Operational Hermeneutics and Communication

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What I am developing right now is a second order hermeneutics.

Rafael Capurro (this issue page 58)

Abstract

We introduce and discuss within the framework that we call *operational hermeneutics* an adaptive cognitive model that allows for the simulation of the perceived part of the world. We discuss potential applications to and their consequences for an environment that contains similar cognitive systems leading to an agent-based communication system entailing an interface problem. Via the *simulus* each agent is capable of 'stepping into the shoes' of other agents which may give rise to a cooperation and/or exploitation (if this is not the same). Very much like the hermeneutic circle the model has a bootstrapping character concerning the update of knowledge. This is how we think that the model can manage the self-referential situation in a processual way. Another way to view the model is, however, to take up the hermeneutic perspective. This leads to a second order hermeneutics (as Rafael Capurro calls it) which strengthens the fact that second order cybernetics and hermeneutics have a common goal expressed in different languages. The model as well as the link to hermeneutics are motivated through a historical back view to relevant features of dynamical system theory and to the Bayesean inference principle in statistics.

1 Introduction

In this paper we make some cautious steps towards a cybernetics model for a system of coupled agents, i.e., a communication system, and the gain of knowledge. Each agent per-/re-ceives 'messages' [1] from the environment/medium[15], whereby the latter as well as the agents' own actions and locomotion, are to be optimized under consideration of the given contraints. In other words, we formulate a model of how brains model the world and compute strategies therewith. First applications of the model are auspicious with respect to the adaptation and synchronization of complex models and real dynamics [3, 4, 5, 6]. Our ambition in the long run is, however, to understand how communication and the epistemological[16] discourse works and whether humanities and system theory can fertilize each other, as Heinz von Foerster believed [7]. This is what we want to focus on in the paper in hand. The warning that this convergence leaves a final gap between the disciplines does not hinder us to go as far as possible with our studies and experience this gap, if it existed.

The expression 'to understand' used above with respect to the epistemological discourse will certainly provoke hermeneuticians. In natural sciences 'to understand' usually refers to the capability of giving an explanatory description. Causually, hermeneuticians argue that the hermeneutic approach remains where the artifical intelligence approach fails (cf. [8, 2]). This in turn provokes a system theorist with a reductionistic view who may argue that for doing hermeneutics nothing else than the brain is responsible which is amenable to system theory – at least in principle. Dealing with self-referentiality, non-decidability and non-computability in mathematics and cybernetics one tries to account for bounded rational or endo-systems. This weakening and macerating process within the 'hard' sciences likewise indicate a tendency towards the harmonization with the 'soft' discoursive sciences. Terry Winograd and Fernando Flores pointed in a convincing way towards a connection between computer science and hermeneutics [2]. In the following we develop on their work bridging the gap between cybernetics and hermeneu-

[15] Terry Winograd and Fernando Flores [2] prefer to use the term *medium* to emphasize the fact that the brain and the environment in which it is embeded are not strictly separable due to Maturana's autopoiesis.

[16] 'Epistemological' here is meant in the sense of 'knowledge theoretical' (erkenntnistheoretisch).

tics (Fig. 1). Our hermeneutic stance has also been fruitfully influenced by the works of Ichiro Tsuda, Peter Erdi, and Rafael Capurro. [9, 10]

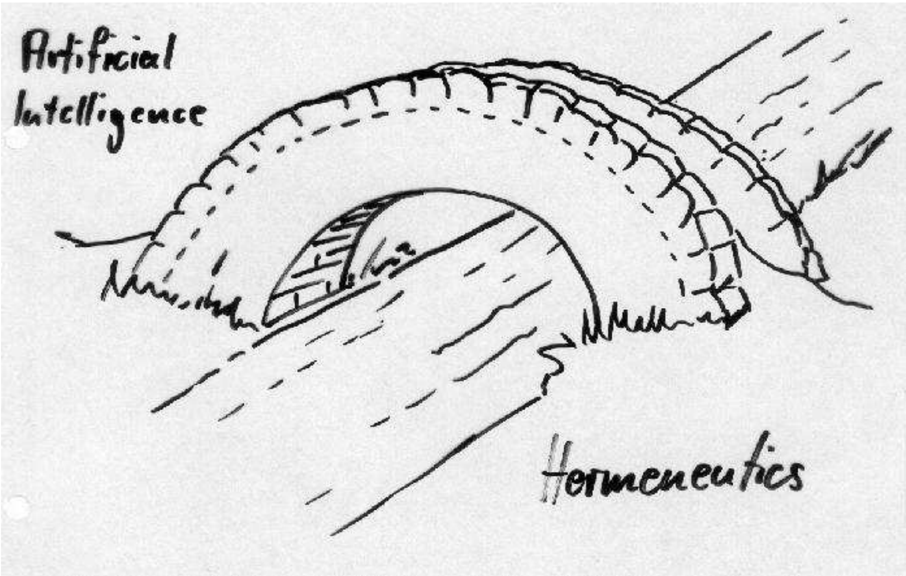

Figure 1: *Bridging cybernetics and hermeneutics.*

We feel certain, that the art of interpretation, specifically the 'hermeneutics circle' manifests itself also in the methodology of sciences with the Bayesean inference principle as a prominent representative. The hermeneutic circle describes the evolution of knowledge by anticipating the whole, experiencing the part, therewith re-think the whole and so on. Likewise, the Bayesean inference principle and other so-called bootstrapping methods are constructed so as to update given knowledge.

