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**Computational Semiotics as a Basis for Automatic Text  
Categorization**

Bachelor's thesis

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## **Introduction**

### **A few words on the English translation**

The following is my bachelor's diploma thesis in semiotics. I have decided to translate it into English so that others with similar interests might use it as a stepping stone in the study of computational semiotics. The thesis was successfully defended before a committee on 29.05.2008 and was graded "B".

The thesis can not and does not give a complete overview of the emerging field of computational semiotics, but my hope is that the pointers and general material in here will help others avoid the confusion that I faced while assembling and working through the material. If readers find errors or want to contact the author for any other reasons, please feel free to contact me at [lemmit@kaplinski.com](mailto:lemmit@kaplinski.com)

In the course of translating I have corrected a few obvious errors in typing or terminology, rephrased sentences to sound better in English and removed Estonian translations of citations. In all other aspects the work mirrors the Estonian original. My English is a weird mixture of British and American though and as this is an English version of an Estonian text based in turn mostly on English materials, a sort of double translation process has occurred and I hope my readers will disregard the occasional clumsiness.

## **The semiotics aspects of computers**

The following work speaks about computational semiotics, connected more or less explicitly to a long scientific tradition. Leibniz, Babbage, Lovelace, Wiener and Turing are one of many, whose work has provided the foundation for developing the modern binary digital computer. Being a carrier for most of our everyday communication, computers no doubt have a major role in supporting the functioning of our ambient sign system, maybe even mediating it as an active participant. Bouissac has stated that if the main characteristic of computers was their ability to crunch numbers, they would be no more than an abacus from a semiotic viewpoint. In reality, computers have at least three aspects important for semiotics: computational capability, interfaces (between users and computers) and networks (with this, Bouissac does not mean the internet or any other widespread data exchange technology, but the general integration of hard- and software facilitating the use of computers by humans) (Bouissac, 1998 *sub Computer*)

Of these aspects, the interfaces between users and computers, or „user interfaces“, have been studied the most. Based on the traditions of Saussure and Hjelmslev, Andersen considers user interfaces from a structural semiotics viewpoint as closed systems, which elements can be compared and juxtaposed with the phrases of natural language, but the similarity is only seeming:

The disguise technique consists in designing the interface language in such a way that it is parasitic upon English by employing English spelling and syntax, so that English and interface will form one language system if added together. (Andersen, 1990: 13)

Andersen calls the branch of semiotics studying interfaces and related questions computer semiotics and this corresponds to the second aspect highlighted by Bouissac. The most precise definition of the first aspect, computational semiotics, has been given by Gudwin:

Computational Semiotics refers to the attempt of emulating the semiosis cycle within a digital computer<sup>1</sup>.

Although the definition of Gudwin has several deficiencies owing to its shortness, I will have to rely on it as minimal in the following text due to the unavailability of others. At the end of Chapter 1 I will give a new, more specific definition, that has been derived from Gudwin, but extended according to materials discussed.

Concerning the third semiotic aspect highlighted by Bouissac, there has been no further definition or development of it in later tradition. On these grounds I consider the differentiation of computer semiotics and computational semiotics made by Bouissac valid, leaving aside the term „networks“ as loosely defined and without supporting scientific tradition.

## **Information overload**

The explosive growth in the numbers of computers and embedded devices has not merely altered the ways in which we produce, retrieve and process information. The amount of information available to us has grown to volumes unpre-

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1 Ricardo R. Gudwin, homepage in internet  
<http://www.dca.fee.unicamp.br/~gudwin/compsemio/> Visited 26.05.2008

cedented in the course of human history and the end of the growth and its final consequences are yet to come.

Although the questions regarding the volume of information and its accessibility precede computers in time, the first to formulate it as a projection of technological developments was Bush (Bush, 1945). In the article „As We May Think“, published in July 1945, he tried to sketch the logical extensions of the technologies developed during the war<sup>2</sup> and the influences of these extensions on scientific research and everyday life in general. Speaking about the technological achievements of his time, he already then had to acknowledge the difficulties of navigating in a growing amount of information:

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. (ibid)

It might be interesting to note that Bush sees as a solution a device he himself calls “memeks” and that consists basically of a personal computer with a specialized hypertext application. His final conclusion is however, that man has created for himself an environment so complex, that mechanical solutions for the storage and retrieval of information are needed to navigate it and spare the finite memory resources of humans (ibid).

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2 During war, scientific research with scientific value is allocated enormous amounts of funds, compared to peacetime. The fruits of strategic research from the II World War include, besides nuclear energy, microwave ovens, the radar and jet planes, also digital computers. Computer technology was first developed to decode the encrypted messages of Germany and Japan.

A similar problem has also been described by Eco, who in an interview conducted by Coppock gives an example where he was searching, for a conference paper, an electronic text for citations where Thomas Aquinas had mentioned Jerusalem:

Now, if I only had these books - well, that index is a reasonable index which focuses only on the larger, more intensive treatments of the word 'Jerusalem' - I would have found say 10 or 15 tokens of 'Jerusalem' which I would have been able to examine. Unfortunately I now have the Aquinas hypertext...

[..]

and there I found, that there were - well I don't remember the exact number - but there were round 11,000 or so tokens...

[..]

Working with 11,000 references is just impossible. That's far too many. (Coppock, 1995)

Extending this example, Eco says that based on his personal experience, he is able to pick out from ten books the one that has new and valuable information for him, a student of 20 or 30 years does not have this kind of selection proficiency however. As a solution, he proposes the development of a "filtering" or "decimating" method, postulating that even if such method does not exist today, it has to be invented, the rules can be derived (ibid).

Theoretical remarks on information overload are supported by scientific data on the growth of information volume. The study „How Much Info“ by Lyman and Variani from the University of California, Berkeley tries to evaluate the amount of information produced annually. According to their opinion, 5 exa-

bytes of new information was produced in the year 2002 (Lyman, Variani, 2003). To give a point of comparison, the authors bring as an example the American Library of Congress which 17 million books would only take up 136 terabytes in digitized form<sup>3</sup>. This means that in 2002 the equivalent of 37 000 times the capacity of the Library of Congress of information was produced on print, film, magnetic and optical media combined, 90% of on magnetic media, mostly hard drives.

A study by the same authors from the year 2000 can be used as comparison, according to which the amount of new information produced in 1999 was estimated at 2.3 exabytes maximum (Lyman, Variani, 2000). In the time period between 1999 and 2002 there occurred a growth in production by more than 100%. Speaking more specifically about the internet, Odlyzko estimates its continued annual rate of growth between 10% and 60%, although he mentions that reliable information on this subject is still hard to find (Odlyzko, 2008).

Even if exact data differs from the given amounts by a certain margin, it is still clear that today the volume of information accessible to a human is terminally beyond his individual processing capabilities.

Besides practical questions concerning the locating of required and relevant information, more fundamental problems of human personality and identity may develop in the conditions of the growth of information volume. McLuhan believes that this might be the most important conclusion of the 21. century and warns directly that man might not have been created to live „at the speed of light“ (McLuhan, Powers, 1989: 97). Elsewhere he mentions that data communication creates „non-persons“ (ibid: 143).

<sup>3</sup> One terabyte is 1000<sup>4</sup> bytes, exabyte is 1000<sup>6</sup> bytes (SI units).

As a conclusion it can be said that the unprecedented developments in (information) technology have created a situation where the amount of information might start affecting not only human behaviour, but his whole nature. The studying, modelling and finding solutions to discovered problems might, based also on Gudwin's definition, be one of the central tasks of computational semiotics.

### **The aim and structure of thesis**

Th problems caused by information overload are predicted to become only more acute. Practical helpers are needed to navigate information regardless if the problem is constrained to sorting spam from electronic mail or if information overload is considered a form of censorship (Coppock, 1995).

The preliminary aim of the thesis was to outline, supported by the methods and arguments of computational semiotics, a model for processing data automatically and semi-automatically to sort it into categories that would have meaning for the user of the model. Such a model should be the basis for a later software application that could be used to solve practical tasks in sorting and selecting data based on user feedback. During the writing of the thesis, the need became clear to first give a thorough overview of the research goals and topics in computer semiotics, also of the studies of scientists working in this field. Due to such overview being missing so far, the chapter originally assigned to it grew out of its bounds and now forms the main body of the thesis.

Not to give up on my preliminary goals, the description of the model that was to occupy two chapters has been condensed into one shorter chapter.

Due to the smaller length it does not give complete overview of my solution in progress, but should give the reader a good example of a possible field for application of computational semiotics, also of the connections of computational semiotics with the developments in information technology. During the writing of the thesis, the model was extended in several important aspects.

The main aim of the thesis is therefore to give the reader for the first time an overview of the current state of computational semiotics and a further definition of this field. The secondary aim of the thesis is to provide an outline for one possible further study in computational semiotics and of its possible applications as a modern solution in information technology.

# **1. Overview of computational semiotics**

## **1.1. Uexküll, robotics and the codes of life**

Beginning a longer discussion of computational semiotics, I will first mention Jakob von Uexküll, who was born in Estonia, received his education in Tartu and is better known in the discourse of biosemiotics. The scientists mentioned in the beginning of the thesis – Leibnitz, Babbage, Turing et al. – were some of many who put forth mentionable efforts in the development of electronic computers. Uexküll however can be considered not only to have formed the basic principles of biosemiotics, but also those of cybernetics through which connection the scientific tradition of computational semiotics can be traced back to him.

Although modern cybernetics does not use Uexkülls terminology directly, we can, according to Lagerspetz, consider the feedback driven model originating foremost from Uexküll (Lagerspetz, 2001: 646). Similarly Lagerspetz claims that Uexküll formulated the principles of pattern recognition first in 1928, reducing these to essentially simple, but parallel nervous mechanisms (ibid: 649).

