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Information and Meaning in Life, Humans and Robots.

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Abstract: Information and meaning exist around us and within ourselves, and the same information can correspond to different meanings. This is true for humans and animals, and is becoming true for robots.
We propose here an overview of this subject by using a systemic tool related to meaning generation that has already been published (C. Menant, Entropy 2003).
The Meaning Generator System (MGS) is a system submitted to a constraint that generates a meaningful information when it receives an incident information that has a relation with the constraint. The content of the meaningful information is explicited, and its function is to trigger an action that will be used to satisfy the constraint of the system.
The MGS has been introduced in the case of basic life submitted to a "stay alive" constraint. We propose here to see how the usage of the MGS can be extended to more complex living systems, to humans and to robots by introducing new types of constraints, and integrating the MGS into higher level systems.
The application of the MGS to humans is partly based on a scenario relative to the evolution of body self-awareness toward self-consciousness that has already been presented (C. Menant, Biosemiotics 2003, and TSC 2004).
The application of the MGS to robots is based on the definition of the MGS applied to robots functionality, taking into account the origins of the constraints.
We conclude with a summary of this overview and with themes that can be linked to this systemic approach on meaning generation.

Keywords: Information, meaning, systemic, constraint, life, anxiety, self-awareness, human, robot, grounding, Chinese room.

I) Introduction

It is quite obvious that information and meaning are present all around us and within ourselves. And it is clear also that these notions are complex as they can apply to very different items like words, sentences, signs, thoughts or feelings. In everyday reality we are faced with a huge variety of meaningful information. And we speak more easily about 'information' than about 'meaning'. Because meaning is more complex than information, and probably more subjective an item. Scientific developments have been implemented for 'information'. Very little has been done for 'meaning'.

What about animals ? For some pets and for highly developed animals like great apes, we tend to consider that they deal also with information and meaning like we do. But for basic simple life like paramecia, we tend to hesitate attributing the performance of dealing with information and meaning.

And Robots ? Are they involved with management of information and meaning ? This is a different question. Robots are not alive. Can we consider that artefacts are concerned about the notion of meaning ? Many philosophical debates have taken place on this question, and are still active. For sure robots (including artificial intelligence and artificial life) deal with information. A computer is an information processing machine. But what can be said about meaningful information within robots ? There is currently no clear answer on this point. We have to deal with hypothesis.

Not much is existing today as concept of 'meaning' that can be used for humans, or for animals or for robots. And even less is available to cover all cases together.

The purpose of this paper is to provide an overview on these subjects by using a systemic modelization of meaningful information generation. Systemic tool has the advantage to avoid hypothesis on covered domain, and so offer some generality in terms of applications. We use here the notion of 'Meaning Generator System' (MGS) that has been already presented [1]. A MGS is a system submitted to a constraint that generates a meaningful information when it receives an incident information that has a relation with the constraint. The content of the meaningful information is explicited and has the role to trigger an action that will be used to satisfy the constraint of the system.

The MGS has been introduced for the case of simple basic life submitted to a 'stay alive' constraint. We propose here to see how its usage can be extended to more complex living systems, to humans and to robots by considering new types of constraints and by integrating it into higher level systems. This approach is evolutionist (bottom up, from simple organisms up to humans). The case of robots will be looked at as a construction of humans.

We begin (II) by reminding the basics elements of the systemic approach using the MGS with its application to living organisms where the constraints are 'stay alive' and 'group life'. We show how these generic constraints can be declined into sub-constraints, and that MGS applied to group life introduces the notion of network of meaning. We then look at the case of great apes (considered as close to prehuman primates) where recent neurological research on mirror neurons indicate the possibility of intersubjectivity (III). To identify constraints specific to this prehuman level of evolution, we use an evolutionist scenario already presented [2] where the performances of intersubjectivity and body self-awareness are shown to naturally induce anxiety. The limitation of anxiety then becomes a new constraint at this prehuman level of evolution. The evolutionist scenario contains a positive feedback loop on body self-awareness development where anxiety limitation feeds the loop via the development of empathy, imitation and language. We extend the evolutionist scenario to humans by considering self-consciousness as a possible outcome of this positive feedback

