Preface
The field of Artificial Intelligence has been in turmoil since its conception at the Dartmouth conference in 1956. It has never settled down into a state where it can claim that there is a paradigm that defines the field. From that moment on the field consisted of at least three major ideas. The first idea was the creation of models of the mind in order to get a better understanding of human thinking. This eventually led to systems based on many different types of logic and lately also some ‘subsymbolic’ processing that assists the reasoning engine. The second idea was the creation of intelligent machines, especially robots. Many scientist felt the need to understand the mind of the robot and used introspection for the creation of the artificial brains. This perspective was challenged in 1969 (Simon, 1969) based on the ideas of biosemiotics, which is the interpretation of signals in biological systems. Eventually the ideas from the beginning were thwarted in the mid-eighties by roboticists (Brooks, 1986) who built a robot without internal mechanisms that looked anything to what humans think they are using. It is mandatory for the creation of intelligent robots to get into the perspective of the machine and acknowledge its affordances or ‘action possibilities depending on the capabilities of the individual latent in the environment’ (Gibson, 1977) . Still, today, no human will give any machine the credit of possessing general intelligence. The third and mostly forgotten path to pursue was the idea of cybernetics, which was already being investigated when the Dartmouth conference was being held. Before the conference, in 1950, an article in the Scientific American showed two robots which consisted out of a few vacuum tubes, control loops and feedback mechanisms (Grey, 1950). These robots were created using the principles of cybernetics. The field of cybernetics could be defined as: 'The theoretical study of communication and control processes in biological, mechanical, and electronic systems, especially the comparison of these processes in biological and artificial systems.'

This turmoil in the field of Artificial Intelligence (AI) has become the status quo. Nowadays researchers often feel that they belong to one of the different paradigms of AI, which has split up into even more sub-areas than the three described above. The line of thinking to which the author belongs is a different one. The division in the field of Artificial Intelligence, the status quo, is not accepted and cannot be accepted. An integrated perspective is necessary. The field of neo-cybernetics tries to bridge the gaps in AI by adding the notion of emergence, i.e., process properties which allow for autonomous dynamic evolution as opposed to fully handcrafted and continuously engineered systems. It is unknown whether neo-cybernetics is sufficient to overcome

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1From: http://www.answers.com/topic/cybernetics
the problems of contemporary AI. What is it to study Artificial Intelligence if there is not even a common denominator within the field? Thomas Kuhn has an answer to this question:

It is, I think, particularly in periods of acknowledged crisis that scientists have turned to philosophical analysis as a device for unlocking the riddles of their field.

The structure of scientific revolutions, (Kuhn, 1962, p.88)

The creation of intelligent machines is a complex endeavor. There are several authors who speak about this creation, even in the same fashion that this thesis is talking about it (Johnston, 2008; de Landa, 1991). The entry chosen in this thesis toward the creation of intelligent machines is a post-structuralist approach based on the dynamical aspects of non-linear systems. This is a different approach toward Artificial Intelligence than is common. A potential problem with most post-structuralistic writings is that the (afore-mentioned) authors think that the creation of machine intelligence depends on dynamical systems, but these authors do not state how to proceed, how to actually create the intelligent machines they are talking about. This dissertation collects the materials from relevant authors and explains a general theory of self-organizing intelligence. It investigates whether the essential processes for the creation of machine intelligence are available to contemporary AI researchers, beyond the primitive intelligence present in machines at the moment. A new and general framework will be presented for a better understanding of the creation of intelligent machines. A number of important practical research problems in AI will be used to explore and illustrate essential aspects of this framework. Amongst the conclusions of the dissertation are formalizations of the new theory, called Generative Artificial Intelligence (Generative AI, GAI) . An important aspect is that Generative Artificial Intelligence is steered instead of created or controlled by human endeavor. The machine intelligence is provided with generative mechanisms to actively explore possibilities. The environment, including humans, selects the possibilities which function well or are desirable. The conclusion is positive in the sense that all the essential methods are currently available within the discipline of AI.