The founder of cybernetics as a discipline Norbert Wiener has not himself mentioned the name of Uexküll in “Cybernetics: Or Control and Commu-

nication in the *Animal and the Machine*”, his work concerning the basic principles of Cybernetics (Wiener, 1948). This could be attributed to the historic situation, the impulse for the birth of cybernetics came yet again from the ongoing war and the requirement to solve several practical issues, like the enhancing the control mechanisms of anti-aircraft cannons in response to German dominance in the British airspace (ibid: 11). It is doubtful that Wiener had at that moment access to scientific achievements of occupied Europe or that a scientist working on classified government projects would have been granted sufficiently free communication with “enemy” scientists.

Disregarding the lack of direct links between Wiener and Uexküll, Wiener's definition of the founding principles of cybernetics are indeed quite close to Uexküll's functional cycle. Speaking about fire-control devices, ship's steering mechanisms<sup>4</sup> or simply controlling muscles to lift a pencil, Wiener emphasizes the importance of cyclical feed-back:

Mr. Bigelow and I came to the conclusion that an extremely important factor in the voluntary activity is what the control engineers term *feed-back*. I shall discuss this in considerable detail in the appropriate chapters. It is enough to say here that when we desire a motion to follow a given pattern, the difference between this pattern and the actually performed motion is used as a new input to cause the part regulated to move in such a way as to bring its motion closer to that given pattern. (ibid: 13)

If Wiener had consented with describing and developing merely utilitarian devices, his connection to bio- and computational semiotics would be merely theoretical. Next however the author outlines a possible future of these devices, speaking about the construction of automata (robots) that – as explained below

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4 Wiener derived the term “cybernetics” from the Greek Κυβερνήτης, translated as steersman (Wiener, 1948: 19)

– are an important topic for both bio- and computational semiotics and for the understanding of which we can use Uexküll's research that was probably unknown to Wiener:

It has long been clear to me that the modern ultra-rapid computing machine was in principle an ideal central nervous system to an apparatus for automatic control; and that its input and output need not be in the form of numbers or diagrams, but might very well be, respectively, the readings of artificial sense-organs such as photo-electric cells or thermometers, and the performance of motors [...] we are already in a position to construct artificial machines of almost any degree of elaborateness of performance. (ibid: 36)

Wiener has to be credited not only for predicting the possibilities of technology, but also the dangers inherent in it. Worrying over the fate of labourers in a setting of automated production, he contacts local trade unions, trying to explain to them the possible developments and problems that will arise. As a conclusion he mentions that while the unions listened to his opinions, they lack the capabilities to deal with such issues (ibid: 38).

In what way is the robotics outlined by Wiener relevant for computational semiotics? Emmeche and Gudwin have disputed the question whether robots have an *umwelt* in the Uexküllian sense or not. If the question is of the existence of *umwelt* as a necessary element for semiosis, it is also a question about robots belonging to the sphere of interest of computational semiotics. In the case we can speak of the *umwelt* of robots, we also have to agree that robotics and computational semiotics, the aim of which according to Gudwin's definition is the modelling of semiosis, are partially overlapping fields.

In his article "Does a robot have an Umwelt?" Emmeche has discussed both the issue of robots and *umwelt* and also the connections between robotics and semiotics in a larger scope (Emmeche, 2001). Although he leaves the question about the *umwelt* of robots unanswered, he defines cybernetics, study of artificial intelligence, information technology, artificial life and the study of autonomous agents as close and mutually interconnected disciplines. Noteworthy is Emmeche's opposition between "good old-fashioned AI" and "nouvelle AI" that studies the modern autonomous agents. If in the first case intellect is an a priori phenomenon and agents or robots are built according to "top-down" principles, then the theory of autonomous agents uses "bottom-up" approach, where the autonomy of an agent is not coded into the agent, but is expressed in its behaviour. The latter is always more complex than the blueprint of the system and mirrors the complexity of environment, like the zig-zag movement pattern of an ant is not the ant's purposeful goal, but adaptive behaviour caused by the environment. This understanding stresses foremost the dialogue between an organism and its environment and presupposes a feedback based mechanism like the functional cycle. Based on Emmeche's article it can be said that while the existence of *umwelt* in the case of robots is not verified (and might not be verifiable), the posing of the question in today's robotics and semiotics is valid.

Gudwin has replied to views expressed in Emmeche's article, agreeing with some of them and confronting others (Gudwin, 1999). As counter argument, Gudwin primarily points to the fact that *umwelt* and its representation inside an organism are not identical concepts and in the case of the autonomous agents Emmeche uses as examples in his article, we cannot speak of the internal

representation of *umwelt*. That however is important for sign-based behaviour, because precisely in the internal representation of *umwelt* exist “objects” while in *umwelt* itself we can only speak about sensed “qualities” (ibid: 9). It is precisely the mathematical modelling of objects that is central to all of Gudwin's works.

Gudwin also offers the proposition that while *umwelt* cannot be approached as an a priori phenomenon, in the case of autonomous agents this has to be done with their purpose. The purpose of robot agent must originate from the creator and is outside the bounds of agents *umwelt*, while the purpose of a living organism is encoded in it during natural selection and evolution (ibid: 8).

At the same time Gudwin acknowledges that the general question is valid and also considers important Emmeche's distinction between “old” and “new” artificial intelligence. In the case of latter, he also sees some role for semiotics, writing:

The creation of a new generation of intelligent autonomous systems will have to be inspired somewhat in semiotics. [...] How do we pass from signals to true signs. [...] These are the challenges for the future. These are the questions we have to solve, in order to be able to create new kinds of machines that are really more "intelligent", and maybe could help humanity to create a better world to live in. (Gudwin, 1999: 9)

Computational semiotics is one method for the creation of autonomous agents and intelligent systems (Gudwin, 1997a: 1) and is in this way also connected with Uexküll. Taking a wider look, computational semiotics is also close to biosemiotics in several aspects, using sometimes same terms like information, code, modelling, signal etc. and solving same problems. Emmeche and Hoffmeyer have in their article „Code-duality and the semiotics of nature“ (Em-

meche, Hoffmeyer, 1991) discussed exactly the questions of information and its meaning, several of which are also important when considering the secondary aim of the current thesis. Authors contrast the concept of information as the bandwidth for signal transmission in information technology and the semantic concept of the meaning of information<sup>5</sup> (ibid: 120-121). The cause for the appearance of meaning is considered to be the capability to differentiate and select:

For differences to be information, we humans have got no choice but to select. And therefore information does not belong to the sphere of matter and energy, but to the subjective and non-dimensional sphere of structure, pattern and form. (ibid: 123)

Authors here make the same differentiation that Gudwin (Gudwin, 1999), separating the “external” *umwelt*, that is made up of sensed qualities, and its internal representation that is made up of objects, signs. The former embodies the sphere of “matter and energy” pointed by the authors and in this case we cannot speak about the meaning of information, but of signals.

The rest of the article is concerned with questions about interpreting the information in DNA/RNA molecules, posing a hypothesis of life as the constant change between two codes – the digital (DNA) and analogue (organism). Separated, neither of them could constitute a whole. By this, the authors hint at the nature of information as a process and criticise both individualism and “DNAI-

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5 It is interesting to note that, citing Foerster, authors believe this contrast may have arisen during II World War when information technology took a big step forward, but was constrained to military uses and was the carrier of a very specific form of communication: orders. An order is a form of communication regulated to the maximum and the amount of new information is reduced to the minimum as both the sender and receiver are presumed to have a common understanding of the message. This situation contrasts with the inescapable ambivalence of everyday communication.

ism”, pointing to their inadequacy at explaining the essence of life (Emmeche, Hoffmeyer, 1991: 149). Again we can draw connections between this topic and the problems of computational semiotics, where the questions concern the storage of knowledge and the contrast between “top-down” and “bottom-up” principles in constructing autonomous agents. In the case of “top-down” approach we fall to what the authors call “DNAism”, trying to explain agents behaviour as a whole with an a priori program. In the second case we ignore the importance of the program and (genetic) memory and reduce the agent to a mere automaton reacting to the environment.

This contrast between signals and signs, old and new artificial intelligence is older and much broader than just bio- or computational semiotics. This also means it is not solvable on the level of bio- or computational semiotics and the solution must come from a broader framework theory. One such theory – cybersemiotics – that will help understand the historical background of this contrast will be introduced in sub chapter 1.2.

While computational semiotics and biosemiotics have several common interests, computational semiotics differs from biosemiotics primarily in its approaches. While the latter tries to explain certain aspects of our surrounding natural environment, computational semiotics tries to model the sign-based processes taking place in this environment. It is understood that to model, one needs theories about the nature of the process to be modelled, and those are provided to computational semiotics by biosemiotics. Cooperation could however work both ways and the modelling, simulation conducted using methods of computational semiotics could be successfully used to test theories and discard less probable ones. The importance of computer-based experiments is

stressed by Rieger among others (Rieger, 1988: 3). Beginning with Uexküll, the flow has been from biosemiotics to computational semiotics, hopefully we will also see more movement in the opposite direction. In any case the roots of computational semiotics lead us to a scientific tradition nearly a hundred years old and are closely entwined with the study of nature itself.

