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Fundamental Interfaciology: Indistinguishability and Time's arrow

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Abstract: It is argued that the notion of indistinguishability provides a link between epistemological and fundamentally ontological reasoning, i.e., for the interface problem or endophysics. In Newtonian molecular dynamics simulations of autocatalytic chemical reactions as a basic step to describe life one encounters with the problem of reversible computation which has been compared with Newtonian physics by Fredkin and many others. The introduction of chemical identities in such simulations raise questions concerning the link of information to ontic qualities and in turn to the experience of Time's arrow. In reactions like $A+B \rightarrow 2A$, the production of indistinguishability on a molecular level strikingly leads to an apory. In the backward path after a reversal of momenta in a traditional computation it is imposible to assign the correct identities, A or B, to the two indistinguishable molecules of species A. If the logical operation were reversible then this information is available but contradicts a "true" indistinguishability of molecules. Both, treating it as an objective or as an observer dependent, i.e. subjective entity lead to inconsistencies of a kind that have been summarized by Heidegger as "self-missing" (Selbstverfehlung) of Being (Dasein). According to Heidegger's view, Being has no difference, thus our exploration of Being by necessarily drawing differences fails. To speak of indistinguishability is the result of an epistemological distinction of subject and object that is avoided in Heidegger's approach, however, somehow on the cost of losing grip to nature. Related problems are the complementarity of discreteness and continuity and many others. Even quantum mechanics that addresses problems at the micro level, although inherently endowed with complementarity, not really supplies an explanatory basis for the aforementioned problems because concepts like indistinguishability are here introduced by fiat, too.

This paper is dedicated to Otto E. Rössler on the occasion of his 65th birthday in May 2005.

Keywords: indistinguishability; molecular dynamics simulations; micro-macro-interface; endophysics; time reversibility; fundamental ontology

Indistinguishability is a mysterious concept that caused many scientists to speculate. Is it a notion that can be understood only in quantum mechanics, as sometimes argued? It has been introduced in classical mechanics, probably by Boltzmann, to dissolve the paradox emerging in entropy computation from the distributions of the atoms' states [1] in diffusion processes of a gas, for example. We briefly outline the problem for those how are not familiar with it.

A relaxed gas in thermodynamical equilibrium leads to a diffusion of molecules from the right half to the left half of the available volume and vice versa. Neither entropy nor energy is affected thereby, because the gas was and remains relaxed. However, if the molecules in the right half are marked "red" and those in the left "blue", for example, both species will spread into the whole volume and thereby changing entropy through mixing. This difference is captured by the permutation symmetry associated with the particle's identity.

E.T. Jaynes interpreted the dependency of entropy as observer-dependent because he related identity with the human capability of distingushing two systems from each other [2]. In fact, Shannon's entropy exactly accounts for this knowledge but whether this holds for thermodynamical entropy, too, is still very controversially [3, 4, 5] and sometimes polemically debated [6].

That Boltzmann's treatment of indistinguishability was part of a profound explanation of thermodynamics by means of statistical mechanics is folklore [7]. To point to quantum mechanics does not really contribute to a more profound understanding of the nature of indistinguishability. It rather leads to an increased confusion. It is remarkable that in the classical application the assumption of indistinguishability leads to an entropic effect by reducing the phase space by the factor $\frac{1}{n!}$, when n is the number of identical particles. In quantum mechanics, on the other hand, indistinguishability has before anything else an energetic effect through the exchange interaction. With respect to entropy the quantum mechanical calculations are just adoptions from classical physics and do not provide any news. But what is with the energetic effect in classical mechanics? According to Noether's theorem a symmetry should lead to a conserved entity. But even in quantum mechanics where exchange energy exists in stationary considerations a dynamics subscribed to this energy is not discussed. Can indistinguishability be produced or annihilated and what is the physical impact?

In this paper we want to point to questions that arise from molecular dynamics simulations (MDS) which may throw new light on the discussion. MDS are classical since computers are classical, so far [8]. Therefore, MDS can be seen as a testbed for classical statistical mechanics. The never-ending dispute on the differences of Boltzmann's and Gibbs' approaches to statistical mechanics counts to the frequently addressed problems in MDS as well as questions concerning Poincaré's recurrence time and so and so forth [2, 3, 9, 10]. Thereby, in dealing with MDS-algorithms, sometimes problems emerge that have been overseen before.

Orban and Bellemans, for example, computed Boltzmann's H-function in a Newtonian particle simulation in order to test the time symmetric behavior by exchanging momenta of all particles at a certain instance of time [11]. Then, clearly, the H-function (essentially the negative entropy) has to be exactly retraceable provided a deterministic Newtonian computation is performed. As expected, the H-function rapidly decreased in forward direction and it increased in backward direction. However, the backward course of Boltzmann's H-function was not exactly the same as

in forward direction and it did not reach the same magnitude as it once had at the intitial time. Reproducablity of the H-function decreased even more with increasing time intervals of forward computation until the flip of momenta were executed. In the case where the H-function was close to its asymptotic value in forward direction after a sufficiently long computational time it even remained at this low value after exchanging momenta. The correlation is this case was fully lost.