loop (IV). Meaning generation in humans is introduced with the complexity of human nature related to the unanswered question on the nature of consciousness. We show that the usage of MGS at these different levels of evolution is dependant upon a clear enough understanding of the corresponding constraints. We highlight the fact that a lot remains to be done on this subject as the concept of constraint has not so far been much developed besides specific applications.
Usage of the MGS for robots (including artificial intelligence) is introduced by recalling some philosophical analysis on the possibility of meaningful information in a material system (Searle, Harnad) (V). Application of the MGS to the symbol grounding problem allows to introduce two types of groundings: 'grounding in' and 'grounding out'. This separation brings us to reword the problem of grounding as a problem on the constraint of the MGS and to consider the possibility of an evolutionary approach on a continuity of meaning generation thru evolution, similar to the continuity of species.
We finish this paper by summarizing the main points that have been addressed with some related themes (VI).

II) Information and Meaning Generation. Meaning Generation for Life.

II-1) Information and Meaning. The Meaning Generator System (MGS).

(This paragraph summarizes the presentation made in 2003 Entropy publication [1]. A few additional points are introduced).
Information and meaning are important part of the world surrounding us, as well as part of ourselves. Relations exist between information and meaning, but these relations are not always clear. Depending if we are on the beach or under shelter, noise from thunderstorm will generate different meanings for us. Bees of hive colony will extract meaningful information on food location from a bee dance because this food has meaning relatively to the survival of the hive. It is generally agreed upon that information processing machine do not take into account the meaning attached to the information they process. Because the meaning related to the information comes from the user of the machine or from the designer. And it cannot be transferred to the machine.
These few examples show that questions relative to the nature and the content of meaning attached to information can come up in many circumstances of our everyday life. Be they relative to ourselves or to our environment.
The notion of information has been theorized by Shannon in the middle of the xxth century. Important work has been done by philosophers and scientists on questions relative to the meaning of signs, sentences, words, or emotions (semiotics, linguistics and analytic philosophy, psychology and psychoanalysis). These studies are devoted to rather well defined types of information or systems managing information and meaning. We propose here to use a systemic approach for the relations that can exist between information and meaning by defining a system managing the information and the associated meaning. Such approach allows a bottom up analysis of meaning generation, beginning with simple living organisms and climbing up the ladder of increasing complexity of evolution. This evolutionist approach of meaning generation avoids to take as a staring point the case of human that is not scientifically understood (problem of the nature of consciousness). Starting our analysis of meaning generation with basic life offers a more secure scientific base.
We build up a Meaning Generator System (MGS) defined as a information processing system that is submitted to a constraint and that can receive an incident information. The MGS

generates a meaningful information (a meaning) when the received information has a connection with the constraint. The content of the meaning is the connection existing between the constraint and the received information. The purpose of the meaning is to participate to the implementation of an action aimed at satisfying the constraint of the system. The MGS applies to simple cases of elementary life, like a paramecium having to react to water becoming acid:
- System submitted to the 'stay alive' constraint: a paramecium.
- Incident information: acid in water.
- Connection identified by the system between the constraint 'stay alive' and the presence of acid: acid not compatible with staying alive.
- Meaningful information: acid not compatible with staying alive.
- Determination of an action satisfying the constraint of the system: move away from acid area.

Fig 1 summarizes the functional content of the MGS: constraint, reception of incident information, identification of the connection between received information and constraint (with application to the case of paramecium).