## **1.2. From cybernetics to cybersemiotics**

I have named a few views and studies that are important for computational semiotics, that have a multitude of similarities, but are separate from one another. They shed light on narrow specialized topics and while they overlap in areas, they do not belong in a common theoretical framework. These are fragments that are in every instance connected to larger existing paradigms. For example the “top-down” and “bottom-up” opposition, also that of “DNAism” and individualism repeats within itself the opposition between materialistic and phenomenological world views. Brier sees that the comprehensive explanation of different world models cannot stem from any of these in isolation:

I cannot find a way to explain everything as evolving from either a dead mechanical deterministic world, or a completely indeterminate material world that pre-exists all knowing systems, or a radical and social constructivism wherein our 'world' amounts to tapestries of language and concepts, and in which all phenomena – even nature – are merely social constructions. (Brier, 2008: 147)

Not to reach the same insurmountable oppositions in different branches of science among other things, Brier creates a new interdisciplinary scientific theory, calling it cybersemiotics. Speaking about his goals, Brier emphasizes the need to bring under a common roof social sciences and humanities, biology and physic-

al-chemical sciences (ibid: 150). Such an approach has the potential to bind into a coherent theory the aforementioned robotics, cybernetics (bio)semiotics and other disciplines, giving an adequate explanation of the workings of information, senses and communication. By this, also the more specific definition of computational semiotics, its place and function within the cybersemiotic framework could become clear.

From the standpoint of the current thesis, Brier's views are important also due to the reason that to illustrate his theory, he constantly brings examples from the field of library and information services, where he again sees the navigation problems arising due to the growing volume of information (ibid: 72). On the other hand Brier argues that while a classification system should correct itself according to changing language and in its ideal form should create different sets of keywords for different user groups, this is currently neither achievable automatically, nor economically feasible (ibid: 287). This argument runs exactly counter to the secondary goal of current thesis: to describe an automatic classification system that would correct itself based on user feedback and create by this different classification and keyword systems for different users. As Brier has not given reasons for his opinion, I lack the opportunity to present my arguments.

The larger part of Brier's work is aimed at the critique of existing theories to display their inability to solve the problems of communication and cognition as a whole. At the same time, the author aims to integrate important terms and models from the criticized theories. One of the pillars of cybersemiotics is again cybernetics, where Brier differentiates between the 1. and 2. order. The

first is based on Shannon's, Wiener's et al. understanding of information as negative entropy, which from a semiotic viewpoint however has only statistical, not signifying properties. The unit of such information is a bit. This is the measurement that Emmeche and Hoffmeyer call the mere semantically impoverished statistical structure of a signal, the capacity, not the meaning of it (Emmeche, Hoffmeyer, 1991: 120). Brier also largely discards 1. order cybernetics from the cybersemiotic theory.

2. order cybernetics stems from Bateson's definition of information: „In fact, what we mean by information – the elementary unit of information – is a difference which makes a difference<sup>6</sup>.“ Also Maturana's definition of autopoietic systems:

A composite unity whose organization can be described as a closed network of productions of components that through their interactions constitute the network of productions that produce them and specify its extensions by constituting its boundaries in their domain of existence, is an autopoietic system [...] (Maturana, 1998)

These two definitions stress that in addition to the observed system, we have to include the observer as a system and that the observed system is closed, autonomous and directed at self-preservation. In other words – we can talk about sign-based information only within an organism, in embodied form. This agrees with both the understanding of Emmeche, Hoffmeyer and Gudwin described earlier, and also with Peirce's understanding of the sign, that stands for something only for someone. Brier relies on Peirce to a great extent, utilizing both his sign triad, a component of which is always connected to an interpreting

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6 Bateson, G. 1973. Steps to an Ecology of Mind. University of Chicago Press. Quoted in Brier, 2008: 174

organism, the concepts of firstness, secondness and thirdness and the 10 main sign types based on these, to explain the different levels of information, knowledge and meaning.

Based on Bateson, Peirce, Maturana, Varela and many others, Brier comes to the final description of a theory of information that recognizes five “levels of being” (ibid: 389-390, 437-438). These are in general terms:

1. The level of continuity, sense and potential, a chaos preceding rules, that Peirce calls firstness.
2. A dual level where physical aspects bring about causality. The secondness of Peirce.
3. The quasi-signifying level of organisatory and chemical signals. The devices of 1. order cybernetics operate on this level.
4. The sign-based level of life and semiotics where the thirdness of Peirce appears.
5. Intentional socio-linguistic level where organism becomes a sign itself and participates in Wittgenstein's language games. At present moment only humans reach this level.

Although Brier emphasizes in his work several times the need to define and explain the essence and operating principles of knowledge, he does not reach a more detailed description than the described five-level distinction. From the viewpoint of the current thesis, Brier's main shortcoming can be considered the fact that computational semiotics has not once been mentioned in his work, al-

though for example Gudwin also aims at describing knowledge, trying to formulate the rules that operate on Brier's 4. level and in this also borrows heavily from Peirce (Gudwin, 1997b: 5). Owing to this, Brier cannot be accepted without hesitation to define the goals and limits of computational semiotics. Brier has however done an enormous amount of work in criticizing different theories dealing with knowledge, cognition and communication and building a new theory based on these. Cybersemiotics has at least the potential to also envelop computational semiotics, even if the author has never explicitly brought out this connection himself. To clarify the possible position and role of computational semiotics within cybersemiotics, it is now necessary to look at studies that can be defined or have been explicitly defined as computational semiotic and that define the field *ipso facto*. Then it will be possible to define more precisely also the nature of computational semiotics.

### **1.3. Modelling knowledge**

The scientist, whose work can be called computational semiotics both in his and Bouissac's definition, is associate professor Ricardo R. Gudwin from the Faculty of Electrical and Computer Engineering, State University of Campinas, Brazil. As his topics of interest, he lists neural networks, fuzzy systems, evolutionary systems, computational semiotics, cognitive sciences, autonomous agents and artificial cognition<sup>7</sup>. He has published over 80 articles and conference papers, the larger part of which are freely downloadable from his homepage. He is also the co-editor of two books on modelling artificial cognition and semiotic sys-

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<sup>7</sup> Ricardo R. Gudwin, homepage in internet <http://www.dca.fee.unicamp.br/~gudwin/> Visited 23.05.2008.

tems: Loula, A., Gudwin, R. R., Queiroz, J. (ed) 2006. Artificial Cognition Systems. Idea Group Publishing. and Gudwin, R. R., Queiroz J. (ed) 2006. Semiotics and Intelligent Systems Development. Idea Group Publishing. In his works, Gudwin deals with the questions of modelling knowledge and meaning mathematically. Unfortunately his works have not found a wider recognition in the discourse of semiotics and have not therefore defined computational semiotics as a unified discipline, although the author participates in projects that aim for wider coverage<sup>8</sup>. This might be due to the reason that in most cases his works presuppose from the reader a good understanding of mathematics and set theory.

In an article introducing his early views, Gudwin mentions as his source of inspiration on the one hand the experiments of hard sciences with artificial intelligence, neural networks and fuzzy logic, on the other hand the semiotic developments taking place in the humanities in parallel (Gudwin, 1997b: 2). As shortcomings of the approaches taken so far, Gudwin sees the lack of an integrated and organized description of intelligence. As a solution, he sees computational semiotics, that is based on the mathematical description of semiotic concepts and through this connection eliminates the individual shortcomings of artificial intelligence and semiotics (ibid: 3).

At first, Gudwin postulates a statical or dynamical (adaptive) cognitive system that senses the world with its imprecise and limited – depending on the systems sensors – inputs. As the system is itself also an object in the world, it is

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8 Computational Semiotics Group, homepage in internet  
<http://www.dca.fee.unicamp.br/projects/semiotics/> Visited 23.05.2008

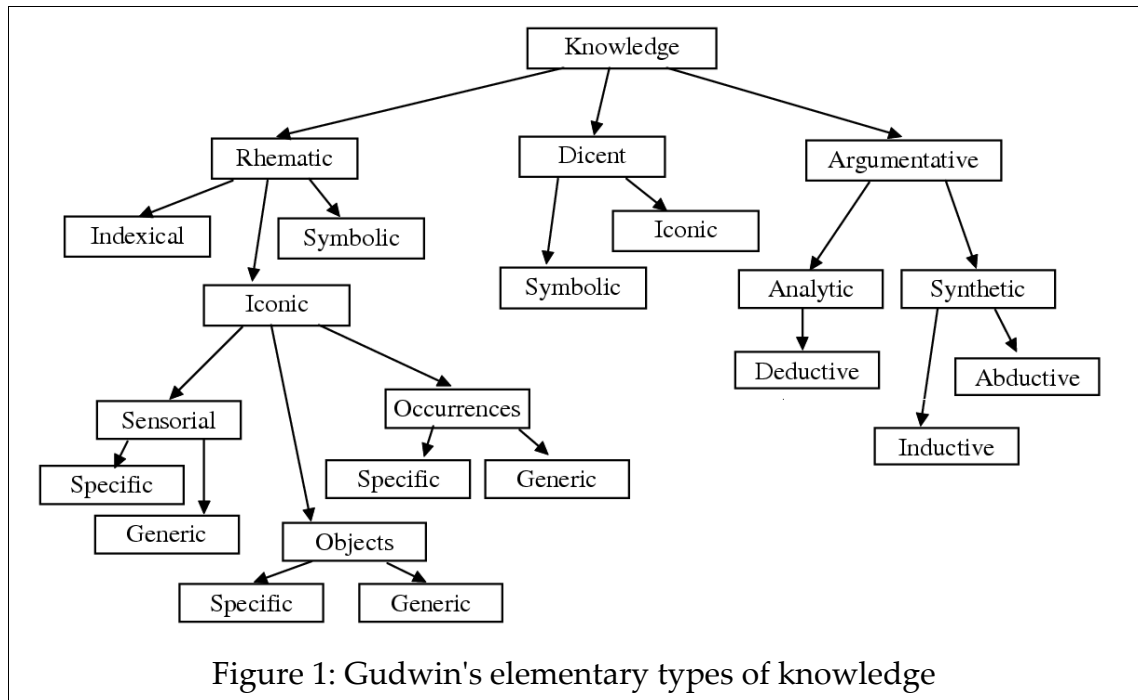
Digital Encyclopedia of Charles S. Peirce, homepage in internet  
<http://www.digitalpeirce.fee.unicamp.br/> Visited 23.05.2008.

capable of sensing (in an imprecise and limited way) also itself. The recognizing of objects in the world Gudwin calls interpreting and the basis for interpreting is the input received from sensors, that Gudwin calls a sign<sup>9</sup>, or a previously recognized internal representation, interpretant. In this way Gudwin reaches the concept of a triad, the components of which he calls sign-object-interpretant. This approach to knowledge differentiates for him computational semiotics from artificial intelligence, because representation is not any more connected directly with physical objects and the ability of an interpretant to become a sign for the next interpretant is not explicitly clear in the models of artificial intelligence (ibid: 4).