The explanation is quite simple. The algorithm, i.e. the discretization of the underlying Newtonian equation of motion, is dissipative. But moreover, there are nonlinear effects in the rounding-off errors. The forward and backward computations lead to different rounding-off errors at a given instant of time. Thus, it can be asked whether the (discrete) computer is principally capable to perform such kind of consistency analyses that rely on exact reversibility. On the other hand one may infer from this artifact to features of nature as is analogously done for example in the case of Lorenz' chaos which has been found as a result of the impact of rounding-off errors. Here, the finite digital accuracy can be transferred to a principally finite accuracy in measurement or/and to a principally noisy surrounding how small this noise might be. Thus, the inherent "noise" of a simulation (the rounding-off errors) and perhaps additional inaccuracies due to (temporal) discretization do not matter with respect to the invariant structure of an attractor. To be precise, it does not matter when a certain class of proper algorithms is used that preserve the invariance of the system which has been shown by Kloeden and others [12, 13]. The concrete trajectory of the simulation and that of the real system that is to be described with that simulation cannot be compared, which is the well-known main conclusion from chaos studies. In principle, this argument holds also in Orban's and Belleman's MDS of molecular chaos which may also be called "Boltzmann chaos" to credit the merits of this outstanding physicist.

A dissipative system however is irreversible even in the exact continuous case and it therefore does not make much sense to compute such a system in backward direction. The application of a reversible algorithm to a dissipative dynamics entails so called parasitic solutions. The algorithm in this case forces the dynamics to an invariance that the continuous dynamics does not obey. But such an argument fails in the Newtonian case where one may be interested in reversing the computation in order to check consistency and, even more important, to conserve a basic symmetry of the continuous dynamics in the discrete representation. If one, for example, intends to simulate a Newtonian system forward in time as long as the entropy falls below a certain threshold or reaches the intitial low magnitude in order to measure the recurrence time, then this would principally fail in a non-exactly reversible MDS even if the continuous system were able to show a large fluctuation away from equlibrium after a time interval that would be managable in an MDS. The frequent interpretation that the second law of thermodynamics holds in a extremly good approximation because such fluctuations have an almost vanishing probability to appear would never be capable to check. On the other hand, one may conclude from the very fact that the enterprise of reversible computation is so extremely hard to realize, that this is so to speak already an empirical proof for the second law. However, as we will see in the sequel, even from the perspective of treating it partially as a gedankenexperiment one can derive interesting insights.

In micro physics reasoning one tries to capture the surrounding as well and the aforementioned consistency check includes the test of whether dissipation can be explained by a high-dimensional but still Newtonian surrounding with of course astronomically large recurrence times that validates the second law in an almost perfect approximation, as mentioned. Within this reasoning,

the possibility of a remaining irreversibility is shifted in a cascade of surroundings of surroundings to the question of whether the Universe is open or not.

After Orban's and Belleman's work every endeavours have been made in deriving so called symplectic algorithms that preserve volume in phase space of Hamiltonian systems according to Liouville's theorem [14]. The frequently in MDS applied Verlet algorithm [15] turned out to be symplectic due to its symmetric form

$$x_i(t+h) = 2x_i(t) + h^2 f_i\left(\mathbf{x}(t)\right) - x_i(t-h), \mathbf{x} = (x_1, x_2, \ldots, x_{d \cdot n}), \tag{1}$$

with the configuration vector $\mathbf{x}$ and the configuration space dimension $d \cdot n$, where d is real space dimension (often chosen as two in MDS) and n is the number of particles. The spatial discretization is given by h and $\mathbf{f} = (f_1, f_2, ..., f_{d \cdot n})$ is the force given by the underlying Newtonian equation of motion, $\frac{d^2(\mathbf{x})}{dt^2} = \mathbf{f}(\mathbf{x})$, where the masses have been chosen to be 1 for all particles. The momenta of the particles (if needed) can be derived from the approximation $p_i(t+h) = \frac{x_i(t+h)-x_i(t)}{h}$.

If one applies a symplectic algorithm like Verlet's algorithm of Eq. (1) to a set of initial states equidistributed in an area of the phase space then the computed states after a given time interval remain equidistributed in an area of the same volume as in the beginning. This does neither mean that the single trajectories are exact nor the shape of area. It says, that the volume of the area is preserved. And from that, an invariance of global measures like momenta and engery is ensured. For a precise mathematical proof we refer to [14].