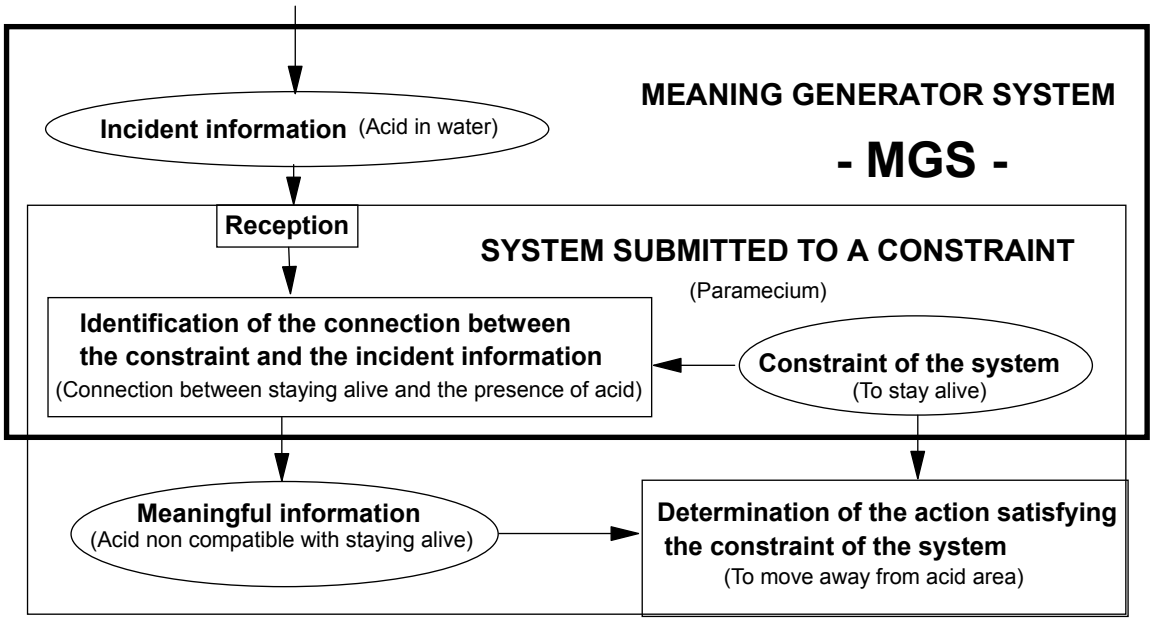

Fig. 1: Meaning Generator System

The above systemic definition of 'meaning' calls for the following precision and complements:
- A meaning does not exist per se, it is the result of a meaning generation by a MGS. Only information related to a MGS outcome is meaningful. An information can be meaningful or meaningless. A meaningful information (a meaning) is an information, it can be transferred memorized, modified, combined with other information.

