Lloyd at all.)

Now, in order to summarize this unusual lengthy introduction (which turns out to be a kind of "discourse on the method"), we can say the following: Similar to the concept of energy, information is already always present in fundamental physics. Both energy (and the matter which it is manifesting) and information are two different aspects of the same underlying primordial structure of the world we will know not before there is a consistent TOE. Within this theory, both concepts have to be unified, and by doing so, there will also enter the aspect of some cognitive meta-theory which tells us how human modeling is coming about as part of a process actually performed by nature. Such an approach will also establish an innovative relationship between philosophy and the sciences, because epistemologically, all of them have to rely on each other. Hence, the appropriate TOE cannot be found, if not a philosophical framework for the grounding of the world is also developed which in turn is only possible, if philosophical research gets interdisciplinarily entangled with the other fields of the sciences. What this attitude is actually up to shall be discussed in this present paper.

1 Starting from Floridi's Viewpoint

Much of what we have said in the introduction is the foundation for the results announced here earlier. The generic tendency of these results is already entailed in the role which is attributed to the concept of information when applied within the framework of fundamental physics. So, Floridi is certainly right when mentioning that "information can be said in many ways just as being can" and that "th[is] correlation is probably not accidental." (2004a, 40) But it is not clear why a UTI project should be necessarily reductionistic, because – different from the unified projects in physics – it deals with a conceptual rather than physical unification, because primarily it aims at a conceptualization which is for information what it was before for energy and mass. In other words: Unification means here *unifying energy and information* rather than unifying different types of information. Hence, it is also a project of unifying a catalogue of terminologies, but at the same time one of unifying two irreducible phenomena. Similar to quantum physics where the difficulty is to differ between what is axiomatic and what is empirical, modern information theories have to differ between what is substantial and what is accidental. (This is summarized somewhat in Capurro's Trilemma.) In the first case, the result is a bundle of interpretations of quantum physics altogether, and it is hoped that eventually it will be possible to decide which one is the master interpretation. In the second case, the task is practically the same. The crucial difference may be the fact that certainly, an adequate UTI will not be grounded on the mathematical theory of communication in the sense of Shannon, but will instead turn out to be part of a physical TOE. But the more is it necessary to actually determine what *meaning* is all about, a notion which according to common terminology obviously surpasses the concept of mere information. In so far, it is quite to the point that Floridi stresses the advent of hermeneutic theories (Ibid., 41), but it is possibly insufficient to let things be as they are without going into further detail as to a possible definition of the underlying basis of meaning. (See also Floridi 2011a-c.)

This is mainly so because the concept of meaning enters the discussion very early: For starting with a proper definition in the first place, it is immediately part of what Floridi calls the *General Definition of Information* (GDI). This definition states that an instance of information visualized as objective semantic content is given, if and only if (iff) it consists of n data (n ≥ 1) which are well-formed and *meaningful*. (Ibid., 42 – our emphasis) There we are: From the beginning on we have to deal with meaning. And if having a look on the list of possible data within the definition's range (Ibid., 42 sq.), we notice that primary data, metadata, as well as operational data can be found throughout nature. They are not restricted to social systems proper. Only derivative data extracted from the first three types are possibly reserved for the latter. The question is whether this is also true for meaning. If there is no information without data representation, and if a datum is a relational entity (Ibid., 43), then obviously, throughout nature, there is information which by its very relational quality always entails meaning in the first place. If Bateson is right, and information is the difference which makes a difference (Ibid., 44), then it is quite straightforward to notice that the existence of a difference immediately implies the means of recognizing a difference as difference, in other words of interpreting differences. (Zimmermann 2007, Zimmermann, Hofkirchner 2009) Hence, there is a minimal nucleus of proto-type forms of cognition and communication essentially comprised of a detection device which is able to differ between what a signal actually shows and what this actually means (cf. Díaz Nafría et al. 2010) – independent of whether the physical structure (be it a living structure or not) is able to also reflect about the fact that presently, it *possesses knowledge* of this process.

As to the concept of meaning we find this line of argument confirmed from time to time, if often only as a side-remark. Seth Lloyd e.g. is quite clear with respect to meaning: "If you adopt Wittgenstein's perspective that the meaning of a piece of information is to be found in the action this information provokes, the meaning of a computer program written in a particular computer language is to be found in the actions the computer performs as it interprets that program." (Lloyd 2006, 26) And we remember that action is already there from the beginning on, namely speaking of spin networks as the fundamental fabric of space which actually process the information which is produced by means of the organizing action of the loops co-operating in order to constitute the network in the first place.