Reversing the momenta becomes very simple in this case: Just exchange $x_i(t+h)$ by $x_i(t-h)$ $\forall i$. But even in this case the computation is not exactly reversible using the usual floating point representation due to different rounding-off errors in forward and backward computations as a result of the nonlinear impact of representing numbers with finite mantissa and exponent. Just sum up any number, say h, sufficiently many times, say n times, and then subtract h from the result n times, this will lead to a different initial number of the summation.

Not so, however, in the case of an integer implementation. It took however quite a long time to recognize, that integer implementations can be used to make Newtonian simulations exactly reversible [9, 10, 16, 17]. The investigation of exactly time reversible algorithms in [9, 10] was strongly inspired by Fredkin's reasoning of reversible computations where he mapped the Boolean logic that determines the logical gates in computers to a Newtonian billiard ball dynamics and eventually derived an equivalence [18, 19]. This led to a comparison of the Newtonian nature of the Universe with the also Newtonian nature of computation.

To actually build a reversible Fredkin gate, however, turned out to be a rather difficult task. The billiard ball model is a vivid description that allows to grasp the essential point: computation is equivalent to a Newtonian mechanical system. However, it is unpractical for building real computers. A electronically implementable technics would be fine. The problem of actually constructing Fredkin gates may be as academic as the performance of an exactly reversible simulation. However, as mentioned above, we here treat the existence of Fredkin's gate as a premise (in the sense of a gedankenexperiment) in order to point to a contradiction but also to a possibility of calculating energy related to transitions of indistinguishabilities.

The reversibility in Fredkin's gate is ensured by introducing a so called garbage bit. This can be easily understood from the example of an AND-gate. The simple AND-gate has a $2 - bit$ input and a $1 - bit$ output. The output is 1 if both input bits are one and zero in all three other cases. In the case of a zero output one has to remember somehow which of the three input posibilities led to this output, if one intends to ensure full reversibility. Thus, from the demand that a feedback of the output back to the input has to yield the original input, a logical gate can be derived that has as many input as output bits. But to use this gate for and AND-operation, one of the output bits is superfluous and has to be kept only for ensuring reversibility, if needed. If this garbage bit is erased, however, reversibility will be destroyed. The erasure of bits leads to a dissipation of energy as a result of the loss of information [20, 21, 22]. We refer to the orignal publications by Fedkin and others who proved that each Boolean operation can be constructed by a proper combination of Fredkin gates [18, 19].

In the course of an iterated process however one may be forced to erase these additional bits to keep storage manageable. But the most interesting point from an endophysical perspective is the fact, that drawing the result from the computation may lead to an erasure of garbage bits and thus reanimating Szilard's treatise from 1929 on the impact of intelligent beings to thermodynamical systems [23]. "Observation" means an interaction with the system to gain information and this in turn leads to energy consumption because otherwise we have contructed a Laplacean or a Maxwellian demon [24, 20]. In this case one may ask, whether the information is transmitted and conserved in the brains in a way that statistical mechanics feels reassured. Thus, one may ask whether the discussion of reversibility in computation is nothing but just a shift of the already ongoing debate for more than a century in physics into the fields of information science?

Let us have a closer look at some concrete problems of exactly reversible MDS. We ignore for a moment the problem of whether there is any energy consumption of computation. Indeed, the many-particle-problem of identical particles can be solved exactly reversible using the aforementioned extended version of Verlet's algorithm on an integer implementation [9, 16, 17, 10] indepentendly of whether the CPU produces much or only little heat. The behavior of the H-function in a simulation of a dilute monomolecular gas as investigated in Orban's and Belleman's work could be reproduced, however, in the new reversible MDS by being able to exactly retrace the function backward in time. It is ensured by using modern computers to follow up the dynamics of the molecules for more than 1000 particles in a simultaneous visualization to check the plausibility of how the particles behave on-the-fly, so to speak. Thus, there is absolutely no problem for a monomolecular particles arrangement to check consistency of statistical mechanics by means of MDS.

It is worthwhile to note, that from the exact reversibility of MDS no accuracy information of the trajectory can be derived. Reversibility ensures invariance of global measures. The momentum is conserved and energy is free of drift. Thus, comparable to a chaotic attractor, it is a global structure that is kept invariant. In the same fashion, due to molecular chaos (or "Boltzmannian chaos") in a Newtonian many particle system, even the smallest possible perturbation of only one (integer) unit after reversal of momenta leads to a different trajectory and destroys reversibility. This is why it seems on a first glance that besides a philosophically motivated reversibility check an exactly reversible MDS has no further advantages because even in a not excatly reversible floating point implementation the energy drift can be kept acceptably low. However, the ambitious quest

for exact reversibility in MDS leads to an awareness of fundamental problems as we will show in the sequel.