As is well known, statistics splits into two schools of thought – the Bayesians and the frequentists. The Bayesians rely on pre-knowledge (*anamnesis, a priori*) to gain *a posteriori* knowledge via an experimental result or an observation. The frequentists, in contrast, try to infer directly from the given result or observation only. This reminds of the conflict between structuralism and hermeneutics, where representatives of the former (in a nutshell) interpret a painting, for example, by drawing exclusively on the painting but not on the biography of the painter and other contexts as hermeneuticians do. A valid objection is that neither structuralists nor frequentists can really get rid of their own previous histories and contexts.

With this in mind we explain in the sequel a differential equation based model for an adaptive system that receives a 'stimulus' and contains a 'simulus'. It has some essential features in common with Bayes' inference principle, although it goes beyond the latter. We already discussed this model in earlier publications, however, with a focus on technical applications [3, 4, 5, 6]. In [6], for example, we applied the system to an on-the-fly adaption to a human pulse. In the paper in hand we design in a more speculative way possible applications that mimick communication structures. This model is doubly hermeneutical: it is designed to perform aspects of the hermeneutics circle and the result of the performance of the model is used to improve it.

The functionality of our simplified model brain is in line with Otto Rössler's ansatz within deductive biology where the brain is treated as an *autonomous optimizer* [11, 12, 13]. With respect to our model this means, that the simulus is used to anticipate the near future and to react to the result in order to exploit the environment. In this context an experimental finding is noteworthy. There is evidence that the brain is really endowed with simulation features as has been shown by Rizzolatti and others [14, 15]. They discovered a functional part of the brain which they call *mirror neurons* that are comparable with our simulus concept. The principle of mirror neurons has further been investigated by Detlef Linke [16] and Vilayanur Ramachandran [17]. The latter authors diagnose a close relation of the mirror neurons to self-consciousness, social behavior and empathy. Malfunctioning mirror neurons are related to typical diseases where 'self' and 'foreign' can no longer be distinguished as is the case in schizophrenia and autism. We mention in passing, that also the cerebellum seems to be best paraphrased as a 'virtual flight simulator' because of its simulation capabilities [18].

To put what we have mentioned so far in other words, we deal with the interplay between perception and construction of reality, best circumscribed by the German play on words 'Wahrnehmung' and 'Wahrgebung' ('truth taking' and 'truth giving'). The external reality is perceived via stimuli by the sensorial organs and passed on to the brain where a model of the world is constructed and performed as a simulus. The continuously ongoing process of re-adaptation can be paraphrased as a *tuning and measurement process*. We think that this process reflects crucial features of the hermeneutic circle.

2 'Classical' System Theory

In this section we – far from claiming completeness – highlight some historical basics of dynamical system theory and its ontological as well as epistemic principles as they are needed for our approach to cognition. The term 'epistemic' hereby has to be understood in the sense of an observer dependence best paraphrased by quoting the title of David Mermin's article on epistemic aspects of quantum mechanics: "Is the moon there when nobody looks?" [19]. As is well known, in quantum mechanics substance ontology has been replaced by introducing a wavefunctions as reference objects that contain all possible outcomes of an observation and randomly collapse into particular observable states through observations [20]. Our goal here is to formulate on a classical basis a complementary cognitive model that comprises both aspects, the ontological as well as the epistemic one. In order to make the philosophical discourse mathematically accessible we end up with the minimum requirement to use an operational epistemology.

René Descartes (1596–1650) can be seen as the father of modern (classical) physics. Specifically, he introduced the notion of an *automaton Universe* [21]. According to this concept a certain state of a physical system is the cause for its own dynamical changing. Technically, if the state is denoted as x, the changing of that state (generalized velocity) is the time derivative, $\frac{dx}{dt}$, of it, frequently denoted as $\dot{x}$. Therefore, Descartes' concept translated into the mathematical language reads $\dot{x}(t) = f(x(t))$: The changing of the state is a function of the state itself[17]. The mathematical formulation by means of differential equations has been worked out by Gottfried W. Leibniz and Isaac Newton.

Assume the intuitive case where x is the vector of positions and velocities of particles in space that constitute the system. Furthermore,

[17] Note, that depending on the concrete application x denotes an n-dimensional vector embracing all degrees of freedom of the treated system.

assume given a single particle system. Newton's (1642–1727) first law reads [22]:

> Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

In this case, f is identical to zero. Needless to say, that Newton's view presumes absolute space and time and an *exo-being*[18] who does not interact with the described body and who experiences absolute space and time as an *a priori*. An isolated point-particle with no internal structure is a terminology that makes sense only in an approximation formulated from the perspective of the rest of the world. However, seen from the eyes of a single structureless particle the space concept does not make much sense because there is nothing else in the Universe with respect to which a distance in space or a velocity could be experienced.

Assume now given more than one particle. Now a distance as a precondition for the space concept can be introduced. Thereby, it is not clear how many particles are really necessary so that space becomes differentiated. This differentiation most probably does not only depend on the amount of particles but also on the complexity of interactions between them. Whatsoever, it is the existence of an arrangement of many particles that eventually leads to an experience of space and time via the relations between them. We leave the question open, how complex a Universe has to be in order to bring forth a cognitive being that is aware of space and time which 'seem' to be absolute categories needed to speak of a single particle Universe. In our interpretation of Heidegger's 'being-in-the-world' it does not even make sense to ask such questions ([24], cf. also [1]). Anyway, concerning the perception on our 'natural' biological scale we obviously do not need to distinct between an absolute exo- and an endo-space. Browsing in fringe areas, however, tends to result in inconsistencies.