This has an interesting consequence: A loop in the above sense fulfils what Stuart Kauffman calls the criteria for autonomous agents. (S. Kauffman 2000, 2004; S. Kauffman, Clayton 2006) This aspect has already been mentioned in the recently emerged field of biosemiotics. (Taborsky (ed.) 1999, Zimmermann 2007, Hoffmeyer 2010, 192) Some more details are given here in the appendix.

Hence, although we can live with Floridi's formulations ON 1 through 4 with respect to adequate data representations, we actually dispute formulation GeN (data can have a semantics independently of any informee) and also the viewpoint that false information is no information. (Ibid., 44 sq.) In other words: We would like to stay with the GDI, but would prefer to choose another interpretation of some of its consequences.

In fact, what we would aim at can be illustrated in more detail when looking at the catalogue of main concepts assembled in the handbook edited by Floridi: beside information, there is computation, complexity, and system. From elaborating on the first (Copeland, 2004) we obtain the importance of Goedel's theorem which restricts the power of computability from the beginning on. Complexity however, is visualized exclusively as *computational complexity* which is probably a little too narrow after all. (Urquhart, 2004). Finally, Mainzer (2004) is quite correct in stressing the origin of systems which is in *dynamical systems* (in the mathematical sense). The importance of this insight lies in the idea that one cannot describe any dynamical system without describing its state space at the same time. And as we know from more recent developments, the KAM theorem points to the ubiquity of mixed systems such that dynamical forms of deterministic chaos dominate the processes throughout nature. (Cf. ibid., 31) Now, if structures in nature and society can be explained by the dynamics of complex systems and their attractors (Ibid., 33), then indeed, the existence of observable structures is essentially grounded in their underlying information: Hence, "[a] dynamical system can be considered as an *information processing machine*, computing a present state as output from an initial state of input. Thus, the *computational efforts* to determine the states of a system characterize the *complexity of a dynamical system*." (Ibid., 36) The point is here that as far as computation goes, this formulation is certainly correct. But in view of the Goedel theorem, computational complexity is not quite satisfactory after all. The solution may be found in what Mainzer calls "computational ecologies": Possibly, it is self-organizing agents as they are already available in computer networks which open a new perspective here. (See also what we said above on S. Kauffman's autonomous agents.) But then, game theory becomes relevant again. (Jantsch, Waddington, 1976; Zimmermann 2004, 2005, 2006)

Hence, in order to summarize, we can state that the GDI is confirmed as to the emergence of meaning which is visualized as a concept to be handled parallel when dealing with information: Information is always meaningful indeed. On the other hand, the GDI has to be modified with respect to false information and meaning. The idea is that also false information can be actually utilized for a productive purpose, not only in the case of biological systems (when a copying error of the DNA produces a mutation which may be able to survive and even grow),but also for the case of fundamental physical systems (the difference being that copying errors in spin foams have not yet been studied sufficiently so as to determine what a surviving mutation would be in practice).

2 The Standard Approach and Some Of Its Consequences

Before coming back to our main topic, let us have a short look onto the conventional structure of what we may call "standard approach" to information. A useful survey is given e.g. in Lyre (2002), and we follow here its systematics. (See also the early viewpoint as put forward by Weizsaecker 1982.) But first of all, we would like to replace the semiotic 3-dimensionality of information (syntax, semantics, pragmatics) by the trinity of lexicology, syntax, and semantics, because we find that the former terminology which has been essentially introduced by Charles Sanders Peirce, is redundant with respect to semantics. Instead, we find that the classical dualism between syntax and semantics which mirrors the inherent dualism of *signifier* and *signified* in the sense of Saussure already incorporates the pragmatic component, because semantics can only mean "to produce a *meaning-for* something … a *meaning-of* in order to do something". (On the utilization of these concepts see e. g. Zimmermann 2007, Zimmermann, Hofkirchner, 2009. In particular, for the Lacanian utilization see Evans, 1996, 186.) Starting then from the probability viewpoint of information (chiefly pointing to *potential syntactic information* in the first place), we can define the usual concepts of information content (measured in bits) and information entropy as originally developed by Shannon. Immediately, we find the following: 1) Information (transport) theory in the sense of Shannon deals with *potential information in syntactical terms*. 2) Algorithmic information content is a measure of syntactical complexity in the sense of Kolmogorov et al. But different from the assumption of equally distributed binary symbols we deal here with structural differences in terms of a semantic framework which is determined by means of ordering rules of given patterns. Hence, information is measured here according to syntactical *as well as* semantical aspects.