- The content of the meaningful information is the connection existing between the received information and the constraint of the system. If there is no connection between the received information and the constraint, there is no creation of meaningful information.
- The generation of meaningful information by a MGS establishes a relation between the system submitted to a constraint and the world.
- A given system can present several connections between its constraint and a received information. The system will then generate several meanings as answers to the incident information.
- A meaningful information is meaningful relatively to the constraint of the system that has generated it. Calling S the constraint of the system, we will write ‘meaningful (S) information’ or ‘meaning (S)’ the meaning relative to the constraint S.
- The constraint can be defined as the ensemble of automatisms, rules, laws and finalities that the system must respect to satisfy its nature. The content of the constraint can become dynamic due to interactions with the environment via other functions in higher level systems. The notion of constraint is today used in various areas like programming, linguistics, mechanics or organization theories. But there is no formal philosophical conceptualization of the notion of constraint. This lack impedes its usage in systemic approaches like the one presented here.
- An information is always carried by a signal. An information can be memorized or transmitted. A text in a closed book is memorized information (the printed characters). The text we are reading from a book is transmitted information (the photons reaching our eyes). In both cases, information is carried by a signal. We call ’signal’ any variation of energy (ex: sound vibration like noise or voice; electromagnetic field change like light; chemical diffusion like odour; presence of an element like ink, protein,..). By associating an information to a signal, we define ’information’ as the content of the energy variations of the signal (ex: Amplitude and modulation of a vibration; variation of chemical concentration at a given point; ink density; molecules in the protein,...).
- A given signal can carry several different information, and a signal always carries an information. The elementary information being the signal itself.
- A signal is not a priori permanent. The variation of energy that has produced the signal can have a limited duration in time (thunder produced during a thunderstorm has a limited duration). But the signal will propagate, and so will continue to exist, even if the energy variation that has produced it does not exist any more (Three km away, the noise of thunder can be heard 10 seconds after its creation, which is terminated).
- A meaningful information that has been produced by a system will continue to exist even if the system that has originated it does not exist any more (or is not any more a MGS). More specifically, a meaningful information as we have defined it will still be meaningful in the absence of the constraint of the system that has produced it. The meaningful information exists with the signal that carries it, and this even if the system that has created the meaningful information disappears. A meaning (S) stays meaningful in the absence of S.
- The action aimed at satisfying the constraint of the system can take place outside the system, and eventually implicate other systems that can be other MGSs. These cases corresponds to the transmission of a meaningful information to other systems: the formal action that will satisfy the constraint of the system will come after the transmission of the meaningful information and its reception by other systems that can also be submitted to specific constraints. In order to take these cases into account, we introduce the notions of efficiency of a meaning that will characterize the possibility for a transmitted meaningful

information to participate to the determination of an action.
- In most cases, a MGS does not exist alone per se. It is a building block for meaningful information generation as part of a higher level system that uses it to manage information. Higher level systems contain other functions that can exchange information with the functions of the MGS, or can combine meaningful information with other information.
- The MGS generates a meaningful information by using information received from the environment. If the received information is also meaningful, the MGS links together several meaningful information.

II-2) Meaning Generation for Life. Group Life Constraints. Network of Meanings.

We want here to extend the usage of the MGS to more complex types of living elements, but still staying in the world of animal less developed than prehuman primate that display specificities that will be taken into account later.
The MGS defined here above is usable as it is for very simple organisms. More complex cases bring in several constraints that contain sub-constraints, as well as the ability to receive different information from the environment. This implies the presence of different MGSs combined in a higher level system.
The basic constraint 'stay alive' that has been introduced in the above MGS presentation can be considered as a generic constraint that contains several levels of sub-constraints. 'Stay alive' applies to the living element and to the species. The organism has to manage its own survival and reproduce itself. These are different types of constraints that generate different meanings and participate to different actions implementation.
The constraint relative to the survival of the organism has also some sub-constraints: the survival of the organism implies to find food and to avoid dangers. These two sub-constraints can be conflicting: food can be present, but close to a predator. Some conflict management functions need to be considered in a higher level system in order to define priorities among conflicting meaningful information. We can use generic constraints do define MGSs, but such implementation can be too general and contain sub-constraints that will generate conflicting meanings. As life gets more complex thru evolution, new information is received from the environment thru different senses. These new information will generate new meanings that need integration and conflict management by functions of the higher level system where other functions exist and can interact with MGSs. The functional nature of the MGS is not modified by the interactions with outside functions. However, information links with functions of the MGS can modify the content of these functions. For instance, the content of the constraint function can be modified by the results of previous experiences. The constraint function becomes dynamic as participating to the evolution of the interactions of the higher level system with its environment.
Fig 2 illustrates an example of interactions between a MGS and a higher level system memory function.