Next Gudwin describes a classification of knowledge, supported by the classification of signs by Peirce. Figure 1 depicts the types of knowledge Gudwin himself calls elementary and not final (ibid: 5).

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<sup>9</sup> Although this term does not conform to Peirce's representamen-object-interpretant triangle, I will use Gudwin's terminology when referring to his work.



In addition to the types depicted in Figure 1, Gudwin also classifies knowledge according to its use as designative, appraisive and prescriptive. All types can appear in all uses, but some types fit certain uses better than others.

Having explained his concept of signs and knowledge, Gudwin presents a mathematical model of objects, that is based on fuzzy sets and operations performed with them. In the second part of the article (Gudwin, 1997c) he ties objects to knowledge types and, supported by Albus, describes an internal structure of an intelligent system where the objects are realized. The article ends with a description of the operation of an autonomous system built in such way. As an experiment, Gudwin has chosen the often studied problem of finding a path in a space filled with obstacles, and his system achieves this goal relatively well, avoiding collisions in all instances (ibid: 37).

On the basis of the article described, it can be said that Gudwin deals with the questions of cognition, knowledge and meaning from an utilitarian viewpoint and he has admitted himself that the presented classification of objects is lacking and does not achieve the status of a general theory (ibid: 37). On the other hand the theory is founded on semiotic principles and is one possible solution for moving from signal to sign (from Brier's 3. level to 4. level). As a critique of Gudwin's approach the aforementioned heavy reliance on mathematics and set theory can be brought out, which makes its understanding problematic for a semiotician with a background in humanities.

In his next semiotic articles (Gudwin has also published numerous articles on other topics in information technology, including on industrial robotics) Gudwin with his colleagues continues to refine and develop the described models. In general, a movement from more specific mathematical formulas to broader theoretical questions can be detected and this makes his later works more accessible.

In the article "Semiotic Synthesis and Semionic Networks", published in 2002 (Gudwin, 2002), Gudwin presents the concept and mathematical model of a semion as the smallest unit supporting semiotic processes and possessing memory. Semions are classified into types and connected in semionic networks. When proposing the theory Gudwin, by the way, remarks that questions of the possibility of semiotic processes or autopoiesis within computers are still unanswered (ibid: 2).

The concept of semions is based on a triadic model, making a distinction between internal and external semiosis. External signal can become a sign

and cause one or several internal interpretants, some of which can in turn become a sign for either an internal or external interpretant. The latter case brings about a change in the environment and constitutes a link in the chain of communication between organisms (ibid: 8).

The article also describes different operations that can be performed with units of knowledge. While comparing these operations to Peirce's terms of abduction, induction and deduction, Gudwin for the sake of clarity uses the terms knowledge extraction, knowledge generation and knowledge evaluation (ibid: 18). The classification of semions is based on the classification of knowledge types depicted in Illustration 1 and described in the previous article (Gudwin, 1997c).

As the application of semiotic networks, Gudwin sees both the artificial brains for intelligent agents as well as models of organizational semiotics, also the control of industrial robots (ibid: 25). To test his theories, he has developed a software program for designing and utilizing semiotic networks.

In his more recent article „Towards the emergence of meaning processes in computers from Peircean semiotics“ Gudwin with his colleagues again looks at Peirce's sign triad and presents a three-level model of semiosis based on this (Gomes, Gudwin, El-Hani, Queiroz, 2007: 5). The first, micro level of semiosis, is concerned with making choices between possible objects and embodies the potential of semiosis. Here a connection with Brier's described firstness as chaos full of potential can be made.

The second level is the focal level of semiosis, where the triadic movement from a sign through an object to an interpretant, that is itself a sign in the next triad etc. takes place, constituting a continuous chain.

The third, macro level of semiosis, is made up of parallel chains of semiosis, giving a context to the focal level. The semiosis taking place on the focal level is caused by the micro level and influenced by the macro level.

Next, authors introduce the question of emergence, differentiating between “weak” emergence that is reducible and “strong” emergence that is not. Based on the fact that a triadic relationship between sign, object and interpretant is not, according to Peirce, reducible (dual connections sign-object, sign-interpretant or object-interpretant, even if they are possible, do not allow the prediction of connections taking place in a triad), contains new information and is unpredictable, they classify the described semiosis occurring on three levels as emergent (ibid: 12).

The article ends with a conclusion that to this day there is no precise computational model based on Peirce's sign model and the given work is one step in that direction (ibid: 13).

In the referenced articles Gudwin has proposed both mathematical models as well as theoretical viewpoints that allow if not to emulate, then at least simulate semiotic processes in a computer on an adequate level. Being familiar with previous scientific studies in cybernetics, artificial intelligence and philosophy, Gudwin tries to avoid the opposition between materialism and phenomenology highlighted by Brier. To achieve this, he on several occasions refers to Uexküll among others and always makes a distinction between intern-

al and external representations. With his strong background in engineering, Gudwin in most cases mostly accompanies his works with practical examples. He uses the term computational semiotics when referring to his works consistently, seeing it as different from computational linguistics and artificial intelligence, basing this difference foremost on Peirce's sign triad.

In an unfortunate manner, Gudwin has not been mentioned in Brier's theory of cybersemiotics and has he been rarely referred to in the larger semiotic discourse. He has however proposed the most explicit definition of computational semiotics, its goals, interests and problems this far. Owing to this, I believe it justified to consider Gudwin the fundamental author when talking about computational semiotics and use him as a point of comparison to evaluate other authors and studies. This does not mean that I consider as computational semiotics only works following his definition, his terms and models. The concept of computational semiotics is no doubt broader than this – a question that will find more thorough discussion in sub chapter 1.5. – and also his proposed method for modelling semiosis, that is based on fuzzy sets, might not be the most adequate. Next I introduce the studies of another scientist belonging to the core of computational semiotics and hope to find points of comparison with Gudwin.

#### **1.4. Semiotic Cognitive Information Processing Systems (SCIP)**

The professor emeritus of computational linguistics at the University of Trier, Burghard B. Rieger has been interested in computational linguistics since 1960s. His works mostly deal with computational semantics and knowledge represent-

ation from a statistical aspect. Rieger has published close to 90 articles, edited several publications in the fields of computational linguistics and -semantics and presented papers at more than 170 conferences<sup>10</sup>.

In the article "Fuzzy Word Meaning Analysis and Representation in Linguistic Semantics" published in 1980, Rieger discusses the questions of word-level semantic analysis based on material from natural language. According to the views at that time, linguistic units are discreet and categorizable, and the membership in a category is binary. In light of newer studies, Rieger criticizes such inflexible approach and proposes as an alternative one based on fuzzy sets and empirical procedures connected to those (Rieger, 1980: 3).

Based on traditional theories, he separates the referential and connotational meanings of language. Introducing the works of Zadeh for the formal description of the referential meaning, Rieger reaches the conclusion that while Zadeh takes into account fuzzy logic, where the connection between a term and an object is not binary, his work is not based on the empirical study of natural language, but the experimentator's understanding of a terms refernce. In Rieger's opinion, the only certain thing that can be said about knowledge is that it is derived from texts in natural languages (ibid: 6). Next Rieger builds on Zadeh's theory, describing terms not as autonomous units, but as a system, where the frequency of occurrence, that takes into account both the occurrence of terms together and separately, brings forth an additional relation. Rieger also gives formulas to compute all relations.

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10 University of Trier, homepage in internet <http://www.ldv.uni-trier.de/index.php?rieger>  
Visited 18.05.2008.

The empirical theory based on the statistical connections of words is described in more general manner in the article „Definition of Terms, Word Meaning, and Knowledge Structure“, where Rieger writes:

In a first step, the statistical coefficients applied will map lexical items onto fuzzy subsets of the vocabulary according to the numerically specified regularities these items have been used with in the discourse analysed. The resulting system of sets of fuzzy subsets is a data-structure which may be interpreted topologically as a hyperspace with a natural metric. Its elements are abstract meaning representations and the distances between them represent their mutual meaning differences. (Rieger, 1988: 10)

From this wording several important aspects can be derived. First Rieger emphasizes that analysis can and must take place not using sign-and-meaning tables created in laboratory settings, but all relations must come from the corpus of text (discourse) analysed, during the process of analysing itself. Second Rieger sees difference as an important aspect of meaning, which leads us to a structuralist understanding of both the sign and sign systems. In the given case, Rieger interprets meaning as the difference of sets in an abstract semantic space. The third and most important conclusion, that envelops the others, sees frequency of occurrence of units as the method of mapping the meaning (difference). This approach allows us to speak about the emergence of meaning in accordance with the discourse analysed, possibly also solving the question about the origin of meaning (see below). Also a theory based on statistical frequencies can be experimentally modelled in computers. Rieger holds the latter fact in high regard in the fields of computational semantics and -linguistics. Speaking about a movement from theories dealing with general questions to more detailed models in computational semantics, Rieger writes:

It is this kind of distinction between “theory” and “model” — after having been made and practised in the sciences and in engineering for some time now — that is to become fertile for some computational approaches in linguistic semantics and the cognitive sciences. In these disciplines, general theories may still informally be assumed or heuristically be developed, but only so that certain components of them may be specified as to be studied in small-scale models. (ibid: 3)

If I correctly understand the author in this case, he does not see the need to create general validating frameworks, because computational semiotic and -linguistic devices make it possible to experiment and test individual solutions far more efficiently and faster. This makes validation with the help of a general theory pointless, as models can be implemented in computers and their success evaluated experimentally. Concerning theories as frameworks for developing models, Rieger undoubtedly does not oppose them, relying even in this article on authors like Frege, Russell, Wittgenstein, Saussure, Hjelmslev, Peirce et al. (ibid: 4-5).