The major deficiency of current approaches to Artificial Intelligence derive from a method of working which does not allow the machine to scaffold its own internal structures. The systems which are created are engineered by humans. The systems are also
Closed. Open AI systems would allow the intelligent machine to adapt itself to new situations, to find new ways of solving the problems it faces while operating in the world. Currently for every new problem a human is needed to engineer a solution, which may contain a learning method or not. Even if it contains a learning method, the only thing the machine will learn is a solution to a specific problem. As far as the knowledge of the author goes, there are no open systems at all in contemporary AI. As has been shown by several scientists (Prigogine, 1984) and philosophers (Deleuze et al., 1987; de Landa, 1991), only open systems display interesting properties, such as self-organization and emergence, required for the scaffolding of the mind (Hendriks-Jansen, 1996; Varela et al., 1992).

... the old puzzle, the mind-body problem, really involves a hidden third party. It is the mind-body scaffolding problem. It is the problem of understanding how human thought and reason is born out of looping interactions between material brain, material bodies, and complex cultural and technological environments.

Natural Born Cyborgs, (Clark, 2003, p.11)

This 'scaffolding of the mind' is what this thesis is about. It involves the fundamental requirements for the development of intelligent machines. The scaffolding of the mind is automated in GAI, in contrast to the manual construction of contemporary machines which are optimized for a single or a few tasks. How to create this generative type of general machine intelligence is still a mystery. A new approach is needed. It seems to fall within the area of neo-cybernetics, because many of the concepts are closely related to cybernetics combined with the property of emergence. On the other hand, the term Generative Artificial Intelligence seems to more accurate. The generative aspect of GAI is very important. To keep in line with the proposed theory in this thesis, both terms are coined here, and history can work as a sorting machine on these concepts.

Generative Artificial Intelligence could be defined as the field of science which studies the (fully) automated construction of intelligence. This is in contrast to contemporary AI, which studies the understanding and construction of intelligence by humans. The 'by humans' part of the definition of AI is usually a hidden variable in the construction of contemporary AI systems, but the manual construction is what researchers do. The difference might seem subtle, even unnecessary, but the automated construction requires a radical new perspective not available in the present day AI literature. In
Generative Artificial Intelligence it does not matter whether humans understand how the internal mechanisms of a machine operate, although it might assist the researchers in their quest for the creation of intelligent machines. What does matter is that the process of the creation of internal structures by the machine can be controlled and steered into desired directions. It is similar to raising children: Humans do not know what processes go on in the mind, but they do interact with their children on a different level than talking about their neural substrate. Instead they use all sorts of sorting machines to sort out the good from the not-so-good behaviors that might assist the child in its adult life. These sorting machines range from corporal punishment to educational institutes to mass media and beyond.

In contemporary AI two aspects often do not get the attention they require. The first aspect is that the network of the (AI) modules are fixed. There is usually no openness such that modules can inspect and learn from the internal mechanisms and data structures of other modules. The interfaces are defined by humans and usually fixed in the types of data that can be transfered. If (learning) modules would be able to create their own interests into the internals of other modules and select the information they retrieve, then they could sort out for themselves what assists them in their own goals. Correlations that remain dormant due to the lack of preprogrammed interactions can be revealed in such a scaffolding system. The second aspect is that AI systems usually do not run for a long period of time while also being in a constant learning mode. Usually the system is trained beforehand, tested until the performance is good enough and then executed 'as is'. The combination of dynamical network structures between modules and longterm running systems in order to create intelligence is only seen in biological organisms, with the hominids as a prime example. Hominids have relatively little prestructured networks in the brain compared to non-hominids, although much of the large scale structures is defined by gene expressions in all parts of the brain. The details of the networks, the local interactions between modules and even where modules exactly reside are generated and structured during the experiences of the individual.