Note, that in the above argumentation we implicitly assumed that 'awareness' is a result of a sufficently complex arrangement of matter, x, as well as a sufficently complex relationship, $f\,(x(t))$, in-between. This is in line with Leibniz thinking, that we only have relations and that there is nothing absolute in the Universe. In physics as well as in all other dis-

[18] We frequently use the terminology of Rössler's endophysics [23].

ciplines we got accustomed to the term *system* which essentially means to relate different objects to each other. In system theory we investigate the interactions of the parts, i.e., the control and regulation processes. A definition of 'system', very much like the definition of 'time' which is some multiple of a period, has unavoidably a tautological component. The part cannot be understood without the whole and vice versa. In practice we proceed with performing experiments on parts of the system from the findings of which we try to infer to the whole by comparison with other parts. This inference in turn leads to re-interpretations of the functioning of the parts and so on — a process driven by the demand for consistency. A very similar procedure can be found in textual interpretations within literary studies where it is frequently called the 'hermeneutic circle', as mentioned in the introduction. This indicates that the gain of knowledge can be understood only in a processual, performative sense. We come back to that point when we link it to the adaptive cognitive system that we are going to introduce below.

We stress the fact that dynamical system theory is a relational theory. From this system theoretical perspective new light can be shed also on earlier works on language, communication and consciousness. Language and perhaps even consciousness does not make sense in a single-individual 'society' which is why Ludwig Wittgenstein emphasized that consciousness is a social phenomenon — a topic that recently has become explosive with respect to artificial intelligence. In this regard it is very illuminating to read the fictive story by John Casti in which Wittgenstein, Turing, Schrödinger, Snow and Haldane meet for a dinner to discuss the artificial intelligence paradigm [25]. Casti goes into some crucial elements of different hypotheses on perception, cognition and consciousness in a synoptic way. The narrative aspect of Casti's story is a good example for our understanding of how understanding works, which is an additional reason to mention it.

Besides the determinism of Descartes' automaton concept it is its completeness as well as its consistency that is so convincing and intimidating at the same time. On the one hand, it rules out the *deus malignus*, which was extremely important for Descartes [21] and the succeeding rationalists:

> Nun habe ich aber Gottes Dasein erkannt und habe

> gleichzeitig eingesehen daß er kein Betrüger ist;[19]

On the other hand determinism questions the existence of free will. In the first part of his *meditations* Descartes wondered whether humans obey the same automaton laws than, as he believed, all other biological organisms do. Looking out of his window at the people passing by on the sidewalk he noticed [21]:

> Was sehe ich denn außer Hüten und Kleidern, unter denen auch Automaten stecken könnten.[20]

Later in his famous work he restricted this extreme mechanistic perspective by treating consciousness as a non-relational entity not being the matter of system theory. We would like to express in passing that in our opinion the Cartesian dualism is due to a cautious writing and — conscious and or not — false reading of his contemporaries determined through the massive clerical pressure. In this respect it is illuminating to read Eike Pies' "Murder case Descartes" [26].

The dynamical behavior of a system is given by the solution of the corresponding differential equation. Given the state of the system at an instant of time we can continuously update this state by reading the magnitude of the changing (velocity) from the differential equation. Therefore, if we believe that the dynamics of the entire Universe is given by a differential equation we can in principle compute the whole future once we know the initial state. Pierre Simon Marquis de Laplace (1749–1827) metaphorically circumscribed this fact by introducing a fictive being — now called Laplacean demon — who knows the precise initial condition and has, therefore, the whole future at his disposal [27]:

> We ought then to regard the present state of the Universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it — an intelligence sufficiently vast to submit these data to analysis — it would embrace in the same formula the movement of

[19]Now I recognized however God's existence and have at the same time seen that he is no cheat.

[20]What do I see other than hats and cloths underneath them automata could be hidden.

> the greatest bodies of the Universe and those of the lightest atoms; for it, nothing would be uncertain and the future, as the past, would be present to its eyes.

Laplace's metaphor for determinism counts to the most ambiguous explanations of concepts and is still controversially debated [28, 29]. Following his motivation for the introduction of the demon makes evident that he obviously thought on a complementary exo-endo-concept, as it would be called today. Though being a professing determinist — "the freest will is unable without a determinative motive to give them [actions] birth" — Laplace is famous for his seminal work on probability theory [27]. In accordance with his strict deterministic point of view he treated chance as a pure pragmatic notion that accounts for the human ignorance, i.e., of being unable to observe the exact state of a given system: "...but these imaginary causes have gradually receded with the widening bounds of knowledge and disappears entirely before sound philosophy, which sees in them only the expression of our ignorance of the true causes." [27].

In this sense statistics and therefore entropy as well as information is an anthropomorphic concept as has been pointed out again about 200 years later by E.T. Jaynes [30]. The entropy[21] of a system vanishes as soon as we have full knowledge on that system. Note, however, that there exist opposite opinions as for example Stonier's belief that information is a natural entity like mass and energy that exists in a Universe irrespective of the existence of higher cognitive beings [32].

The term *information* has been introduced in the technical context by Leo Szilard in 1929 [33]. He discussed in his famous paper the impact of an intelligent being on thermodynamical systems, a topic that has been revisited several times thereafter (see e.g. [34, 35, 36]). The essential point of that work is that an information flow from an observed object to the intelligent being changes the state of both the observer's brain and the object.