The question about the origin of meaning mentioned above again repeats the opposition between hard and soft sciences. Rieger has criticized computational linguistics also from this viewpoint and argued that the discipline has so far failed to show interest in the origin of meaning, its emergence and the processes modelling it. Describing traditional understanding of labelled units that referentially point to external objects, he writes:

It has long been overlooked that relating arc-and-node structures with sign-and-term labels in symbolic knowledge representation formats is but another illustration of the traditional mind-matter-duality presupposing a realm of meanings very much like the structures of the real world. (Rieger, 1992: 2)

According to Rieger, the questions of semantics never arise in this duality. Using a semiotic approach, it could in his opinion be possible to overcome this opposition and find the ways to take into account the aspects of language like creativity, dynamics, effectiveness and fuzziness (ibid: 2).

Rieger expresses his views consistently in his articles. Moving with them in time, it is possible to note a tendency, much like with Gudwin, towards a general theory and supporting model. Rieger himself uses the term SCIP (Semiotic Cognitive Information Processing System) and next I try to give a description of such a system, based mostly on the article „A Systems Theoretical View on Computational Semiotics“ (Rieger, 1998).

Rieger first differentiates computational semiotics from computational linguistics and the study of artificial intelligence, based on the format of describing knowledge. While the latter two use rule or symbol based formats, then according to Rieger, computational semiotics models knowledge as processes (compare with Emmeche, Hoffmeyer, 1991), that can be expressed as formulas and applied in a computer programs. A system operating with such formulas is called a SCIP by Rieger (Rieger, 1998: 1). Comparing this understanding with Gudwin's, it most closely matches Gudwin's argumentative knowledge type (Gudwin, 1997b: 8).

Next Rieger introduces the concept of life, which in his description is the ability to survive, adapting to changes in the environment. Sense, identification and representation are in such case forms of information processing that systems perform motivated by this goal and their structure. Humans have in addition to the vertical form of information processing (genetic) also a horizont-

al form. Such development was made possible by the semiotic distinction between a process and its result, the latter of which can be formed into knowledge. The carriers of semiotic differences are representations, in other words complex sign systems that constitute languages and that can be actualized in words, sentences, texts (Rieger, 1998: 1).

From this definition, Rieger moves on to a definition of SCIP as a system that, to ensure the survival of itself, creates adequate couplings between the internal and external structures of the system (ibid: 2). This description seems to agree with that of autopoietic systems, whose only means of communication – and therefore also of acquiring external information or affecting the external environment – is also through mutual structural couplings. Not discussing here the issues regarding the enclosure of the system, Rieger mentions that humans are unique, cognitive systems whose ability to use natural languages makes it possible for them to experiment with unmediated situations separated from time and space (ibid: 2). I understand from this statement that language makes it possible to create structural couplings not only between the internal and external structures of a system, but freely chosen structures, including internal structures of other organisms. In this case humans, semiotic cognitive systems have indeed something unique that gives Brier the right to place them on the 5. level, where they themselves become signs.

Rieger also links his works with the sign triad of Peirce, describing conditions under which the system becomes semiotic. According to him, this happens when the knowledge used to identify and interpret environmental structures is itself derived from previous identification of external structures and is applied using self-organizing (self-organized) feed-back (ibid: 3). This is a

multi-level application of the triad that Rieger, in the tradition of Peirce, calls semiosis. The components of the given triad are a sign from the external environment, a virtuality that is sensed by the system as an object of its environment, and the actualization process (interpretant).

After giving the main description of the SCIP, Rieger also emphasizes in this article the identification of frequencies arising due to the syntagmatic and paradigmatic constraints of language as the basis for the emergence of semantic structure and considers fuzzy sets to be the most adequate means of measuring these frequencies (ibid: 4). The article ends with a brief description of an experiment, where a SCIP was created to map its environment according to descriptions given in natural language and detected the location of two objects within the environment (ibid: 6).

The Rieger's works described, when compared to Gudwin, are not based as strongly on fundamental semiotic authors, but Rieger aims for the expression of a clearly semiotic aspect in his cognitive systems as well. Also he has in most cases defined his works as computational semiotic or computational semantic, to differentiate them from computational linguistics or artificial intelligence. This gives in my opinion a reason to take also his approach as representative of computational semiotics. Other than the described main approaches, several of which have either semiotic aspects or semiotic background, the understanding of knowledge and cognition as dynamic processes, not statical units with truth values, is evident in his works. This is undoubtedly a semiotic approach, as is the mapping of meaning in a semantic space constituted by differences. Whether the statistical approach to engineer this space used by Rieger, also the using of fuzzy sets to compare units of meaning, are the best solutions,

are already technical questions that are, in Rieger's spirit, answered best by experimentation.

### **1.5. The boundaries of computational semiotics**

On his homepage<sup>11</sup> under the heading „Main Definition“ Gudwin gives a short definition of computational semiotics, lists some goals and currently relevant questions of the discipline. When speaking about the boundaries of computational semiotics, these are good starting points, that also Gudwin's own computational semiotic works refer to and that can be summed as follows:

- a) intelligence can be largely attributed to semiotic processes inside an organism;
- b) computational semiotics aims for the emulation of the cycle of semiosis within a digital computer;
- c) the goals of computational semiotics include the creation of autonomous intelligent agents;
- d) the key issue of computational semiotics is the definition of atomic units of knowledge;

Largely these views agree with those of Rieger for example, so they can probably be considered to hold for the whole of computational semiotics and they constitute the kernel of the field. Neither author however deals with the borders and the periphery, rather we might build an understanding by looking at the

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<sup>11</sup> In internet <http://www.dca.fee.unicamp.br/~gudwin/compsemio/> Visited 21.04.2008.

materials of COSIGN conference and based on them try to draw conclusions about the material.

According to the conference website<sup>12</sup> COSIGN is a series of conferences centred around computational semiotics, new media and games. Workshops and conferences have taken place between 2000 and 2004 and the organizers are planning future conferences<sup>13</sup>. The main organizers are Andy Clarke and Grethe Mitchell, participants include among others P. B. Andersen. During 5 years close to 90 papers have been presented. The organizer's understanding of computational semiotics is rather broad. For example the topics covered in the workshop (the organizers refer to the event as a conference since 2001) of 2000 were limited as follows:

The aim of the workshop was to explore the ways in which new media systems encode and convey meaning to system users. Papers were invited on any subject that explored areas of overlap (or potential overlap) between semiotics and new media<sup>14</sup>.

This means that the conference as a whole is faced with the problem of defining computational semiotics and errs in this matter more on the side of tolerance when limiting the range of topics. Also the scope of next conferences was wide on purpose and about the event of 2003, the organizers write:

The theme of the conference was, as always, issues of meaning in new media, particularly the way in which semiotic-based theories can be applied to creating and analysing computer-based media<sup>15</sup>.

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12 In internet <http://www.cosignconference.org/> Visited 23.05.2008.

13 Source: private email exchange with the organizers. 22.05.2008.

14 In internet <http://www.cosignconference.org/conference/2000/> Visited 23.05.2008.

15 In internet <http://www.cosignconference.org/conference/2003/> Visited 23.05.2008.

Working through all conference papers would grow out of the bounds of the current thesis, therefore I have made a short selection from the papers of 2004 (Clarke, 2004), as works of later date will, in the case of a loosely formulated phenomenon, form a more coherent whole than earlier ones. The criterion for selection was at minimum the existence of a semiotic, modelling or computer component. Additionally I have selected from similar topics only one representative specimen.

Next follow short descriptions of selected papers that will help to map the boundaries and possible applications of computational semiotics.

a) Anstey et al. (ibid: 5-13). Psycho-Drama in VR.

The subject of the paper is the creation of emotionally binding interactive narrative in virtual space. To create the narrative, authors use a virtual environment, which is brought about by projection devices and registering of users somatic actions, interactive story and autonomous agents. The function of the agents is to react to users actions and authors see the need to enable the agents to act, possess sensors, natural language processing capabilities (input and output), knowledge base and plan of action. From the viewpoint of computational semiotics, what is important is the aspect of creating agents, and interactive narratology is one of its possible fields of application.

b) Böhlen et al. (ibid: 19-24). Unremarkable, and Ambivalent OR How the Universal Whistling Machine Activates Language Reminders

The authors describe a “Universal Whistling Machine” they have created and using it as an example, ask a series of questions about computer interfaces. This subject falls of course better within the focus of computer semiotics, but when describing the concept of the whistling machine, problems of modelling natural language also arise. This definitely already connects with computational semiotics, on the background of both autopoietic systems and cybernetics. From this perspective the author's hypothesis of whistling as semantically impoverished – and therefore made easier to model – language is important also for computational semiotics.

- c) Do et al. (ibid: 25-33). Formal Semantic Models for Images and Image Understanding

The paper describes problems faced by image retrieval systems, that today are no match for text search solutions. When in the simplest approach text can be looked upon as a cluster of elementary language terms, then in the case of image indexing, problems arise even with defining the elementary semantic units.