The consequence for physics is that usually, the state function (in quantum theory) represents (quantum) information. In other words: Physical objects can be completely characterized in terms of the information which can be extracted from them. (This is what is behind Wheeler's "It from Bit" (cf. Davies 2010) and Lloyd's and Zizzi's "It from Qubit" theses.[1]) (Zizzi 1999, 2000, 2003, 2004) This

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[1] There is actually a problem of priority as to the first utilization of this formula: Apparently, the idea to visualize the universe as a quantum computer had its origin at a conference in the Villa Gualino, Torino (Italy) in 1995 in a talk between David Deutsch and Seth Lloyd. This is reported by Deutsch himself in

is particularly true for the Universe altogether: In the case of black holes, the entropy measures the potential information content by means of the event horizon's area. Indeed, as the most fundamental level of physics (the Planck level with quantized space and time) can be visualized by groups of six loops which co-operate in order to form one hexagonal cell of the underlying spin network, and because such a network operates like a quantum computer, we can visualize the Universe altogether as such a device and identify quantum gravity with quantum information. (Zimmermann, 2008) That agent activities entail meaning can be seen more clearly in the appendix (S. Kauffman, 2000). (Partly we have discussed this aspect in the preceding section in more detail.) The same is true for biology, because the activities of the DNA structural network (following the reactive chain: DNA replication → transcription → RNA → translation → polypeptide) demonstrate that the semantic aspect of genetic information lies in the functionality of produced proteins. In other words: The syntactic structure of a nucleotide sequence is meaningful, because it exhibits well-defined interactions within the cell. Note that this meaning is being recovered by the sequences as to initiating their functions, but *it is not reflected upon* in the sense that these same sequences would actually "know" that they rely on information and meaning. Obviously, the difficult problems of consciousness (matter-mind duality, problem of qualia, epistemic asymmetry = communication of subjectivity) do not arise before one does not take the mediated subjectivity of information *for humans* into account. But then, we are amidst social systems, and the idea is to characterize these as a particularly complex special case of something which is universal within all of nature.

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the first 2002 version of his 2004 paper. The first paper of Lloyd (Universe as a quantum computer) is published then in www.arxiv.org/pdf/quant-ph/9912088 while Paola Zizzi's first topical paper is in www.arxiv.org/pdf/gr-qc/9907063. While Lloyd is not referring then to the above-mentioned phrase, Zizzi is in this latter paper. Hence, this formulation which has been used since then in a considerably inflationary manner, actually comes from Paola Zizzi.

3 Barbieri's Approach

More recently, Barbieri (2003) has introduced semantics into biology proper talking of organic codes. He maintains the validity of four principles starting (1) from the concept of *epigenesis* which he redefines as the characteristic property of a system enabling it to increase its complexity. (Ghiselin, 2003, x) He actually selects the capacity to increase one's own complexity as a defining property of life itself. The important point then is that (2) for him, achieving complexity amounts to reconstructing a structure from incomplete information. (3) Furthermore, it is necessary to realize that epigenesis requires a memory. (Leyton 2005) And hence, (4) therefore it requires organic codes. And Barbieri concludes: "But if codes exist, they must have had origins and histories, and above all they must have had a specific mechanism." (Barbieri, 2003, 2) In fact, this conclusion is relevant for the grounding of evolutionary systems in philosophy. This most significant mediation of concepts cannot be discussed here, but has been explicated in more detail at other places. (Zimmermann 1998, 1999, 2004b, 2010, 2011) Similar ideas have been put forward by Thom (1975, 1983) and Prigogine (1979, 1993, 1996). Under a perspective of evolutionary systems, this has been discussed in Morin (2010).

Barbieri calls epigenesis a convergent increase of complexity, in the sense that its outcome is neither random nor unexpected. (Barbieri, 2003, 3) Practically, he follows here the line of argument as being put forward by Stuart Kauffman for sciences in general running under the terms of "order out of chaos". (S. Kauffman, 2000) Modern mathematical terminology has been utilized to clarify these topics, particularly in Boi (2005), Louis Kauffman (2005), and Zimmermann (2007). From the beginning on, therefore, Barbieri introduces the concept of meaning, although with a primarily anthropomorphic connotation. (Barbieri, 2003, 5) However, his idea of the necessity of a codemaker which is an agent ontologically different from what it mediates, can be straightforwardly subscribed to: In principle, the threefold cooperation between two interacting "parties" on the one hand, and the codemaker on the other, can be localized in many natural structures. (For the case of spin networks though, it is not quite clear yet what we could visualize as codemaker here.) More recently, one of us (Zimmermann, 2010; Zimmermann, Hofkirchner, 2009; Zimmermann, Wiedemann, 2010) has started the attempt to formalize the relevant concepts within the framework of (mathematical) topos theory in order to utilize a unified language applicable to both the theory of evolutionary systems and information theory, respectively. There is no way however, to avoid the discussion of hermeneutic concepts, which is mainly due to the incompleteness of computability in the sense of Goedel's theorem. Hence, we cannot circumvent a treatment of meaning which is leading out of mathematically formalized sciences, guiding us into the field of quite another type of interpretation. Fortunately, this field is connected with the others by means of a sound semiotic viewpoint.