The same results hold for the computational process of a computer [37, 38, 39, 40]. In principle, a computation can be performed reversibly, i.e., under conservation of energy [38], however, the withdrawal of the

[21] Here, the so-called Gibbs entropy is meant that is to be distinguished from the non-anthropomorphic Boltzmann entropy. Cf. [28, 31]

final result violates the energy conservation and makes the computer a dissipative system. Analogously to the quantum mechanical feature discussed above a computer is capable to calculate reversibly "as long as nobody looks". Therefore, if one desires to integrate a reversible system like a thermodynamically closed system then a great deal of effort has to be taken to simulate such a system correctly, i.e., without artificial dissipation [31, 35, 40, 41, 42, 43]. Of course, a computer cannot be fully compared with a brain, but at least the physical computational limits should also apply to brains.

To give a tentative summary what all this means assume given the striking example of the observation of a photon. The photon will be absorbed in the eye and changes after a cascade of physico-chemical processes the state of the brain. This means that the observed object is fully destroyed and the information on it can only be used in a statistical sense to say something about the unobserved photons. This is a first indication that we have to be satisfied with bounded knowledge on the rest of the world for thermodynamical reasons and that the information on a system and the integrity of the latter is in a certain balance. To circumscribe a second time what we have learnt from the above discussion in a very simple way, assume the existence of as many parallel Universes as you wish, they do not concern us (our Universe) as long as there are no interactions between them.

To conclude this excursion to computational physics, the processing of information in the brain, i.e., perception and cognition, acts back to the world. Perception is an interaction of the brain with the observed part of the world. Therefore, real observers cannot be compared with Laplace's demon. The latter simply is a metaphor for determinism. The misunderstanding by several physicists of Laplace's demon that gave rise to thermodynamical paradoxa of generating neg-entropy (perpetuum mobile) stems from the assumption that the demon's knowledge can be used to exploit the rest of the world without interacting with it. However, with the exception of a *deus ex machina* who contradicts a consistent theory according to Descartes, an intelligence who wants to observe the state of a system has to this end to interact with it. Within a consistent dynamical system theory the observer should be included as an operational part [7]. The according extended theory has been called second order cybernetics by Heinz von Foerster.

How to incorporate operationality into a differential equation? The latter is the mathematical tool of dynamical system theory and emphasizes the relational approach to reality. The task of a system theorist is to find and to analyse the function f that determines the evolution of the system. In practice we have to be satisfied with finding an efficient interim model that has to be modified from time to time in order to meet some fitness criteria that change with our knowledge on the modeled system. This leads to an adaptive process of the model which we already compared with an analogous situation in text interpretation — the hermeneutic circle. In a certain sense, to build up a model of the environment is what everybody does in order to exploit the system. The model is in our brain and it is there where we perform it virtually. The better our model of the system is the better we can anticipate what will happen. The adaptive process of the model is driven by a continuous comparison with the external world that is to be described with the model.

3 Decision Making Processes

In 1928, one year before Leo Szilard published the abovementioned article on the impact of intelligent beings on thermodynamical systems [33], John von Neumann came up with a paper on game theory [44]. Obviously, it was time to allow for a rigorous mathematical treatment of the observer's impact and social phenomena. Szilard used the term 'information' in a technical sense in his paper and set the course therewith for the mathematical theory of communication worked out by Claude Shannon and Warren Weaver [45]. However, the scope of Shannon's theory of communication is basically limited to technical problems of coding, decoding, transmitting and processing messages/information an a purely syntactic level whereas game and decision theory increasingly try to account for the behavior in systems with bounded rationality. Thus, we are back in communication and the evaluation of situations due to a given context in which the Bayesean inference principle plays an increasingly important role probably not only from the system theoretical point of view.

Thomas Bayes (1702–1761) [46] introduced an extremely powerful statistical method to update an *a priori* knowledge via a test or an experiment to an *a posteriori* knowledge. In this section we argue that the Bayesean method mimics at least some important features of the discoursive process of gaining knowledge and is, therefore, a first albeit crude approximation to a mathematical formalization of the hermeneutic circle, i.e., *operational hermeneutics.* Since statistics, as discussed above, is the result of our restricted knowledge of the observed part of the world it seems even to be natural that we recover features of the epistemological discourse within that discipline.

Recently, learning cognitive systems have been endowed with this method — a technique called *Bayesean learning* [47]. As already mentioned in the introduction, statistics splits into two schools of thoughts called the frequentists and the Bayesians. The frequentists rely on results from actual surveys only and do not use *a priori* knowledge from previous investigations. The Bayesians, to the contrary, are biased because they use *a priori* knowledge for their decision making processes which led them to formulate the joke: "We are not the better humans but the better statisticians". The medical term *anamnese*, which means a patient's previous history, stems from ancient Greek philosophy. Plato (ca. 428 BC – ca. 348 BC) saw in the *anamnesis* the capability to elude from *aporia* (apory), namely the cognitive perplexity when facts and truth do not coincide. He regarded the *anamnesis* as something innately given to the soul that needs no previous cause.

Assume given the simple dichotomous case of testing whether a hypothesis H holds or not. The probability for the hypothesis to be true is denoted as $p(H)$ and its complement that it does not hold is $1 - p(H)$. The quotient $o(H) = \frac{p(H)}{1-p(H)}$ is called an odd. In terms of odds the Bayesean inference principle reads $o_{post}(H) = L \times o_{pre}(H)$ where the subscripts *post* and *pre* refer to *a posteriori* and *a priori*, respectively. The factor L is called the *Likelihood quotient* and is determined by the result of the experiment — namely whether the test for the hypothesis is positive or negative — and by the *sensitivity* and *specificity* of the test, i.e., efficiency parameters that characterize the capability to yield the correct diagnosis as a result of the hypothesis testing.