Authors introduce, based on their previous work, a formal model that is able to use the semantic characteristics of images on four levels and several methods for deducting the characteristics of higher levels from lower ones.

Other than the subject – search systems – the paper also discusses several other questions relevant for computational semiotics. Chief among them is the deduction of characteristics and is linked with Gudwin's (Gomes,

Gudwin, El-Hani, Queiroz, 2007) work, also with the question of emergence.

- d) Gartland-Jones (ibid: 34-38). Visual Blends: A Computational System Exploring Digital Creative Spaces

Gartland-Jones describes experiments to create art objects with the help of evolutionary computer programs. This is a subject that could, following the example of computational semiotics, be called computational art. Modern computational art is generally based on a model that separates genotype and phenotype, is created according to the principles of artificial life, takes into account feed-back and stores the developments that have proved to be successful.

In semiotics – and although the author brings an example using Picasso's work "The Guitar", we can here also refer to Lotman, who speaks about the pair of seemingly unconnectable units of meaning as the mechanism for creation of new relations of meaning (Lotman, 1999: 219-210) – the mechanisms of art creation are well defined and their emulation in computers should take place utilizing a sign-based process.

- e) McGee et al. (Clarke, 2004: 87-96). Partner Technologies: an alternative to technology masters & servants

Authors propose a concept of software that in comparison to systems currently in use does not follow the master/servant paradigm and that they call partner technology. In contrast to rule-based or limitlessly improvising systems, this concept stresses the importance of cooperation

and process as a goal. While in describing their models, the authors stay far from semiotics, occasionally misusing terms, the concept of partner technology as a field of application for computational semiotics is interesting and in need of further study.

## **1.6. The definition of computational semiotics**

Wishing to continue studies in computational semiotics in the future, create a model for semantically motivated categorization of texts based on computational semiotics, the need to give a definition of computational semiotics is inescapable. As mentioned earlier, no such common definition exists today.

Gudwin's short description is too narrow to encompass all works created under the umbrella of computational semiotics. The papers of COSIGN conference as a whole are too fluid to fix the boundaries. Next I try to state general principles, that have appeared in works cited and to reach the definition of computational semiotics based on these.

1. The scientific tradition of computational semiotics reaches back to Uexküll, but is clearly traceable foremost to Wiener and cybernetics. The push for development of computational semiotics came from the emergence of certain insurmountable problems concerning the modelling of communication and knowledge in cybernetics and its sister sciences. To solve these problems, computational semiotics uses an interdisciplinary approach, explaining meaning, cognition and knowledge not as caused either by the outside environment or the agent in itself, but as emergent processes that are the result of relations between these two.

2. Computational semiotics is an experimenting discipline that does not refer only to previous studies for validation, but also to results of experiments. In other words it can be said that computational semiotics is based on general framework theories, for example cybersemiotics, and applies models created using these experimentally, analysing the results as a whole. In this is expressed the interdisciplinary nature of computational semiotics in relation to both hard and soft sciences.
3. To build and operate the models, computational semiotics uses modern digital computers, but with the appearance of new technical solutions – for example quantum computers – there are no reasons why computational semiotics could not and should not use these for modelling. The hardware solution utilized to realize the model does generally not reflect in any aspect the internal structure and operating principles of the system modelled, in most cases even the contrary is true. Computational semiotics operates on the software level of computers.
4. The focus of computational semiotics today is the detection of atomic units of knowledge. Leading scientists have used fuzzy sets for this purpose, but this is not the only possible solution and as is the case with independence from hardware configuration, we can at present moment consider the model for knowledge independent from any certain mathematical-logical model. In all cases is however held true the concept of knowledge as processes that arise from the relations of internal and external structures and that are unpredictable by nature and therefore

emergent. In addition to the atomic structures and their composition, the questions of the different levels of structures are likewise important.

5. Modelling knowledge, computational semiotics differentiates between the existing reality, its aspects mediated by sensors and the internal representation of the latter. When describing the knowledge processes, the concept of cyclic feed-back is used and knowledge can only be spoken about within a discourse.
6. Computational semiotics is an applied science indirectly. This means that computational semiotics does not itself study specific applications, but models that can be realized in applications. For example the question about constructing an agent for use in interactive narrative is not in itself a question for computational semiotics, but the question about creating a model that the agent is based on, is one. Today the models of computational semiotics have a narrow field of application and we cannot speak of an universal model that could be applied in every sign-based process.
7. The indirect field of application for computational semiotics reaches everywhere where sign-based processes occur. It is however possible to highlight the main areas which are search systems, interactive narratology, expert systems, control systems.
8. Today those working in the field of computational semiotics are either engineers, linguists or multimedia specialists, who try to use computational semiotics to solve practical problems encountered. Semioticians who have so far been under-represented in computational semiotics can-

not reverse this trend, but refine the framework theories that support applied models.

These principles hold true in most if not all works described, therefore I consider them to hold true for computational semiotics as a whole. From these it is possible to derive a shorter definition of computational semiotics: "Computational semiotics is an applied field of study, interdisciplinary both from the viewpoints of hard and soft sciences, that experimentally models the semantical processes emerging from the relations between atomic units of knowledge." This definition repeats Gudwin to a great extent, but includes several important topics discussed. It is clearly not the final definition, but is hopefully adequate to be used to delineate the object of interest of the second part of the thesis and hopefully also to assess the studies of other authors.

## **2. A Model for automatic categorization of texts**

I have on numerous occasions referred to the problem of information overload, caused by the explosive growth of the numbers information technology devices and also developments in other branches of science, the scope of which is far wider than simply an annoying factor in everyday communication. The changes in the vertical structures ordering information is inevitable in a situation where the importance of time and space are constantly declining. To ensure the possibility of making motivated and conscious decisions about choosing texts for consumption in the 21. century – choose the signals that will become meaningful for us – it is necessary to use the aid of technological devices.

Next I present a sketch of a model, that follows in its design the principles of computational semiotics and the application of which could be as a component in search systems or other devices, where the categorization of texts based among other aspects also on users choices of texts, is needed. To do this, I first introduce a few studies that, parting from the previous ones, do not use fuzzy sets for modelling knowledge. Also I will use the Bayes' theorem as the central term for atomic units of knowledge.

The description of the model will remain a draft and is not sufficient to draw up a software specification. I will merely try to relate main principles the model is based on and references to develop it further.

## 2.1. Frequency of occurrence as criteria for semantic distances

Rieger in his works relies on the frequency of co-occurrence of word pairs and based on these constructs a semantic space, where it is possible to compare the distances between words and by this, also of the distances of their „meanings“ (Rieger, 1988). A newer article that presents an application created on similar principles, is Cilibrasi and Vitány „The Google similarity Distance“ (Cilibrasi, Vitány, 2007). According to the authors point of view, words acquire their meaning from their use in society and talking about computers, some sort of a database can be considered the „society“. Unparalleled the largest freely usable database is Google, where at the time of writing the article, 8,058,044,651 internet pages were indexed. Although the authors mention that the information in internet tends to be of less than average quality, yet because of the size of the database, we can still consider it to adequately represent the use of terms in society and depict the differences of meaning (ibid: 3).

The formula given by authors allows one to find the Google similarity (Google Similarity Distance, GSD) between two keywords and measures it on a scale from one to zero. To calculate the GSD, four measurements are considered foremost: the number of results for the first keyword, the number of results for the second keyword, the number of results for a joint query (shows results where both keywords appear) and the total number of indexed pages. They test the effectiveness of the proposed theory by having the program sort for example 17. century Dutch paintings and British literary works. In both cases, the system sorted the works by author. In another experiment, the authors entered the names of different colours and numbers and the system sorted them in a lo-

gical manner (colours separately and numbers separately). What is especially remarkable is that on a graphical depiction of the results, numbers were ordered more or less based on their value, starting from zero (ibid: 8-10).

GSD and similar methods are not absolute and are probably powerless in case of certain ambivalent terms, like „right“. Yet the results of models based on statistical frequencies are sufficient to warrant further study and application.

## **2.2. Bayesian data analysis and its applications**

Bayesian data analysis is a practical method for making inferences from data, using probability models using observed and unknown quantities (Gelman et al., 2004: 3). The probability of a given event is not completely random, but is connected to the frequency of occurrence of this event and the number of total events. Bayes' rule allows us to calculate this probability and fits well with the computational semiotic model based on statistics. Using the Bayes' rule for modelling semantic connections has been discussed by Nalimov in "In the Labyrinths of Language". He argues that in language every sign is connected to different meanings in a probabilistic manner (Nalimov, 1981: 56). In the receiver's mind a sign can have several meanings, but every meaning has a different probability. This means that the content of a sign is a certain semantic field of possible meanings, much like in a dictionary the explanation of a term consists of other words, that are more or less closely tied to the term. It is understood that the semantic fields for signs differ according to persons' intellectual background. In more general terms this means the dependence of the semantic field on a discourse and in the case of Bayes' theorem, on the previous occurrence of

phenomena and the total number of all phenomena. In the most marginal case, where a sign has no previous usages for the receiver, the semantic field of the sign is empty. Author illustrates this argument with an example from Stanislaw Lem's book "The Star Diaries" where the main character attempts to buy a "sepulka" (ibid: 61). Thoroughly logical text does not help the reader in any way to understand the meaning of this sign, that is defined in short as "an important element of the civilization of Adrides on the planet Enteropea".

The connection of signs meaning with previous discourse opens an important dimension of the Bayes' theorem, its memory function. With every usage of a sign in a discourse, the probabilities relevant to current discourse become reinforced in the semantic field of the sign. Erroneous meanings are corrected relatively fast (ibid: 59).