Of course, those who want to understand living systems immediately ask what have monomolecular systems to do with life? Ilya Prigogine became famous for his ambition to introduce real dissipation and irreversibility in the world to be consistent with his philosphical understanding of the concept of human being [25]. His valuable contributions and his impact on trying to tackle related problems cannot be overestimated. Life can be only processually understood which has been extensively discussed by Bergson and Whitehead around the turn of 19th to the 20th century and then by Heidegger in "Being and Time (Sein und Zeit)" in the early decades of the 20th century [26, 27, 28]. Prigogine tried to build on the insights of those philosophers. He recognized that ergodicity is a concept in physics that excludes a process by its very definition since time can be transformed away in ergodic systems. Lifting the constraints of ergodicity, however, leads to a loss of mathematical analyticity. In this context, a convincing argumentation can be found in Jelitto's textbook on thermodynamics [29]. A great deal of thermodynamical equations are derived from setting the time average equal to an ensemble average as worked out in the Gibbsian approach to thermodynamics. As Jelitto argues, this leads to the application of a sophisticated mathematical tool box which is not available so far when one abandons from the ergodicity assumption. However, as Jelitto infers, this should not cause physicist to retreat but rather to feel them challenged by deriving an analytical tool that refrains from using the ergodicity assupmtion. This is exactly why some physics argue to use MDS in order to tackle the problem in a "semi-analytical" or "computer-experimental" way through simulations.

Prigogine expelled reversibility of dynamics from being able to describe living systems. The realm of inherently transient dynamics like chaotic itinerancy is entered in both dissipative and conservative systems [30, 31]. Chaotic itinerancy is a promising candidate to provide a new concept for inherent processes, where an attractor is redefined through an accumulation of orbits evolved in the neighborhood of a quasi-attractor. This situation is analog to that occurring in the presence of chaos, namely that a state is redefined through the time-evolution of state, whereby the states are assumed to be ascribed by symbols produced by generative partitions like a Markov partition, for example. [32],[33, Chapter 2]. Can MDS contribute in these fields to gain insight?

The proposed chaotic itinerancy in Hamiltonian systems by Konishi and Kaneko [31] has been checked for reversibility in a real-time visualization and presented as a media installation at different venues [34]. This simulation demonstates the becoming and elapsing of only temporarilly stable complex subsystems (clusters) in a many-particle system. The installation is endowed with a simple interface consisting of two buttons, one for reversing momenta and one for a reset that starts the system in a kind of big bang situation with all particles pooled in a singular state. The spectator is thus able to study that the low entropy initial state can be retraced after reversing velocities and moreover, that in overshooting the big bang backward in time the same waxing and waning can be observed as in forward direction from the fully symmetric initial state on. Of course, this performative approach has to be understood as a method of reflexion rather than an immediately scientifically utilizable investigation. It was however shown by Konishi's and Kaneko's work and our installation that a quite high degree of complexity can emerge in reversible dynamics.

Still, even from a very humble point of view, a crucial ingredient for the approach to aspects of

life in an MDS is missing: autocatalysis as a basis of reproduction [35]. In [36, 10] we introduced within a reversible Newtonian simulation three different particle identities. The following simple autocatalytic reaction scheme has been performed,

$$\begin{array}{lcl} A+B & \longrightarrow & 2A \\ B+C & \longrightarrow & 2B \\ C+A & \longrightarrow & 2C, \end{array} \tag{2}$$

which leads to an oscillation of concentrations (mean particle number). The reaction was performed as follows. If the mutual kinetic energy of two particles exceeded a certain threshold new identities were ascribed according to the reaction scheme. The fact, that this simplification violates basic chemical requirements like detailed balance conditions should not bother with respect to the following argumentation. Anyway, it has been shown by Geisshirt et al. and Toxvaerd [37, 38] that the reaction scheme can be properly enhanced.

The reversibility discussion now enters an interesting phase. If the momenta are reversed it is in a usual computation not possible to regain the same identities in backward direction. The path of the molecules can exactly be retraced as explained above. Thus, the scattering process of two particles can be retraced but not there identities in the case these should have changed in the reaction. If in backward direction the same reaction scheme is applied as in forward direction the average behavior remains the same in case of being close to equilibrium. From an ergodic point of view, i.e., if the system was sufficiently relaxed from the very beginning, then the macroscopic oscillation appears to be the same as in forward direction if one refrains from inspecting minor fluctuations around a moving average of the concentrations. The microscopic behavior however is different. Apart from equilibrium a time reversal even leads to different macro phenomena (frequencies and amplitudes).