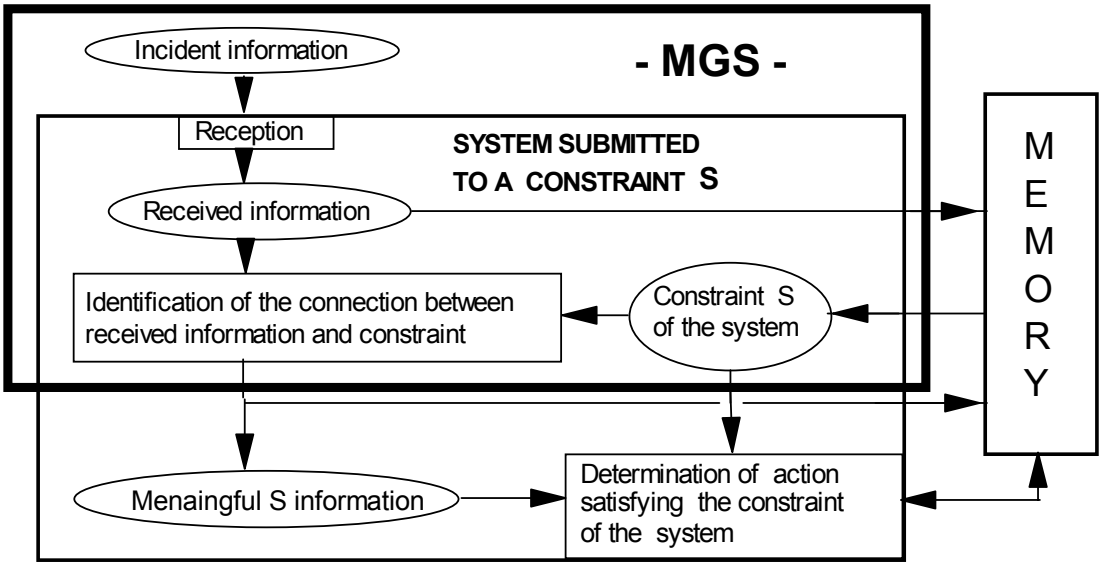

Fig 2: Meaning Generator System and Memory

We have been so far implicitly considering a MGS as receiving information from the environment of the organism. But most organisms have also to deal with internal exchanges of information. All the homeostatic system internal to living organisms is managed thru nervous and hormonal information exchange that trigger internal or external actions. Many MGSs exist inside organisms.

We will not take into account these internal MGSs unless specificly needed. The progresses in evolution we are interested with are more about exchanges of information between organisms than management of information inside the organisms. The items related to meaning generation that will be considered later (language, networks of meanings, imitation, intersubjectivity, ...) are more about social life and information exchanges between organisms than about information processing inside the organisms.

Another element introduced by evolution is group life. Organisms group up and live together as they can find advantages to it. But group life needs a minimum of rules in order to be an evolutionary advantage (hierarchy to comply with, cooperation, group hunting rules, food sharing, responsibilities, subordination, ..). These rules are part of new constraints to comply with that we put under the generic 'group life' constraints. These new constraints come in addition to the existing 'stay alive' generic constraint and will correspondingly participate to new meanings generations. Detailing the sub-constraints that belong to the group life generic constraint is beyond the scope of this paper (we remind that there is no real philosophical development available for the concept of constraint).

An important point to consider relatively to group life is the exchanges of information among organisms. Organisms living in groups tend naturally to exchange information for their own survival and for the survival of the group. The information exchanged will be mostly meaningful, as related to constraints to be satisfied. Usage of MGS to modelize such exchanges of meaningful information introduces the notion of network of meanings.

The meaningful information produced by a MGS is 'the connection existing between the received information and the constraint of the system'. This definition identifies two different types of sources for the meaningful information relatively to the MGS (Fig 1). An external source: the incident information whose origin is external to the MGS. An internal source: the functions which are internal to the MGS (reception, constraint, identification of connection). If the incident information is already meaningful (per se, or related to another meaningful information), then the MGS receiving it gets related to the MGS that produced the meaningful component of the incident information. And so on from system to system, with the possibility for a given meaningful information to be incident on several MGSs, and for combinations of information by functions from higher level systems. These natural interdependencies of meaningful information show that, for communicating systems, meanings are naturally interrelated in networks of meanings. The more communications, the more dense the networks. Consequently, when communicating systems interact, a meaning is to be considered as part of a network of interrelated meanings. In a world of communicating systems, meanings are part of networks of meanings. Societies of communicating systems (animals, humans, robots to come) are organized within such networks of meanings. Language as a high level mode of communication puts humans at the forefront of these networks of meanings.
Fig 3 illustrates this notion of network of meaning.