4 Meaning in Frank's Hermeneutic

Although Frank's approach is essentially one of discussing the literary discourse, it is also relevant for a wider context which covers the relationship between information and meaning in nature in general. This is mainly so, because Frank states at the very beginning of his first significant work on this topic (Frank, 1977, 10) that "[o]ne anticipates a secret interaction between the individuality of meaning […] and the universality of [a] significant order." Indeed, this is an interaction which can be generalized for the whole of nature as it turns out. And this is the aspect under which hermeneutic can be included in this ongoing discussion.

The crucial point is that all what we have said so far is said exclusively in terms of the modeling done by human reflexion. Hence, if Stonier formulates: "Energy is the capacity to perform work. Information is the capacity to organize a system by utilizing work." (1990, 26, cf. id., 1992) and if Lloyd says: "Information tells space how to curve, and space tells information where to go …" (2006, 174), then we have not to forget that this is only true when formulated in human language while communicating the results of reflexion. This is what Frank means when he states that "… playing out the circularity of understanding against the ideal of positive knowledge would mean to misread that the former is nothing but one sort of understanding among others [Frank quoting Heidegger here] in so far each type of knowledge assumes a projection of meaning which is not discursively controllable itself. Hence, according to its underlying intention, existential hermeneutic is not only the foundation of the interpreting science, but also of all kinds of science altogether." (1977, 19 – our translation) So it is the cognitive framework of some suitable meta-theory which is at stake here: in order to eventually learn how to actually utilize the meaning implicit in any type of information.

5 Pre-Reflexive and Reflexive Types of Meaning

Hence, the Universe is meaningful from the beginning. Meaning emerges alongside with information, together with energy, at the Big Bang. Subsequently, the Evolution of meaning is characterized then by emergent steps of the development of complexity. The preliminarily crucial step is being initiated by the emergence of reflexive (or: self-reflexive) meaning as exhibited by human beings. (Cf. Crutchfield 1994) But, how does emergence actually work? Emergence can be best visualized as emergence of averages, very muc in the classical, statistical sense: For a given system, macroscopic phenomena are then nothing but approximations of processes taking place on the microlevel of state space. The former are essentially observable, the latter are essentially non-observable. And why do we think to conceptually solve Capurro's trilemma (Capurro et al. 1999, 9) then? Because it is the evolution of complexity (as related to Stuart Kauffman's 4th law of thermodynamics) that demonstrates that the multiperspectivity of univocity, analogy, and equivocity, respectively, does not actually present a trilemma. Instead, it unfolds the local perspective of conceptualization with respect to that level of complexity which is topical for a given discussion: E.g., if asking what the difference of self-organized non-living and living matter can actually mean (as Wolfgang Hofkirchner asks in Capurro et al. 1999, 24), the answer is simply that it is the level of complexity which gives a ranking to structures (indicating a lower or higher rank in the state of organization, in fact). Hence, as we deal in physics with one definition of energy plus a conservation theorem (overall balance), but with various forms of energy which are permanently transformed into each other (defining various balance equations as to that which describe the fine structure of the mentioned conservation theorem), we equally deal in the theory of information with one definition of information plus a set of evolution theorems (the five laws of thermodynamics), but with various forms of information which are also permanently transformed into each other: The essential idea (obviously well capable of achieving a broad consensus after all) is that in physics, energy is in some sense the prime expression for the potentiality of a system. As McMullin says: "It almost seems that it is to the potential, rather than to the actual, that reality should be attributed at the most fundamental level." (2010, 33) This is in fact compatible with quantum theory. As Jeffrey Bub (1999, xii, xv) has shown, the Schroedinger time-dependent equation characterizes the temporal evolution of what is possible, not what is actual at time t: "… in a classical world, change is described by the equation over time of what is actual, where what is actually the case … is selected by … the classical state – as a temporally evolving substructure against the background of a fixed Boolean lattice of possibilities. In a quantum world, what is actually the case at time t is selected … on a changing background of possibilities. So in a quantum world there is a dual dynamics: the Schroedinger dynamics for the evolution of possibility, and a dynamics for how what is actually the case changes with time … From this perspective, we can understand the phenomena of interference and entanglement … as arising from the way in which what is actually the case at t changes from t to t′ in such a way as to mesh with the change in possibility structure from t to t′. … I still think the essential difference between classical and quantum mechanics is captured by the insight that going from classical to quantum mechanics involves the transition from a Boolean to a non-Boolean possibility structure for the properties of a physical system." (Cf. Magnon 1997)