Now the reversible Fredkin gate may be revisited. As we learnt, Fredkin ascribed logical operations to a Newtonian dynamics. Let us for a moment forget the problem of whether a Fredkin gate can be build by means of electronic chips or something like this. We adopt Fredkin's billiard ball implementation. That means, in our Newtonian MDS a transformation of the logical operation to mechanics is possible within the MDS itself. For example, we can replace the operations of identity changes that appear in $A + B \rightarrow 2A$ on the molecular level by a Newtonian billard system. The identities may change due to exchanging electrons circling around a nucleus or due to different spatial conformations. This in turn may be captured in MDS by introducing more degrees of freedom than those of hard spheres or point particles. To give a vivid example, one may capture the identity of particles by introducing additional point particles (electrons) circling around the previous point particles (nuclei) (which has to be interpreted rather symbolically). Then, if an electron circles around a point particle we may call it A, and if there is non we call it B (mimicking an ion). But even if we assume that this blowing up of dimensions leads to a still acceptable computational performance, the result would be that no new identities can be created which clearly contradicts the assumption of indistinguishability of atoms of the same species. Since we can keep the pathes reversible – that of the nuclei and that of the electrons which both do not change their indentity – each electron exactly knows were it came from in the past, thus keeping the single "atoms" or "ions" distinguishable. This simulation has an obvious analogy to the above mentioned Hamiltonian system which leads to the temporal formation of clusters, if one identifies similar (or subjectively indistinguishable) clusters by calling them molecues of a certain

species.

From a practical point of view, when reversible Fredkin gates (that we assume to exist for the moment) are used in the computation, then in the course of iterated computations we may be forced to delete the garbage bits in order to housekeeping with the storage, because the garbage bits are accumulated over the iteration steps. The erasure of bits in turn increase the CPU's temperature accordingly [21, 22]. We refrain from going into details and refer to the cited literature. We just mention in passing, that the heating of the CPU hinders to make it smaller and therefore faster. Thus, the reversibility arguments in computing have a concrete pragmatic background. We already mentioned above, that the withdrawal of information after a computation has been linked to the observation process which perhaps has a concrete energetical impact. In this case the loss of information with its energetic effect can be tried to transfer to the loss of knowledge on identities in the MDS which is not discussed in classical physics. Thus the discussion of reversible computation may cast light on the energy consumption in the process of creating indistinguishability. Neither in quantum mechanics, the creation and annihilation of identities is discussed in this depth.

Indistinguishability operators are used in fuzzy systems to account for observer dependency. There, they can be linked to semantics [39]. The case in hand, however, is cleary diffent from that fuzzy, i.e., observer-dependent situations, since atoms are regarded as ontically indistinguishable, by its very nature, so to speak without having them observed. Otherwise, only the set of infinitely stable elementary particles could be indistinguishable and each composed particle system that is subject to an eventual decay cannot be trully identical with a composed particle of what we call the same (in this case it is rather a similar) species – if the term species here makes any sense at all. Or, in case they are really indistinguishable, we have non-continuous transitions of identity changes. Entropy would collapse all of a sudden, because it changes not before the particles become exactly indistinguishable. Thus, even classical systems may exhibit quantization phenomena. But perpaps most important: Although there may be a conserved energy, indistinguishability can lead to the emergence of an asymmetric time.

In case the reaction is viewed from a macroscopic perspective and if the ergodicity assumption seems to be justified it may look smooth. But what happens on a microscopic level of the reacting particles, especially when the system is far from equilibrium? What happens with the energy? The dynamics of "real" identity changes are not discussed in the literature, only those of observer-dependent ones in fuzzy systems that are described by a Shannon entropy within the information science context [39].

As is well known, the second Newtonian law states that an isolated particle remains in uniform velocity if it had this velocity before or in rest if it was in rest from the beginning. However, to make spatio-temporal statements about 1-particle systems is absurd. A particle can "experience" space only if there are other particles available so that a measure of distance in space makes any sense. The abstraction of speaking in an objective way (from an exo perspective) about a 1-particle system neglects the impact of our "being-in-the-world" to this description. Identity is a notion that makes only sense in an arragement of individuals as for example Whitehead pointed out in his concept of "organistic philosophy"[27]. Going to the limit of an isolated individual leads to a paradox. In the same manner, speaking of identities as observer-independent entities, i.e., from the epistemological perspective of separating subject and object, necessarily fails in such

fundamental problems.

According to Heidegger, to explore Being means to introduce differences but this in turn fails to understand Being which is not subject to a difference [28]. Being is always ahead of its description. Being and Time are equal in Heidegger's fundamental ontology. Therefore, to deduce Time out of our categorization necessarily fails or leads to a paradox. Niklas Luhmann mapped the unavoidability/uncheatability of Dasein ("Unhintergehbarkeit des Daseins") to an infinitely repeated process of observations. In his arguments he adopted Spencer-Brown's stance that drawing a distinction takes place in a space that is thereby separated in a marked and an unmarked semi-space (cf. [40]). However, the most striking conception has been formulated by Rössler, how calls it an interface problem which reminds to Spencer-Brown's and Luhmann's semispaces but in addition more directly refers to a semantic generating surface of a medium [41, 42, 43]. This has the avantage of operationalizability.