The given reasons provide grounds to suppose that Bayesian data analysis can be a simple and efficient tool for the semantic analysis of text. In practise, solutions based on this method have been already used widely. I will bring an example from a field that most readers might have had encounters with: the detection of junk messages (SPAM) among electronic mail, so called "spam filters". The idea to apply Bayes' theorem here came from Paul Graham in the article "A Plan for Spam<sup>16</sup>" from 2002 (Graham, 2004). In the article, he points to the shortcomings of rule-based filters and proposes a solution based on the frequency of occurrence of terms, that calculates for every term occurring in email correspondence the probability that the term points to spam. Then he assigns every message a probability using for this the 15 most interesting (probability differs most from neutral 0.5) terms. In order for the system to calculate the

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16 Version in internet <http://www.paulgraham.com/spam.html> Visited 26.05.2008.

probability of a term, it has to be based on a discourse, previously sorted messages. Here also the question about handling previously unknown terms occurs and based on his empirical experience, Graham gives them a probability of 0.4, mentioning that terms pointing to spam are in most cases already known and it is more probable that an unknown term is neutral. Speaking about the results of his experiment, Graham says that less than 5 spam messages are not recognized out of 1000 and no legitimate messages are classified as spam.

Graham's proposed solution is today used in almost every email client applications. In server applications, where detecting a common discourse is difficult (imagine the probability that a word like "viagra" might point to a spam message in the correspondence of a sexologist on one hand and a car dealer on the other), rule-based solutions are still used more often, although when possible, they are augmented with Bayesian elements.

### **2.3. Categorizing texts**

Detecting spam mail using Bayesian methods is relatively effective, but it is a simplified solution to the more complex problem of text categorization, where in addition to sorting the texts, also the categories they will be sorted to have to be derived. When sorting spam messages, the categories are fixed and do not change.

Detecting categories with Bayesian methods has been studied by Cheeseman and Stutz, who have developed software called "AutoClass" for this purpose. The authors describe their goals as follows:

We are concerned with the problem of automatic discovery of classes in data (sometimes called clustering, or unsupervised learning), rather than the generation of class description from labelled examples (called supervised learning). In some sense, automatic classifications aims at discovering the “natural” classes in the data. These classes reflect basic causal mechanisms that makes some cases look more like each other than the rest of the cases. (Cheeseman, Stutz, 1995)

This goal also emphasizes the previously stressed demand for discourse. Classes or categories, we wish to sort texts to, have to be derived from these texts themselves. Of course authors argue that at least in the nearest future, best results are achieved in the cooperation of a program and an expert, as the first will effortlessly detect statistical regularities in enormous volumes of text, while the second possesses as an expert a priori knowledge and hypothesis and can better judge the results of the program (ibid: 2).

Authors have used the software to study data on celestial bodies, DNA-sequences and geological measurements among others. For example in the case of celestial bodies they discovered several new, so far unnoticed regularities that allowed them to triple to number of known possible carbon stars (ibid: 16). They also discovered frequent errors and contradictions in the data, that in most cases came from experts wish to make data more easily analysable and skewed the test results. Owing to this, authors again stress that unmediated discourse has to be used and whether wishing or not, the scientist has, to adequately analyse the results, become a partial expert in the discourse (ibid: 17).

Although the software gives good results and in their demand for discourse authors agree with the principles of computational semiotics, it is doubtful we can speak of the internal signs of the “AutoClass” software. Knowledge

as a process emerges in the current case in the repetitive cycle of experiments in the collaboration of the scientist and the software. My goal is to describe a system where the cycle would also take place within the system and there would be a reason to call the model semantic or autopoietic.

## **2.4. An autopoietic model for categorizing texts**

One of the main characteristics of autopoietic systems is their direction towards self-recreation of themselves and to achieve this, they can use limited structural couplings between themselves and the external environment. In other words they constantly seek a point of balance between the sensed environment and its internal representation, correcting the latter based on changes in the former.

We can talk about the external environment, its sensed subset and the internal representation of the latter already since Uexküll. Here I will present in my wording a classification of these phenomena founded on previous traditions.

1. The level of existence. The phenomena on this level „exist“, but no system has the capability to sense them directly.
2. The level of reality. This is a subset of existence, that a given system is capable of sensing.
3. The level of representation. This is a generalizing model internal to the system, that is based on data from the 2. level and can be projected to the 3. level.

For a system categorizing texts, the sum of texts, the discourse, is a 1. level phenomenon. Texts exist, but no system is capable of sensing every aspect of them. Depending on its sensors, a system can comprehend a subset of data in texts, which forms for it the 2. level. Based on Rieger and successful experiences with spam filters utilizing word occurrence frequencies, we can imagine a model for which the 2. level consists of single words. The 3. level is a model, based on frequencies of occurrence, of the regularities on the 1. level – that is classes or categories in the current case.

The three-level distinction given by me also follows the distinction indicated by Brier and derived from Peirce. 1. level (also 1. level for Brier) is the level of potential, where there are no set rules. The second level (also Brier's 2.) is causal and the third (Brier's 4.) is connected to the first through rules, conventions.

Returning to the autopoietic aspect of the model, the re-creation of the system and seeking the balance is expressed in a process where in an environment of constant change – new texts being inserted into the database – the system labours to maintain a projection that would be able to explain all phenomena of the 1. level through their characteristics sensed on the 2. level. In other words the aims labours for a situation where all texts belong to a category.

Foremost the question of creating categories has to be solved. Bayes' theorem is binary in nature, giving a probability of a certain event taking place or not. By binary I mean that while the probability is on a scale of 0 ... 1, it depicts the probability of only two possible states. The states can be the membership of a term (and through several terms, also of the whole text) in a category,

or not, for example “spam” or “not spam”. As mentioned previously, every actual discourse has many more categories than two. In that case we can consider categories as combinations of binary oppositions, for example “Estonian/not-Estonian”, “economic/not economic” etc. In the case of these two oppositions, four categories will be formed: “Estonian, economic”, “Estonian, not economic”, “not-Estonian, economic” and “not-Estonian, not economic”. The membership of a text in a category is determined by the position of the text on the axis of oppositions forming each category and the position is given as a probability by Bayes' rule. So in the case of the given example we calculate two probabilities that show the texts position on the axis of “Estonian/not-Estonian” and “economic/not-economic”. We will round the results to either 0 or 1 and end up with a binary code that corresponds to a specific category.

Before making the simple calculation, it is however necessary to detect the oppositions that are the basis for forming categories. Here we can rely on Rieger's, Cilibrasi's and Vitány's works and use the distance of a pair of terms in semantic space. Going through the pairs of terms in a discourse, we can find those that are positioned at maximum distance from each other in the semantic space. Such pairs of terms will form oppositions which will be used to categorize all texts. The system has to constantly monitor changes in the space that happen when new texts are added, and when required, start using a new opposition, disregarding an old one. In this is also expressed the systems function of self-preservation. If the categorization of texts took place according to initially detected oppositions, the adding of new texts would not any more reflect the texts adequately.

It is understood that it is impossible to measure the relative distances of all pairs of terms in a discourse of any considerable size, so the system has to make generalizations on one hand, and use the time between the addition of new texts to constantly reorder the level of representation on the other hand, processing term pairs, trying to find new oppositions and recategorizing already categorized texts.

## **2.5. The main characteristics of the model**

Next I will sum the main characteristics of an autopoietic text categorization model.

1. The levels of existence, reality and representation are separated. The projection of the last to the first is a structural coupling that is used by the model to ensure its survival, that is the ability to explain 1. level phenomena through qualities and characteristics sensed on the 2. level.
2. All processes taking place within the model are continuous, with the addition of a new text there emerges a conceptual necessity to recategorize all previously categorized texts, this necessity is also brought about by every categorization of a text. This means that the 3. level of the model will never reach a finite form, but the model is constantly seeking this stability.
3. Based on the statistical frequency of co-occurrence of word pairs, the system constructs a semantic space and detects the main oppositions within, that become foundations for categories. As all others, the construction of

semantic space is a continuous process and oppositions can change, which in turn brings about the need to recategorize all texts. The number of oppositions can be predetermined, the system can aim at the most optimal number of oppositions, the number can be based on a balance between processing power and text volume or be derived from other sources.

4. The model has an aspect of memory that is expressed in the probability coming from Bayes' theorem of a terms position on the axis of oppositions. After every categorization of texts, the memory aspect is refreshed, reinforcing thus the probabilities. The models memory forms its evolutionary aspect and by initializing new models with memory data from previously successful models, it is possible to simulate evolution according to certain criteria of selection.
5. The model accepts user input during its operation, who can assign a categorized text to another category. The model will in response correct the probabilities about the position of the terms in the given text on the axis of oppositions.

These points along with the previous discussions should be sufficient to develop a further description of the model, that would also enable the creation of a software program to experimentally test the models effectiveness. In the course of this, a great number of questions have to be solved that I have only touched briefly, also the model has many possibilities for expansion. The main question that must be solved is that of detecting oppositions in semantic space and of the categories based on them. On the one hand is a situation where the model cre-

ates for every text its own category – a result that is completely useless. On the other hand the oppositions must be defined loosely enough to be able to change in accordance with the discourse. This is one of the central questions about the models autopoietic nature.

Another important question is about initializing the model. While in theory it is possible to imagine the development of the model starting with the first text, this development might be too heavily influenced by the order of inserting texts. Cilibrasi and Vitány among others warn about making conclusions based on a small discourse (Cilibrasi, Vitány, 2007: 3). Thus it might be practical to enter a certain preliminary memory database created by experts and then developing models according to their adaptivity. Utilizing the memory function of Bayes' theorem, it is possible to run a great number of models simultaneously and after a certain time period, select from them only the ones that have adapted most successfully.