For a typical example from medical diagnostics assume given an *a priori* knowledge from an anamnese telling the patients age and the information whether he or she is heavy smoker or not. Then assume that a test for lung cancer becomes positive. It is intuitively clear that the therapeutical directive is another one if the patients age is 15 and if he or she is a non-smoker ($o_{pre}(H)$ small) compared to a 65 year old patient who is a heavy smoker ($o_{pre}(H)$ large). In the first case the test result has a non-negligible probability to be false-positive whereas in the second case the directive will certainly be to operate or to carry out a chemo-therapy. In the first case it is quite certain – a good physician presupposed – that other non-invasive methods are applied to enhance the knowledge further.

Because of its importance for the operational hermeneutics we reinforce the aforementioned by investigating a diagnostic procedure. Table 1 shows how a binary diagnostic test is evaluated from a population with a known fraction of sick persons. Thereby, we distinguish two cases. The upper table reports on an evalutation performed on a population of size 100 with 50% sick persons. For 80% of the sick persons the test leads correctly to a positive result. This test-characteristic fraction is called its *sensitivity*. The remaining 20% sick persons are falsely detected as healthy due to their negativ test result. Accordingly, 90% of the healthy persons are correctly recognized as healthy. This fraction is called the test's *specificity*.

If one now throws a glance onto the lower table one sees that the outcome is qualitatively different for a population composed of only 10% sick persons. Sensitivity and specificity have the same values since these are constant parameters of the test that are quite frequently – but fatefully – taken as the probabilities of having a correct test result. In other words, in the case in hand one falsely concludes from the sensitivity that a person showing a positive test result is sick with a probablility of 80%. Instead, this probability called 'positive prediction value', PV_p, can be taken from the right columns of each table and is obviously different for the two populations.

To make this fully clear consider the realistic situation where a person comes to a doctor and is tested for having a certain disease. The doctor knows that the test has the given sensitivity and specificity, respectively, as in the example of Table 1. Assume that the patient has a positive test result. Is he really sick? If the physician assumes that roughly 50% of the population suffers from the disease in question he

test result	Population composition: sick	Population composition: healthy	prediction value
positive	$A = 40$ correct positive	$B = 5$ false positive	$PV_p = \frac{A}{A+B} = 89\%$
negative	$C = 10$ false negative	$D = 45$ correct negative	$PV_n = \frac{D}{D+C} = 18\%$
	50	50	
test characteristics	sensitivity $= \frac{A}{A+C} = 80\%$	specificity $= \frac{D}{D+B} = 90\%$	

test result	Population composition: sick	Population composition: healthy	prediction value
positive	$A = 8$ correct positive	$B = 9$ false positive	$PV_p = \frac{A}{A+B} = 47\%$
negative	$C = 2$ false negative	$D = 81$ correct negative	$PV_n = \frac{D}{D+C} = 97\%$
	10	90	
test characteristics	sensitivity $= \frac{A}{A+C} = 80\%$	specificity $= \frac{D}{D+B} = 90\%$	

Table 1: A typical deciding situation in medicine:
Diagnostics with two different assumptions on the prevalence leading to two different decisions.

can take from the line of the upper table showing the 45 positive cases, that $A = 40$ out of it are really sick and $B = 5$ are healthy. Interpreted as probabilities he derives by $PV_p = \frac{A}{A+B}$ that the patient is really sick with a probability of 89%. However, if the doctor assumes given a fraction of sick persons amongst the population of roughly 10% he derives from the lower table the according probability of $PV_p = \frac{A}{A+B} = 47\%$ for the patient to be really sick.

Diagnostics is a never-ending-story. From an epistemological point of view it has some interesting additional inherent 'apories' besides estimating an *a priori* chance for sickness of a patient who is to be tested. Namely, the correctness of the values of the two test parameters sensititvity and specificity rely on the availability of a golden standard, i.e., a population of persons who are absolutely certainly sick. In reality another particularly trustworthy test has to tell this. Only pragmatics will help now.

In general, for the Bayesian the odds are the degree of belief in a hypothesis. The anti-Bayesean objection is that all scientists will have different degrees of belief, and so the conclusion will be subjective. The Bayesean defence is that the o_{pre} should contain all hypotheses and all previous knowledge, and that if all scientists would pool their previous knowledge, they should be able to agree on a distribution o_{pre} [48]. In practice, a physician most likely acts according to his/her experience by giving the hypothesis a certain weight for being true or false, respectively, without really quantifying it. A more trustworthy physician looks whether a table of recommended values form a large survey is available. Additionally, at a given instant of time not all hypotheses are known; they rather have to be created first. Whatsoever, for an epistemologist it is clear that even the frequentist is subjective and does nothing else than to interpret. In this sense the Bayesean school is more honest since they are behind their subjectivity. The example however shows clearly, that Bayesean statistics and hermeneutics has a lot of features in common. The so-called 'objective hermeneutics' as a controversially debated school of hermeneutics testify through its very existence that also within hermeneutics there is a prevalent argument on objectivity vs subjectivity.