There are several examples for encountering the interface in physics. For example, if one approximates a cloud of electrons by a continuous charge distribution and let the radius of the cloud tend to zero in order to approach the limit of a single electron one is confronted with an infinitely large self-energy [44]. The infinitely large term is thrown away and only a finite one is kept what is sometimes called renormalization. Discreteness and continuity, population and identities, and so forth, are complementary pairs that emerge on the interface that separates epistemic from ontic semi-space. Thus, no need to switch to quantum mechanics to encounter this complementary behavior. Quantum mechanics captures only a small fraction of those problems but does not supply any explanatory framework of it.

In population dynamics the growth of species may be well described by a dynamical model containing zero as an unstable fixed point. Even the smallest perturbation then drives the state away from zero. But if we externally intervene in a brute force way and thereby bring the species to extinction, the zero-population size is the most stable that can be imagined. Zero is a "priviledged state". Approaching the problem from the other side, namely letting an individual emerge, marks an event that creates a causal principle that either did not exist before (or, as a side remark, if one takes Plato's view, we have not been aware of it but it existed as an idea). An attempt to embed such an event into a generalized theory eventually leads via a hierarchy of evolution principles to the totally undifferentiated and maximal symmetric singularity called "big bang", for example. Almost every discipline has created such a singlularity in extrapolating its method to the beginning where an event is the result of a mysterious "symmetry-breaking" or an "emergence" or any comparable fuzzy notion to capture those events somehow.

It is beyond the scope of this article to compare this extrapolations and to embed them into Heidegger's and Whitehead's reasoning, respectively. We just summarize that his fundamental ontology can be seen as the most general approach to the problem which however leads to a loss of grip in dealing with facticity. Each description of being, including logic and causality, is the result of events that precede these descriptions: "Being is the transcendens pure and simple" ("Sein ist das transcendens schlechthin")[28]. The problem on hand reveals the creation of time through events, i.e. the emersion of identities or differences, respectively. Categorizing being is identical with the experience of time through the necessary changes of categories as a result of its non-perfect nature, i.e. its inconsistency when viewed from a pretendedly objective exo-perspective.