A similar differentiation we would like to claim for the concept of information: because it is well-known that there is a generic difference between information about what is actually the case, and information about the possibility for something to become the case eventually. In fact, comparatively early, von Weizsaecker (1971) has mentioned a similar aspect when defining energy as the potential to move matter and differentiating information from both matter and energy. (Ibid., 344 sqq.) For him, information shows up as a measure for the quantity of form (complexity?) and can be determined by the number of single alternatives which have to be decided in order to describe the form. (Ibid., 347) This opens interesting points for discussion, although we would not really describe to his equations matter, motion = form, mass = information = energy, in the end. (Ibid., 361) But we can clearly recognize that the relevant discussion has been begun much earlier than usually noticed. Jantsch refers to von Weizsaecker in his work from 1982 (Ibid., 88 sqq., also 202). In Jantsch, contrary to von Weizsaecker, information is made somewhat more precise when discussing the co-evolution of macro- and microlevels as origin of complexity. Information then (in-formation) refers to a special dynamical regime of a self-organizing structure. (Ibid., 300)

Note that in quantum gravity, the Hamiltonian constraint which acts on states made from Wilson loops and which can be solved therefore by spin network states, mirrors a similar relationship, because it actually reflects what is called the Wheeler-De Witt equation which is the Schroedinger equation for the wave function of the universe whose essence is that this wave function is time-independent. Hence, the universe as a whole does not change in time: "The resolution of this paradox [as suggested by De Witt] is rather instructive", as Andrei Linde states. (2004, 449) "The notion of evolution is not applicable to the universe as a whole since there is no external observer …"

This leads us somewhat back to the metaphysical aspects as discussed earlier. And there is a semiotic turn to this: Some time ago, Wildgen (1982) has summarized Thom's semiological approach as one which serves the purpose of finding *semantic archetypes* within the mapping of attributional results. (It is interesting to compare these with what Floridi calls dedomena. (2011, 340)) Wildgen visualizes the mathematical structures discussed in Thom's theory of catastrophes as mediators between linguistic structures (forms) and cognitive structures (of meaning). He lists principles of association then, such that stable attractors of elementary unfolding (in the sense of Thom) can be interpreted *linguistically,* as satellites of a dynamical centre of propositions (nomina, pro-nomina) and *cognitively,* as stable entities or classes of orders of magnitude within the concrete, observable world (individuals, objects, qualities, states). Hence, catastrophes can be visualized as semantic archetypes such that linguistically, they signify the nucleus of a form (relational terms) while cognitively, they refer to event which can be interpreted as being structure-forming. (The mathematical details have been discussed elsewhere: cf. Zimmermann, 2001, 2002a)

It is interesting to note that Thom's linguistic approach goes actually back to an early meeting on (mathematical) dynamical systems (Thom 1973) and can be understood as a consequence of the mathematical discussion rather than as purely semiotic result. In fact, this can be clearly illustrated by Thom's concept of *chreod* which is essentially originating in the geometry of state spaces. (Zimmermann, 2001, 198) A chreod consists of 1) an initial set U in the space R^3 x R (i. e. an open set at a given time), 2) the union of all cones C(x), with x being a point in that space, and the cones lying within the initial set such that they likewise constitute an open set W which is called *zone of influence*, 3) an open set V in W which contains U in its boundary and some morphogenetic field. The quotient W\V is called *bifurcation zone* of the chreod.

Unfortunately, the difference between a chreod and a morphogenetic field is not always clear-cut in Thom, but the important point is that the latter temporalizes the former such that the time flow becomes irreversible. Following non-mathematical interpretations of this, particularly within the framework of a quite debatable theory proposed by Sheldrake and others, the concept of morphogenetic fields has been utilized for esoteric purposes, to say the least. But the important point for us here, is that in terms of a dynamics of concrete, observable processes, a given morphology is always the outcome of some chreod action induced by a morphogenetic field. (In other words: In the observable world, there is not anything which would not actually evolve.) Even solid-state objects can be visualized thus as an acting dynamical system, simply depending on the level of discussion one is maintaining. With a view to information, a stable configuration of chreods is what defines observable objects or settings of such objects. To this purpose, Thom introduces the concept of *logoi*: They are geometrical structures expressed algebraically which stabilize forms, concepts, and situations of conflict. Hence, the catalogue of possible logoi can be visualized as the characteristic set of catastrophic structures which mediate chreods with cognitive and linguistic structures. Not only does all of this fit nicely into the picture relevant for ongoing discussions (as indicated at the beginning of this paper), but it is also the role of logic which can be stressed with a view to the consequences of logoi: Elsewhere (Zimmermann 2010, 2011; Zimmermann, Hofkirchner, 2009) the proposal of Fontana's has been discussed (Fontana, 1991; cf. Fontana et al. 1995) with a view to establish a direct translation mechanism between observable processes in chemistry and a LISP-oriented operator algebra of logic. (Cf. Abelson et al. 1996, 63 sqq.) All of this functions very much on the same line of argument. And there are close connections to the recent theories of knots (L. Kauffman, 2005) and (mathematical) topoi (Goldblatt, 1982). Obviously, a mathematical topos shows up here as just another instrument of classifying logoi in the sense of Thom.