In order to evolve the knowledge one can think of an iterative application of the Bayesean inference principle. In some cases this is explicitly done and in the most cases at least implicitly, namely when the *a priori* knowledge stems from the application of a preceding Bayesean inference. Once given an *a priori* knowledge one may wonder whether the evolution of knowledge can be algorithmized and a program does the job by itself. In fact, this is currently intensively investigated within the fields of 'data mining' and context sensitive recognition algorithms [49]. However, one hardly hears anything about Michael Lynch's data mining software package 'autonomy' — based on Bayes' inference principle — any more which was enthusiastically announced in 2000 [50].

On closer inspection one recognizes a couple of essential shortcomings of the Bayesean inference principle. The most striking one is that the algorithm cannot create new hypotheses by itself. It can only judge these hypotheses that are *a priori* given (by the user). Additionally, as mentioned above, one is usually lacking a *golden standard*, as an objective reference is called in medicine. This situation is analogous to the missing reference in hermeneutics. Yet, Bayes' inference principle is so strikingly similar to the scientist's update of knowledge that it might not be too speculative to regard this procedure as a useful basis for the construction of a learning cognitive system [47]. Here we pursue with deriving a time-continuous adaptive cognitive system based on a differential equation.

4 Artifical communication

We take over the useful features of the Bayesean inference principle and additionally enhance the system with the missing features of this method. Figure 2 shows schematically how the proposed system works. To the left, we have an external dynamics (the *stimulus*), which is 'perceived' by the system. To the right, we see a representation of the external dynamics as a 'mirror.' This mirror dynamics is the adaptively acquired simulative part of the system (*simulus*). The kernel of the system consists of a pool of dynamical modules, each of which is controlled by the external dynamics. Thereby, the term *control* refers to a method well-established in nonlinear system theory called *Pyragas' force control* [51]. This method allows to synchronize an (almost) arbitrary system to a target system. After switching off the force control the synchronized

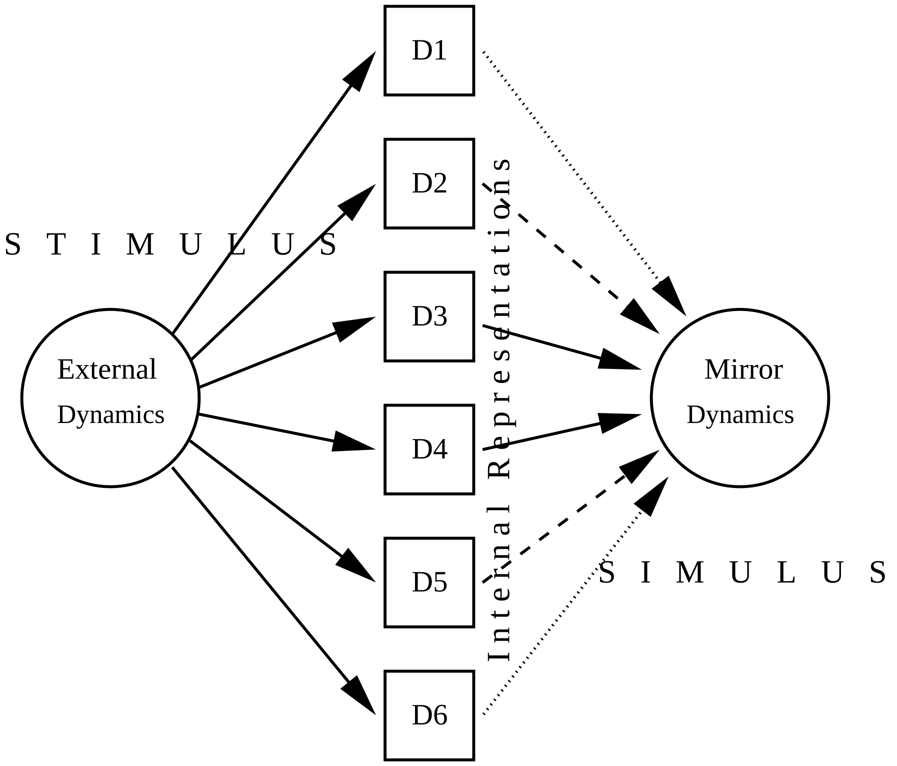

Figure 2: *Scheme of the adaptive cognitive system capable to simulate.*

system falls back to its *eigen dynamics* and usually de-synchronizes very quickly with the target system. Note, that chaos control methods have been suggested to play an important role in brain dynamics [52, 53, 54]. In addition, the following publications on dynamic parameter estimations and pattern replication supply fundamental applications of Pyragas' control within our context [55, 56, 57].

In a more sophisticated application than the original one we use the strength of the control term to serve as a measure of 'fitness' of the corresponding module. This fitness in turn can be used to weight each contribution in a superposition of all modules in order to adapt the simulus to the target system. In the scheme depicted in Fig. 2, the modules D_3 and D_4, for example, fit best to the stimulus and, therefore, contribute with a larger weight (bold arrows) to the construction of the simulus. D_1 and D_6, for example, fit worse and contribute less (dotted arrows) to build up the simulus. After switching off the stimulus modules D_1 and D_6 de-synchronize quickly whereas modules D_3 and D_4 take a longer time to de-synchronize. The adapted simulus remains synchronized for a very long time. For a technical description of the adaptive system confer [3, 4, 5, 6, 58]. We here refrain from writing down the explicit differential equations and refer to the original publications instead. Our attempt in the following is to introduce the system in a vivid way. To this end we come back to the exo-endo-complementarity.