Recently (in 2009) a new journal called 'IEEE Transactions on Autonomous Mental Development' was constructed. The journal addresses the same problems that this dissertation also discusses. The transactions report on recent advances in intelligent systems and are probably the first attempt to formulate a comprehensive set of theories that underly both the natural and artificial intelligences. Many of the ideas in the transactions do not fall within the category what in this dissertation often is described
as contemporary AI and certainly not within the category of Classical AI. Although the author of this dissertation thinks that these transactions are advancing the state of the art in Artificial Intelligence, a unifying framework for the creation of this kind of AI is still lacking. This dissertation tries to find the underlying principles of self-organizing intelligence. Both historical and recent discoveries are treated in the light of a unifying framework and can be regarded as a possible starting point, an entry, into the automated construction of minds. The aim of this dissertation is to contribute to the work of this new brand of AI scientists, who combine the natural and the artificial in order to create a new kind of artificial intelligence.

The next chapter constructs the general framework for the creation of Generative Artificial Intelligence, based on post-structuralist philosophy. This thesis is intended as an investigation into the implementation possibilities of Generative Artificial Intelligence. The research described is a platform to test the abstract ideas formed by a post-structuralistic vision on Artificial Intelligence. In order to stress the difference between the abstract goals of this thesis and the concrete research, the abstract themes have been made salient by means of the text layout, i.e., using a different background color of the text as exemplified by the next chapter. By using this marking, the actual implementations of (parts of) the abstract machine can be localized. This saliency provides the reader a pair of glasses with the generative AI perspective on contemporary AI research.

This thesis is meant as an investigation into contemporary Artificial Intelligence focusing on the question whether science possesses the technologies required for the construction of subjective artificial minds. The investigation into these, perhaps mundane, technological problems is taken as the battlefield where the theory of Generative Artificial Intelligence is being tested. This thesis is also an exercise into thinking beyond the human condition. It is the aim of the hominid author that the philosophical and AI toolboxes created here are another step forward in the progression of machine intelligence.

The hominid author would like to thank some other biological and artificial machines. First he would like to stress that this work is neither some kind of faulty operation of his wetware nor something that is without history. He started to study Artificial Intelligence because he is convinced that the only way to understand what intelligence is about is to create intelligent machines. He worked with many almost intelligent machines and would like to thank some: Dexter (a Pioneer II robot), the Philips soccer
robots, the VolksBots created by Thomas Wisspeintner at Fraunhofer, many Aibos, his Toyota Prius and the high performance cluster of the University of Groningen. These machines gave him precious insights into the impossibilities of present day technologies.

Of the biological machines, there are too many to thank. On a professional level he has had several mentors, although they might not always be aware of this. In alphabetical order they are: Minoru Asada for giving him theoretical advise and the opportunity to start the @HOME league within the RoboCup Federation, Frans Groen for his assistance and stimulation to pursue a career in robotics, Daniele Nardi for stimulating @HOME and for assisting with the setting up, Paul Ploeger for his focus on the creation of intelligent machines (instead of only talking about robots), Lambert Schomaker for supervising his PhD. project and for his pursuit to find new perspectives on AI, Manuela Veloso for stimulating and confirming that something new has to be done, Marco Wiering for his deep insights in all sorts of machine learning technologies and Thomas Wisspeintner without whom there would not be an @HOME league. He expresses thanks for all the interesting discussions and aid he got. Especially with Lambert, Marco and Thomas he had very long and intense discussions that shaped his programming.

On a personal level, there are even more to thank and here the wetware of the hominid writer starts to get into incomprehensible, but still functioning, states. The most important seems to be his wife Sanne though, for all the support and care, and his mother for teaching him to keep going on, no matter what. Besides these female hominids there are too many others to mention, such as his family and friends, team members from different robot (brain) development teams, colleagues at Fraunhofer and the University of Groningen, and the cult group called the “Dark Ages”, where no idea is too strange and no music too weird to listen to at least once. He is very likely, due to the nature of the neural substrate, to forget most of the people he would like to thank and therefore mentions no-one in particular. Please don’t blame him for this, blame evolution for finding a less-than-optimal solution for his mental machinery. The only ones he would like to mention specifically are a few relatively new biological instantiations of intelligent machines: Allysa, Christian, Marius, Mila, Oscar and Stefan: May you fulfill your primary programming!