But most important in the first place is the fact that the above-mentioned is also true for situations that do not deal with human (interpretative) cognition exclusively: Thom's famous example deals with the predator-prey model within the animal kingdom. The essential idea is to identify the interaction taking place in some geographical space with the topological structure of that space which becomes then some abstract state space. One can classify then the various types of interaction according to the types of topologies in state space. By doing so, catalogues of logoi turn out to be dynamic-generative by themselves. (Zimmermann 2001, 201) The same is true for even more primitive organisms which already exhibit an explicit form of co-operation based on the communication of meaning, but also in the upward direction when visualizing an organism as a network of feedback loops (Grand 2001, 121). (An interesting variant is also provided by various forms of artificial life. See Grand 2001, Maes 1995, S. Kauffman 2000.) A prominent example is the initiation of slime mold aggregation discussed by Keller and Segel already back in 1970. (See also Prigogine 1976.) This example is widely utilized for ongoing discussions, but unfortunately, it is often not correctly attributed to their inventors. The above-mentioned work of Fontana makes it possible to trace similar processes back into the realm of anorganic chemistry. We ourselves have put forward here the idea that they can also be found on a far more fundamental level on the physical Planck scale. It is obvious then, that the concept of *autonomous agents* is very much in the centre of ongoing discussion and, by being discussed, progressively involves aspects of game theory on this very fundamental level. (See Bub, 1997, 230 on the IGUS principles introduced by Gell-Mann and Hartle, also Patti Maes 1995, and for organizational aspects Fontana et al. 1995.)

Appendix

Agent-Based Meaningful Games as the Foundation

of Systems, Spaces and Networks

1. Following an idea of Stuart Kauffman's, we think of *agents* in the generalized sense as systems which achieve a new kind of closure in a given space of catalytic and work tasks propagating work out of non-equilibrium states and playing natural games according to the constraints of their environment.[2] In particular, (physical) space is visualized then, as being comprised of autocatalytic autonomous Planck scale agents coevolving with each other serving at the same time as some sort of crystallization of seeds of classicity (in the physical sense). This co-evolution is taking place according to what Kauffman calls *4th law of thermodynamics*: The maximum growth of the adjacent possible in the flow of a non-ergodic Universe maximizes the rate of decoherence and thus the emergence of classicity. There is also a hierarchy of such agents depending on the explicit complexity of those in question ("higher-order agents") such that *human agents* in particular (as constituents of social systems) represent a stage of higher complexity as compared to physical, chemical, or biological systems, respectively. (Games of various types of agents are nicely illustrated by Szabó and Fáth 2006.) But on the fundamental level of physics, Kauffman mentions the possibility to visualize *spin networks* as knots acting on knots to create knots in rich coupled cycles not unlike a metabolism. Hence, they (or their constituents) show up as a sort of "fundamental agents".[3]

2. If we take up the viewpoint of Kauffman's, then it appears to be straightforward to find the fundamental agents in the loops of *loop quantum gravity* (and the associated *quantum information theory*) in

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[2] This is referring to an earlier manuscript version of Kauffman's book „Investigations", cf. the address www.santafe.edu/sfi/People/kauffman/Investigations.html In the actual book version, autonomous agents are defined as systems which can at least perform one thermodynamic work cycle.

[3] Obviously, this remark has not become part of the book version. But without doubt, the idea has been to visualize fundamental systems as fundamental agents on the Planck level. Cf. Investigations, op. cit., 253-265.

the first place: This is so because it is the loops which combine in order to form spin networks. In fact, six of them co-operate in order to produce one hexagon of the network.
With a *loop* (cf. e.g. Loll 1994, Rovelli 1997) we mean here a closed curve α such that $T[\alpha] = - \mathrm{Tr}\, [U_\alpha]$, where

$$U_\alpha\, (s_1, s_2) \sim P \exp \{ \int^{s2}{}_{s1} A_\alpha\, (\alpha(s))\, ds\}$$

is the parallel propagator of the vector field A_α along α defined by (the s_i being points of α)

$$d/ds\, U_\alpha\, (1, s) = d\alpha_i(s)/ds\, A_i(i(s))\, U_\alpha\, (1, s).$$

The SO(3)-field A is here essentially the difference of the SU(2)-spin connection and the extrinsic 3-curvature called *real Ashtekar connection*:

$$A_i{}^j\, (x) = \Gamma_i{}^j\, (x) - k_i{}^j\, (x).$$

The important result (cf. Rovelli) is that each spin network state can be decomposed into a finite linear combination of products of loop states.