An exo-observer (Laplacean demon) may describe the Universe by means of an extremely high-dimensional differential equation. We denote the vector of the states of all particles of the Universe with x. A subset of the Universe's state — we call it endo-observer — builds a kind of a coherent cluster performing an 'almost' independent dynamics. We call the vector of the corresponding micro-states y. 'Almost' hereby means that at a closer inspection the observer cannot be understood as totally de-coupled from the rest of the Universe that we comprise in a vector of the remaining states called z. The dynamics of the observer is then given by means of a non-autonomous differential equation $\dot{y}(t) = f\,(y(t)) + F(z,t)$. In a rough approximation, depending on what is intented to show, the external contribution, $F(z,t)$, to the observer's overall dynamics can be set equal to zero. In the long run, however, a biological stationary state of the observer is in danger, when $F(z,t)$ is strictly zero for all t. Despite the intake of free energy, called eating, we have to perceive. A total sensorial deprivation irreversibly damages the brain in the long term. Since the task of the brain is to exploit the rest of the world z in an optimal way it is nonsense to try to understand it without the interaction with z.

The differential equation of the rest of the world may likewise be written as $\dot{z}(t) = g\,(z(t)) + G(y,t)$ with proper functions g and G. The term g stands for the eigen dynamics of the rest of the world an G is the impact of the considered observer. What allows for such a separation of the observer and the rest of the world is cleary a topic of the emergence of consciousness — or rather *self-consciousness* — in a sufficiently complex Universe as described above indicating that 'drawing distinctions' conflicts with a 'grand unified theory' (cf. also [59]). The scientist's task from the classical point of view is to find the function g that describes the evolution of the external part of the Universe. But even in the ideal case the best we can have is the superposition $g + G$ which contains a subjective part. Although one may question the identification of the Universe' dynamics with a differential equation this seems to be a general feature of each explanatory approach. From the endo-perspective we have to be satisfied with usually non-unique approximations subject to (coarse graining) classification and interpretation.

Let us now closer inspect the stimulus of the proposed cognitive system. It is for sure that the rest of the world does not reveal itself completely by simply providing a stimulus. The perceived stimulus is not only a small fraction of the world but also depends on our intentionality what stimulus we want to perceive. The already adapted simulus plays an important role within this process. With respect to communication the per-/re-ceived stimulus may be called message whose 'information' is nothing externally given but rather determined by internal brain dynamics and, in turn, subject of interpretation.

As system theoretical basis for creativity we demand for internal forcing processes leading to self-modifying features of the cognitive system. Within our model this means that the modules of the internal pool of dynamics mutually force themselves as a condition to bring forth creativity. This is one of the missing parts in Bayes' inference algorithm mentioned in the previous chapter. That the interpretation of the external world is rather a consequence of internal brain states than that the brain state is a representation of the external world is in line with Maturana's 'autopoesis'. The latter essentially means that the stimuli do not determine what happens in the brain, but rather trigger changes of brain dynamics. The best is to view it as a system where external and internal states mutually cause their alterations.

The most exciting moment of our model is the aforementioned potentiality to simulate the simulus of other cognitive beings or their internal state. This is the moment where the term 'communication' fits better than talking of 'interactions'. In Fig. 3 we placed a second cognitive being 'B' into the stimulus of being 'A'. In turn, the stimulus of being 'B' contains being 'A' (Not depicted in the figure). This leads to an interesting interface problem as infinitely nested simuli within simuli. The

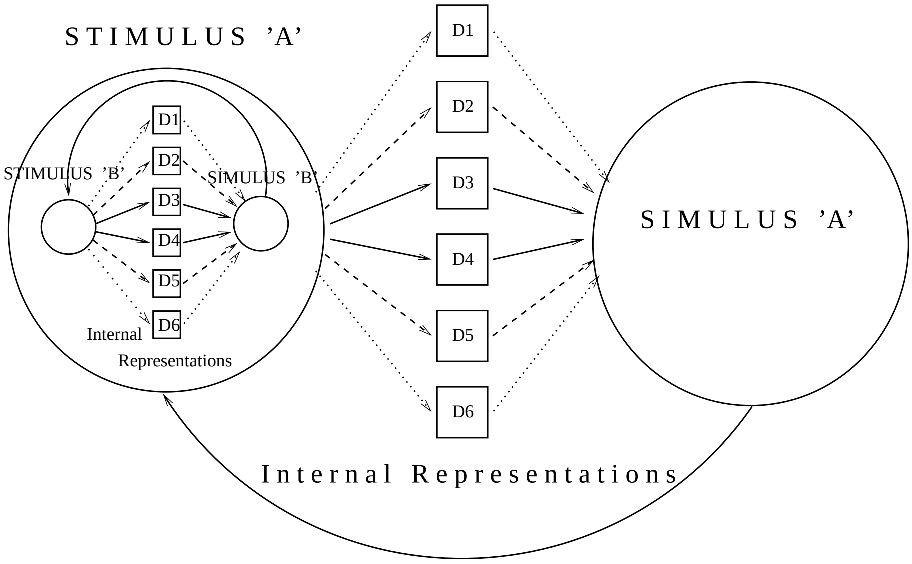

Figure 3: *Nested structure of the adaptive cognitive system.*

curved arrows in Fig. 3 from the simuli of each cognitive being to the corresponding stimuli indicate the motor activity as an efference that stems from the simuli. Of course, the normal case is that the stimulus of an agent not only contains exactly one other agent but rather many of them and other parts of the environment.