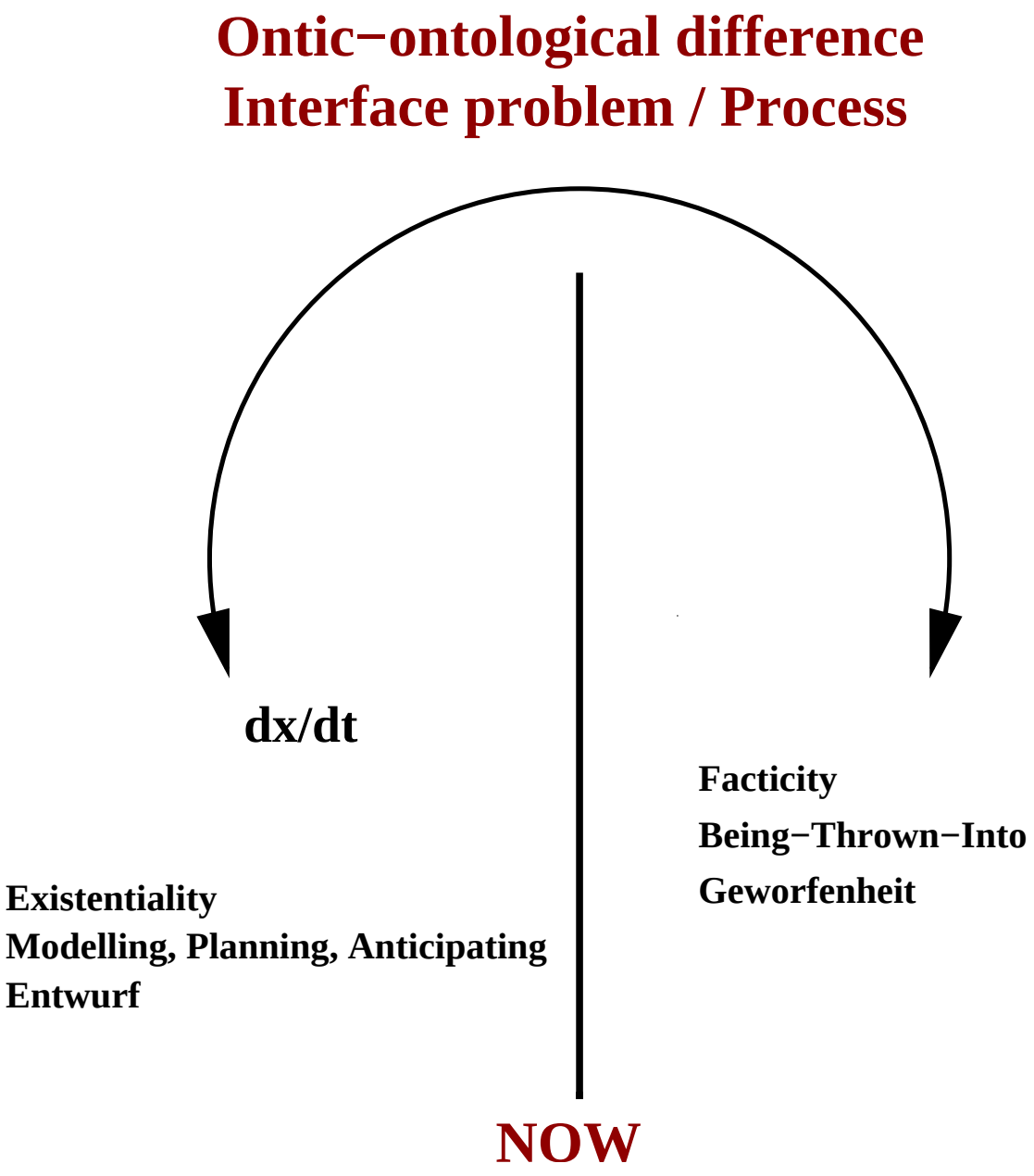

Figure 1: Schema of the "Now" as an interface producing the "ontic-ontological difference".

An attempt to vividly capture the interface problem is done in Fig. 1. The competitive edge of being, in particular our pre-understanding, leads to the creation of a causal principle in form of a differential equation, for example. The right hand side of the interface (i.e., of the "Now" that creates a ontic-ontological-difference) stands for facticity or "Geworfenheit". The latter term has been interpreted by the French existentialism in a perhaps too fatalistic way and may roughly be translated as "being-thrown-into". The left hand side of Fig. 1 marks the "Entwurf", which is an activity based approach to Being through causally, logically or, in general, explanatory models. Draft, model, plan, sketch, concept, conception, etc are possible translations for "Entwurf" that sums up to our scientific and philosophical categorization.

The attempt to caputure the "Being's being ahead of its description" within the causal description itself would lead to a delay feedback equation where the change of a state depends on a positive delay, i.e. a future state. A future state $x(t+\tau)$ determines the momentary state $x(t)$ and its dynamics entails a self-referential equation comparable to Zeno's paradox[1]:

$$\dot{x} = f\left(x(t), x(t-\tau_1), x(t+\tau_2)\right) \tag{3}$$

A causal approach to brain functions reveals the problem in full intensity. In our acting we somehow manage to let this infinte regress collapse and cut the full rational problem to a bounded rational one. With a grain of salt, the emergence of aesthetics and ethics can be understood from this approach although not included in a causal way within this description which in fact is the crucial point. We have to keep in mind that the approach to Being through differential equations already makes us to a victim of the interface. It is only "one" way to describe reality. Equation (3) is the result of converging to the interface from the left hand side (of Fig. 1). However, a mathematical approach as a basis of logic and system theory seems to be unique in the sense, that it has the potentiality to capture the self-referential problem in a maximal precise way.

Additionally, the causal approach given by differential equation (3) reveals a problem we would like to point out, at least in passing. Heidegger's pre-understanding (symbolically grasped with $x(t+\tau)$) is quite frequently misinterpreted as pre-knowledge (symbolically grasped with $x(t-\tau)$. The historical based approach to philosophy and science, for example in Hegel's dialectic, the philosphical discourse, Bacon's induction principle, evolutionary principles and so and so forth, have definitely not been addressed by Heidegger. These approaches are rather epistemology-based than ontology-based. Whitehead identified those approches as those with a strong tendency to dogmatization [27]. The so called "Sokal affair" proves that Whitehead was right and, moreover, that this is still the strongest friction that hinders progess and innovation in philosophy and science [6, 45][2]. Sokal's and Bricmont's polemics addressed the ontological approaches - those approaches that leave space for the "new". Heidegger's notion of pre-understanding is a "futuric"[3] rather than a historic one. This is crucial in understanding the concept of an event and why descriptions of brain functions as adaptive processes can only be rough approximations under the condition of ergodicity. Models like the chaotic itinerancy are much more promising in this context [30, 47]. A dynamic of existing identities that does not allow to constitute new identities as a result of rearrangements does not contain processes. But processes introduce an interface problem of the kind depicted in Fig. 1. After the constitution of identities they can again be traditionally treated by a dynamical description but the transition contains a cut. The interface concept provides a basis for understanding the paradox of the new [48]. The introduction of two forms of time is

[1] We mention in passing that a complex function with complex defined time may lead to a solvable problem very much like the Pauli equation in quantum mechanics where the change of sign aka change of time direction leads to the interpretation of electrons as positrons

[2] Sokal and Bricmont accused ontologists for abusing natural sciences. We refrain from giving a more detailed description and refer to the source literature [6, 45] and to a critiques in [46]. We here only annotate the fact that Ilya Prigogine was amongst the affected persons because of his attempts to implement the process into system theory.