Then there is the question about selecting the texts in the discourse. Implemented in a software program, the discourse should develop automatically, the system should follow links in texts and gather new texts from the internet for example. In experimental phase it is possible to create a discourse with known categories to test the detection of contained regularities by the model.

The practical applications of the model are many, but writing this thesis, the author has envisioned a certain “memex” like device or personalized search engine that Brier has in few words considered impossible (Brier, 2008: 287). The model could be implemented as a server solution that is able to identify every

visitor and offer him search results that have been crafted according to a discourse formed based on his previous searches.

## Conclusions

In the current thesis I have given not a complete overview, but one that is still adequate on an elementary level of the historic developments, of today's focus in research and of scientists actively working in the field of computational semiotics. Also I have highlighted problems that computational semiotics aims to solve and is in my opinion capable up to a certain level of solving. Chief among them are the problems of locating adequate information in the condition of information overload. In some aspects the current thesis is a *par excellence* example of this kind of problem – there is a lot of material on computational semiotics, but it is distributed horizontally and due to the amount of it, the processing of all material is not possible. Thus I have been forced to – as Eco expressed it – decimate existing information. The result is however an overview that has so far been missing and a definition, a certain bump that can serve as a waypoint on the otherwise level and broad field that is computational semiotics.

Besides a theoretical background I have tried to include links to practical applications, based on both personal interests and goals as well as to emphasize the experimental nature of computational semiotics. Unfortunately the model for automatic categorization of texts that was initially intended to form the main body of the thesis has been left short, but during the writing of the thesis

the need to first define the field I am working in became clear. Thus the 2. chapter of the thesis is at most a pointer and guidance in future work.

I see computational semiotics having an important role in the development of future solutions, but this presupposes the emergence of a common understanding, that today does not yet exist. Practical problems to solve are aplenty and scientists working in the field possess more or less similar viewpoints. Cooperation and building of a common framework has however been lacking. Such reproaches can be made also in those situations where such integrity is aimed for. Brier gives a thorough overview of the background of cybersemiotics, that overlaps with computational semiotics to a great extent, but fails to mention any important studies in computational semiotics today. The only scientific dialogue that I can refer to at the current moment has occurred between computational and biosemiotics (Gudwin, Emmeche). This dialogue is of course necessary and fruitful even in its current form, but is lacking on its own. I definitely look forward to the continuation of the COSIGN conference series. Although the topics of conferences were loosely defined, the event has the possibility of bringing together more important areas of study and discover their common theoretical background and main focus.

Although being content with the overview achieved, I have to mention that the current work is just the beginning in solving the question of my interest – that of categorizing texts. But as it was discovered during the writing of the thesis, in computational semiotics, knowledge is not the result, but a process.

## References

1. Andersen, P. B. 1990. A Theory of Computer Semiotics. Cambridge University Press.
2. Bouissac, P. 1998. Encyclopedia of Semiotics. Oxford University Press.
3. Brier, S. 2008. Cybersemiotics. University of Toronto Press.
4. Bush, V. 1945. As We May Think, *Atlantic Monthly*, juuli 1945. The Atlantic internet archive <http://www.theatlantic.com/doc/194507/bush> Visited 22.04.2008.
5. Cheeseman, P., Stutz, J. 1995. Bayesian Classification (AutoClass): Theory and Results. NASA. In internet <http://ic.arc.nasa.gov/ic/projects/bayes-group/images/kdd-95.ps> Visited 26.05.2008.
6. Cilibrasi, R., Vitány, P. M. B. 2007. The Google Similarity Distance. *IEEE Transactions on Knowledge and Data Engineering* vol 19, nr 3, 370–383. In internet <http://www.cwi.nl/~paulv/papers/amdug.pdf> Visited 25.05.2008.
7. Clarke, A. (ed.) 2004. Computational Semiotics: Past, Present and Future. Compilation of COSIGN 2004 papers. In internet [http://www.cosignconference.org/downloads/papers/proceedings\\_cosign\\_2004.pdf](http://www.cosignconference.org/downloads/papers/proceedings_cosign_2004.pdf) Visited 23.05.2008.
8. Coppock, B. 1995. "A Conversation on Information". Interview with Umberto Eco. In internet [http://carbon.cudenver.edu/~mryder/itc\\_data/eco/eco.html](http://carbon.cudenver.edu/~mryder/itc_data/eco/eco.html) Visited 21.04.2008.
9. Emmeche, C., Hoffmeyer, J. 1991. Code-duality and the semiotics of nature. *Approaches to Semiotics* 97. Mouton de Gruyter.
10. Emmeche, C. 2001. Does a robot have an Umwelt? *Semiotica* 134-1/4, 653 – 693. Mouton de Gruyter.
11. Gelman, A., Carlin, J. B., Stern, H. S., Rubin, D. B. 2004. Bayesian Data

Analysis. Chapman & Hall/CRC.

12. Gomes, A., Gudwin, R. R., El-Hani C. N., Queiroz, J. 2007. Towards the emergence of meaning processes in computers from Peircean semiotics. *Mind & Society*, vol 6, nr 1, 2007.
13. Graham, P. 2004. A Plan for Spam. O'Reilly.
14. Gudwin, R. R. 1997a. An Approach to Computational Semiotics. In internet <ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/isas97.ps> Visited 05.05.2008.
15. Gudwin, R. R. 1997b. Computational Semiotics. Part I: Foundations. In internet [ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/rep1\\_97.ps](ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/rep1_97.ps) Visited 17.05.2008.
16. Gudwin, R. R. 1997c. Computational Semiotics. Part II: theory and Application. In internet [ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/rep2\\_97.ps](ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/rep2_97.ps) visited 17.05.2008.
17. Gudwin, R. R. 1999. UMWELTS and Artificial Devices. In internet <ftp://ftp.dca.fee.unicamp.br/pub/docs/gudwin/publications/2sacs99.pdf> Visited 05.05.2008.
18. Gudwin, R. R. 2002. Semiotic Synthesis and Semiotic Networks. *S.E.E.D. Journal*, vol 2, nr 2, 55-83. In internet <http://www.dca.fee.unicamp.br/~gudwin/ftp/publications/SEEDJournal2002.pdf> Visited 23.05.2008
19. Lagerspetz, K. Y. H. 2001. Jakob von Uexkull and the origins of cybernetics. *Semiotica* 134-1/4, 643-651. Mouton de Gruyter.
20. Lotman, J. 1999. Kultuurisemiootika. Olion.
21. Lyman, P., Varian, H. R. 2000. How Much Information. In internet <http://www.sims.berkeley.edu/how-much-info> Visited 22.04.2008.
22. Lyman, P., Varian, H. R. 2003. How Much Information. In internet <http://www.sims.berkeley.edu/how-much-info-2003>. Visited 22.04.2008.
23. Maturana, H. R. Ontology of Observing 1998. *Conference Workbook for 'Texts in cybernetic Theory'*. In internet

- <http://www.inteco.cl/biology/ontology/> Visited 16.05.2008.
24. McLuhan, M., Powers, B. R. 1989. *The Global Village*. Oxford University Press.
  25. Nalimov, V., V. 1981. *In the Labyrinths of Language*. ISI Press.
  26. Odlyzko, A. 2008. Threats to the Internet: Too much or too little growth? In internet <http://www.dtc.umn.edu/~odlyzko/doc/too.little.growth.txt> Visited 22.04.2008.
  27. Rieger, B. B. 1980. Fuzzy Word Meaning Analysis and Representation in Linguistic Semantics. *Proceedings 8th International Conference on Computational Linguistics*, 1980. In internet [http://www.ldv.uni-trier.de/ldv\\_archiv/http/www/public\\_html/ldvpage/rieger/pub/aufsaeetze/tokyo80/tokyo80.pdf.gz](http://www.ldv.uni-trier.de/ldv_archiv/http/www/public_html/ldvpage/rieger/pub/aufsaeetze/tokyo80/tokyo80.pdf.gz) Visited 18.05.2008.
  28. Rieger, B. B. 1988. Definition of Terms, Word Meaning, and Knowledge Structure. *Proceedings International Congress on Terminology and Knowledge Engineering vol 2*, 1988. In internet [http://www.ldv.uni-trier.de/ldv\\_archiv/http/www/public\\_html/ldvpage/rieger/pub/aufsaeetze/dotwmaks/dotwmaks.pdf.gz](http://www.ldv.uni-trier.de/ldv_archiv/http/www/public_html/ldvpage/rieger/pub/aufsaeetze/dotwmaks/dotwmaks.pdf.gz) Visited 18.05.2008.
  29. Rieger, B. B. 1992. SHOE related project research in SATUS, SCIPS, and LLAMA . *Proceedings First SHOE Workshop*, 1992, 161 – 170. In internet [http://www.ldv.uni-trier.de/ldv\\_archiv/http/www/public\\_html/ldvpage/rieger/pub/aufsaeetze/shoerep/shoerep.pdf.gz](http://www.ldv.uni-trier.de/ldv_archiv/http/www/public_html/ldvpage/rieger/pub/aufsaeetze/shoerep/shoerep.pdf.gz) Visited 19.05.2008.
  30. Rieger, B. B. 1998. A Systems Theoretical View on Computational Semiotics. *Proceedings of the Joint IEEE Conference on the Science and Technology of Intelligent Systems*, 1998, 840-845. In internet [http://www.ldv.uni-trier.de/ldv\\_archiv/http/www/public\\_html/ldvpage/rieger/pub/aufsaeetze/isas98k/ISAS98K.pdf.gz](http://www.ldv.uni-trier.de/ldv_archiv/http/www/public_html/ldvpage/rieger/pub/aufsaeetze/isas98k/ISAS98K.pdf.gz) Visited 19.05.2008.
  31. Wiener, N. 1948. *Cybernetics: Or Control and Communication in the Animal and the Machine*. John Wiley & Sons.