5 Discussion

We argued, that principles of humanities, especially hermeneutics play a more important role in natural sciences than usually supposed. Starting out from the basics of dynamical system theory we furthermore discussed a possible link of hermeneutics to cybernetics. We derived a differential equation-based adaptive model for building a model of the perceived part of the world where the latter model is called simulus. At least, this adaptive model has the potentiality to update the simulus that is temporarily valid for a certain range of applicability. This continuous update procedure mimics an essential, system theoretically accessible, part of the epistemological process of gaining knowledge and can, therefore, be viewed as a cautious step towards a model for the hermeneutic circle and definitely towards a realistic communication structure of the society.

The structure of the model inherently contains an interface in form of an infinitely nested structure or a non-orientable topology. This aspect remains to be worked out in detail in the future as well as the aspect of interpretation and semantics that we regard as an emergent feature correlated to that interface problem.

The mathematical tool that we use for the description of dynamical systems is the differential equation. Therefore, one may object that our model at the latest fails when a differential equation is no longer valid. Concerning this point we found an impressive part in Carl F. von Weizsäcker's book "Die Geschichte der Natur" [60] first published in 1948:

> Vergleichen Sie die unbewußten Leistungen der Lebewesen mit denen der unbelebten Natur! Die Pflanze wächst, der Vogel fliegt, die Biene baut ihre Waben, ohne es bewußt gelernt zu haben; sie können es, ohne zu wissen was sie tun. Verfolgen Sie aber mit ausgeruhtem Auge die Flugbahn eines geworfenen Steins, das Strömen eines Flusses, die Bahn der Planeten am Himmel, so werden Sie dasselbe Wunder erleben. Auch diese Dinge der unbelebten Natur können das Ihre, ohne es zu wissen. Wir wissen, daß ihre Bewegung Differentialgleichungen genügt, die wir nur in wenigen einfachen Fällen integrieren können. Sie aber integrieren diese Gleichungen, von denen sie nichts wissen, ohne Zögern und fehlerlos durch ihr bloßes Sein.[22]

Our personal conclusion is that a consistent tool to treat the relational aspects of the world — and that is the task of system theory — is the differential equation. According to C.F. von Weizsäcker the motions of

[22] Compare the unconscious achievements of beings with those of inanimate nature! The plant is growing, the bird is flying, the bee is building its honeycombs, without having learnt it consciously; they are capable to do it without knowing what they do. However, if you follow with relaxed eyes the path of a thrown stone, the flowing of a river, the orbit of planets in the sky, you will experience the same miracle. This subjects of inanimate nature fulfill their task without knowing it, too. We know, that their motions obey differential equations which we can integrated only in a few simple cases. They, however, integrate those equations, which they have no idea of, without hesitation and flawlessly through their mere being.

objects obey a differential equation (...ihre Bewegung Differentialgleichungen genügt...) that are so complicated that we (scientists) cannot integrate them but the objects themselves exactly do this (Sie aber integrieren diese Gleichungen...). In other words: The Universe is an analog computer [61].

Let us deepen this thought by regarding a complex system that is mathematically modeled by differential equations. Due to the nonexistence of closed solutions we (let) the system integrate numerically by implementing it on a computer. I am quite sure that the computer knows nothing about differential equations let alone the one that it integrates (... diese Dinge der unbelebten Natur können das Ihre, ohne es zu wissen ...). But it does integrate (... durch ihr bloßes Sein.). Or doesn't it? We implemented the differential equation.

In our hitherto applications of the adaptive model we formulated a certain class of differential equations defined by some undetermined parameters. The task of the system was to adapt this previously arbitrary parameters to values that lead to a dynamics that mimics the outer world best possible within the given class. The class itself has been chosen by our pre-knowledge. In future applications we try to refrain from formulating an primary class and let the job do the system itself.

The simulus that eventually will be reached mainly depends on the stimulus that is provided by the external world. But it also depends on the already available modules within the cognitive system. This set of modules is the result of the memorized simuli that have been adapted in the past endowed with a loss rate of older modules in order not to blow up the size of the system. We also allow self-modification by means of control processes between the modules. Non-determinism enters the model by means of a non-foreseeable structure of future stimuli that can only be approximately anticipated by applying the simulus. In this sense, a good simulus provides a measure of fitness.

We conclude that the inclusion of the observer-internal dynamics leads us to a complementarity principle perhaps best called *exo–endo–concept* [23], resulting in an interplay between the external reality and the internal model of the reality. Our model has the potentiality to describe essential aspects of hermeneutics and we regard it as a significant step towards the understanding of the interface problem. Within our research program ‘performative science’ we investigate the hermeneutic circle that manifests itself in the sensory perceptible performance of an abstract model, e.g. through visualized computer simulations. In short, this performative process describes the update of dynamical models through ‘Nachvollziehen’ which is somewhat more sophisticated than the direct translation 'understanding' and contains mimesis and/or embodiment. To deepen this is beyond the scope of this paper. But what hopefully became clear is the idea of a twofold hermeneutics: modeling the hermeneutic circle and updating the model in a hermeneutic process – called operational hermeneutics.

We finally want to give credit to Ichiro Tsuda and Peter Érdi who first connected hermeneutics and brain dynamics (for a review cf. [9]). We are well aware of the self-referential fact expressed by these authors namely that our model of how the brain interprets the world is itself an interpretion. But it is, in our opinion, exactly the bootstrapping (‘Münchhausen effect’) character that unifies hermeneutics and system theory.

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