[3] in adopting the German term "futurisch" used by Jahraus [40].

avoided and reduced to a bilateral approach to the Now.

Back to our main problem of the paper at hand: indistinguishability and time reversibility. We regard it as one of the most striking examples of experiencing the equivalence of "identity" (or difference, respectively) and Time or more precise, the "Now". Both are related with the "New" and therefore, with Time's arrow. The second law is an attempt to grasp events within a causal description. It necessarily entails a paradox and therefore a controversial debate. From this standpoint each application of a causal principle to the dynamics of identities has necessarilly lead to a singularity in the beginning. The big bang as the backward in time extrapolation therefore occures as the result of epistemological reasoning that regards consciousness as absolute and as external with respect to the Universe. To adopt the ancient greek idea of a "gaping mouth of an abyss" or a "yawning emptiness" is equivalent, i.e a perfect mixture without differences and maximal possible symmetry. Also Heidegger recognized the undifferentiable "Being" to be equal to "nothingness". The fact of existing identies are quantum mechanically explained by the (random) action of particle creation and annihilation operators. Unfortunately, no understanding can be gained from this explantion. It is rather argued in a positivistic way that quantum mechanics cannot be understood but it works and one can only get familiar with it. Rössler's arguments based on chaos theory to understand the creation of diffenences as a de-mixing process in phase space is a much better candidate for gaining understanding in this context [42].

The fact that a sense of time and a sense of categorizing the world, i.e. to distinguish objects are closely related has found experimental evidence. Bin Kimura recognized the origin of time experience as a result of the development of self-reference in mind, based on the observation of psychiatric patients, in particular schizophrenic patients [49]. He observed in the patients that they lost the sense of time. The cause of this loss, as he inferred from his observations, can very likely be attributed to the malfunction of the capability of a kind of self-reference, which should be established by a mutual-reference between two different forms of "selves": "subjective self" and "objective self". Kimura emphasized that the identification of these two "selves" generates time thereby suggesting that the patients can recover from their schizophrenic stage.

Referring to Kimuras findings, a hypothesis on the origin of time in a general framework has been proposed. This hypothesis is applicable to humans without the restriction to mental diseases, based on the subjective experience. This approach finds evidence through common observations related to human experience [50]. Generally speaking, a child up to about three years age cannot remember his/her experiences as an episode but rather recall them in form of "snapshots". A continuous narration that links these snapshots is missing. It has been inferred in the framework of the hermeneutic circle that this may be caused by the situation that (a sense for) Being is not fully established up to about three years after birth because of a lack of self-reference between the two forms of selves Kimura ascribed. It is important to note that in this naïve observation the establishment of Being is realized by self-referentiality which simultaneously yields time as a result of indistinguishability via self-reference. Additionally, this theory has been applied to solve the structure of self-referentiality in schizophrenia [51].

We repeat the crucial point of our paper: The categorization of the world, i.e., the introduction of differences or identities, respectively, inherently constitutes time. To be precise: It constitutes the "process" or the "arrow of time". Time is incorporated within the concept of atomism. We

conclude by expressing our assurance that the most interesting aspect of interfaciology is the possibility of deriving operational directives in order to wriggle out from perplexity left by a possible nihilistic interpretation of Heidegger's work. From the already mentioned fact that "Being is ahead of its description" it follows, that the enactment of human beings in modelling is obligating. A detailed discussion of how this can be established through "performative science" and "operational hermeneutics" is in preparation. Introductions to these ontologically based approaches are given in [46, 52, 53, 54]. Moreover, as has been discussed in [32] and [33, chapter 2], to concept of chaos inherently contains the process, if properly interpreted. We principally cannot measure or directly represent any irrational number. In other words, we inevitably depend on finite discretization of a continuous assumed world. This in turn entails a class of dynamics that is unpredictable in its nature. It is asthonishing that the concept of chaos which accounts for this fact is often treated as something objective although it has been contructed from an endophysical point of view. Confer [32] and [33, chapter 2] for a proper interpretation based on symbolic dynamics.

In the context of endophysics, exactly reversible MDS, for example, are more than just a funny amusement. It is a source of understanding the interface problem. Therefore, we repeat our statement in [55] as well as Rössler's stance, that the micro-macro-transition is the most fundamental interface problem that is close to Heidegger's fundamental ontological approach to Being which is why we call it fundamental interfaciology.

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