3. Obviously, this bears a strong resemblance to the Wilson loop representation (hence, we think here of a kind of *loop transport* according to Stuart Kauffman's idea of agents), and is also essentially a Feynman-type integral which gives the probability for a (physical) system to go from one state to another:

$$< x2, t2 \mid x1, t1 > = \int{}^{XN}{}_{X1} D(x(t)) \exp i/\hbar\, S,$$

where S is he action of the form

$$S := \int^{t2}{}_{t1} dt\, L(x, x').$$

(The probability is the above expression squared. This is equivalent to the Schroedinger picture of quantum physics on the one hand and a model for quantum computation on the other.) As Freidel and Krasnov (1999) as well as Reisenberger and Rovelli (2000) have shown, spin networks and spin foams, respectively, can be visualized as Feynman integrals of that sort such that the formal Feynman perturbation series of the partition function

$$Z = \int D\,\phi \exp(-S[\phi])$$

is given by

$$Z = \Sigma_J N(J)\, \Sigma_e\, \Pi_{f \in J} \dim a_f\, \Pi_v\, A_v(e),$$

where J is a 2-complex, and the vertices, edges, and faces are labelled accordingly. It is N(J) the number of vertices of J divided by the number of symmetries of J.

4. There is a number of important cross-relationships which connect the notion of loops with the notion of knots: Louis Kauffman's bracket algebra (the boundary algebra of containers and extainers) turns out to be the precursor of the Temperley-Lieb algebra important in order to construct representations of the Artin braid group related to the Jones polynomial in the theory of knot invariants. (L. Kauffman, 2005, Grand 2001, 26, Neuman 2003, 11, 48, 91 sqq.) As the elementary bracket algebra is to *biologic* what Boolean logic is to classical logic, this has important epistemological consequences (Zimmermann, 2007a). On the other hand, the Jones polynomial can itself be visualized in terms of quantum computers, because a similar partition function of the form $Z_K = \langle \text{cup} \mid M \mid \text{cap} \rangle$ with creation and annihilation operations, respectively,

$$\text{cup} := \mid a \rangle : C \rightarrow V \otimes V,$$

$$\text{cap} := \langle b \mid : V \otimes V \rightarrow C,$$

M being the braiding, and $< K > := \Sigma_\sigma < K \mid \sigma > d^{||\sigma||}$ can be related to the process of quantum computation (as can, by the way, the spin network formalism itself.) As spin networks are nothing but graphs, the *agency* in question here is motion on graphs or *percolation in networks* such that phase transitions can be represented in terms of an appropriate cluster formation of connected components. This is what points to a close relationship to cellular automata utilized for the simulation of evolutionary processes (cf. Conway's game of life or Wolfram's approach). Stuart Kauffman has associated this with the emergence of collectively autocatalytic sets of polymers, and in fact with the onset of forming classicity with regards to physics. It is straightforward (in epistemic terms) to generalize this (with a view to higher-order agents) to chemical, biological, and other systems.

5. But there is still another point to that: In the approach of Barrett and Crane (1997), the idea is to generalize topological state sum models in passing from three to four dimensions by replacing the characteristic SO(3) group with SO(4), or its appropriate spin covering, SU(2) x SU(2), respectively. The concept of spin networks is also generalized then, by introducing graphs with edges labelled by non-negative real numbers (called „relativistic spin networks"). Applying this kind of „spin foam" model to Lorentzian state sums demonstrates their finiteness in turn implying a number of choices made from physical and/or geometrical arguments. (Crane at al., 2001) The really interesting aspect of this is its relation to the group SL(2,C): because this is the double cover of SO(3,1) and the complexification of SU(2) which in turn is the double cover of SO(3). On the other hand, SL(2,C) is the group of linear transformations of C^2 that preserve the volume form. Thanks to an e-mail crash course on these matters referring to the Barrett- Crane model and made available online by John Baez and Dan Christensen (2000), where they use the terminology of the former's quantum gravity seminar [29], it is easy to

understand that constructions in the sense of Barrett-Crane turn out to be invariant under SL(2,C). In other words, we essentially deal with states in C^2 which are spinors. And it is from quantum theory and special relativity that we know about their relevance. On the other hand, as Baez notes, and as we will see shortly, a state in C^2 can also be called a *qubit*. So „[w]hat we [a]re really doing, from the latter viewpoint, is writing down ‚quantum logic gates' which manipulate *qubits* in an SU(2)-invariant [in fact, SL(2,C)-invariant] way. We [a]re seeing how to build little Lorentz-invariant quantum computers. From this viewpoint, what the Barrett-Crane model does is to build a theory of quantum gravity out of these little Planck-scale quantum computers." (Baez, Christensen, 2000, 42) This is obviously very much on line with the arguments of Zizzi, Lloyd and others. Moreover, it is referring to the explicit level of spin networks: That is, the aforementioned „boundary layer" between the physical world and its foundation shows up as a „shift of quantum computing" processsing the fundamental information necessary for performing the transition from foundation to world (or in other words: for actually *producing a world* out of its foundation).

6. Utilizing the "skeleton-of-the-universe view" (Zimmermann, 2004b, 2007b), the idea would be to insert various steps of a hierarchy of complexity in the overall functor diagram from topological quantum field theory (cf. John Baez):

$$\begin{array}{ccc} \text{nCob} & \rightarrow & \text{Hilb} \\ \uparrow \textit{em} & & \uparrow\downarrow \textit{id} \\ \text{SpinF} & \rightarrow & \text{Hilb} \end{array}$$

This diagram is commutative, if an adequate emergence (em) mapping is being defined. Here, SpinF is the category of spin foams, and nCob is the category of n-dimensional cobordisms. (For the time being, we can safely set n = 4.) Hence, there remain three things to do:

a) to show that loops are fundamental agents in that their loop motion (their self-assembly and combination into spin networks) corresponds to Stuart Kauffman's definition of agents.

Outline of Proof: From recent work of Donnelly's (2008) we know that the appropriate entropy is the von Neumann entropy of the form $S(\rho) = -\mathrm{tr}\, \rho \ln \rho$, where ρ is a suitable density matrix. In Kitaev and Preskill (2005) as well as Rovelli and Vidotto (2009) we find that for spin networks in loop quantum gravity, it is especially the Braunstein-Ghosh-Severini (BGS) entropy which is relevant here: This refers essentially to a quantum field theory on a space $\Omega \subseteq \Sigma$ with $H_\Sigma = H_\Omega \otimes H_{\Omega^C}$ as adequate tensor product of the associated Hilbert spaces such that $\rho_\Omega = \mathrm{tr}\, H_{\Omega^C} |\psi\rangle\langle\psi|$. In particular, for the loops of this theory, the appropriate Hilbert spaces are defined by the cyclic functions of an SU(2) connection A. Hence: $\{\psi | \psi(A) = f(U(A, \gamma_1) \ldots U(A, \gamma_L))$, where $|\psi\rangle$ is a spin network state. The density matrix turns out as the Laplacian matrix (essentially the difference between degree matrix and adjacency matrix) divided by the degree sum of the underlying graph. Then, $\oint_\gamma dS_E(\Omega) \geq 0$ fulfils Stuart Kauffman's condition for an autonomous agent.

b) to actually describe what the mapping *em* looks like in detail.
c) to introduce intermediate stages of hierarchy into that mapping.

If we accept this viewpoint for a moment, then all of this is compatible with the idea of humans being complex agents organized in complex communities of agents playing natural games which in their case specialize to *social* games and are called meaningful. The cognitive activity of humans then, thinking, and modelling the world, is a complex activity defined according to their complexity as agents. (Cf. Copley 2010) Hence, humans show up as collectives of fundamental agents which co-evolve in an organized community. A social system is a community of communities then. (In fact, this viewpoint is also compatible with the theory of systems according to Edgar Morin.)

7. However, while talking about all of that, we notice that this is the outcome of the modelling procedure. In other words, the systematic approach outlined above is itself a model, i.e. a mapping of the world, not the world itself. We utilize the concepts of *space*, *network*, and *system* according to our epistemological principles: As such networks serve as a formal skeleton for a space and for a system, respectively, while they are graphical representations of both of them. The concept of space serves also the graphical representation of what we call a system. The system is the concept we have of what we are able to observe in concrete terms. But what we observe is only part of the world. (Our ontological directive is: The world is not as we observe it.) But we are products of that world ourselves. Hence, there is the necessity of a *cognitive metatheory* for our other theories which tells us something about the basic limitations of our possible knowledge. This entails the necessity of a self-loop: Humans model the world by inventing theories according to the cognitive constraints this same world is imposing upon humans. Theories constitute categories of meaning. If humans show up then as communities of communities of fundamental (natural) agents, they are, with respect to the latter, *emergent structures* in nature. And so are all of their reflexive concepts. Hence, the concept of (human) meaning itself is emergent with respect to fundamental *proto-meaning* defined in terms of the directed behaviour of fundamental agents. This may be utilized as a grounding of the concepts of *pre-reflexive* and *reflexive meaning*, respectively. (For „reflexive mentation“ see also Jantsch, 1982, 237, and as early as 1748 La Mettrie! Cf. Grand 2001, 6) Hence, the Universe is meaningful from the outset, but it is only humans who develop reflexive meaning such that they actually know that there *is* meaning.

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