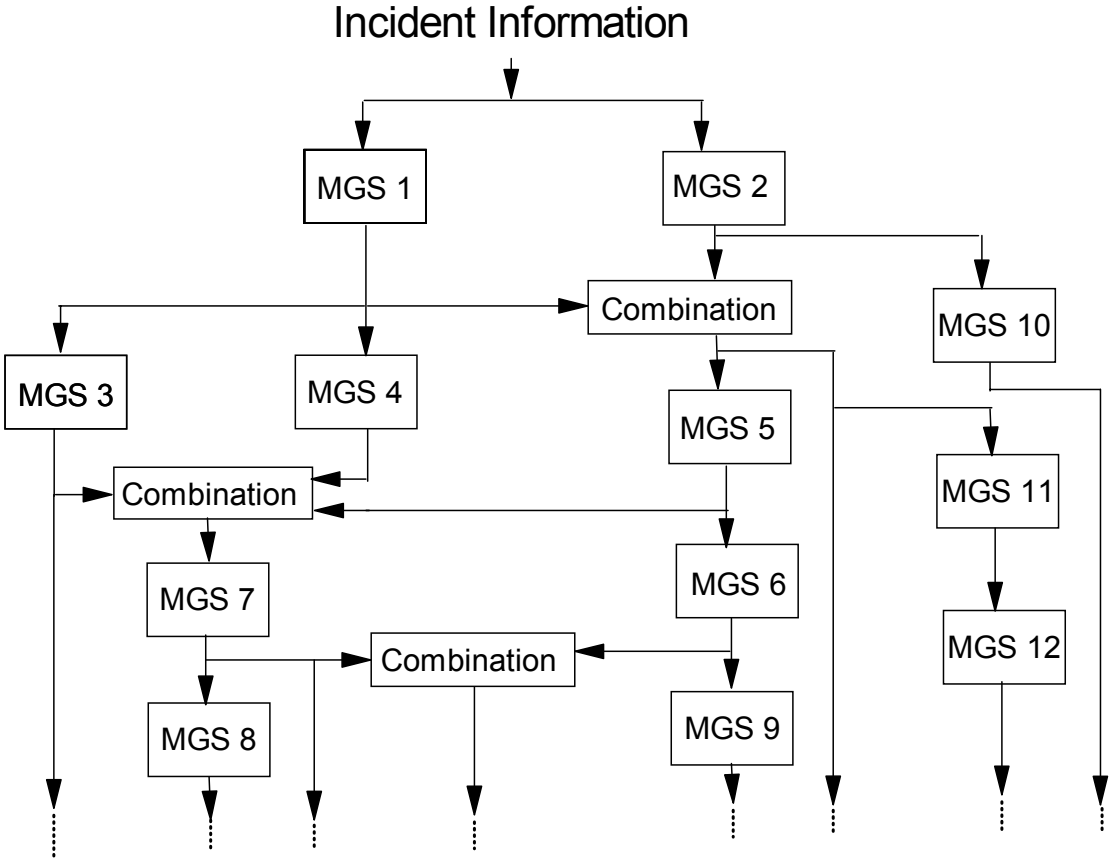

Fig. 3: Network of Meanings

Networks of meanings can also be used on an evolutionary standpoint. Understanding that species are linked thru evolution from simple living organisms up to human, we can apply such continuity to networks of meanings. A given MGS at a stage of evolution can be considered as related to MGSs of lower stages. A complex system generates meaningful information with its external source coming from simpler systems thru evolution.

III) Meaning Generation for Great Apes

III-1) Great Apes in Evolution

Evolution presents an important gap between animals and humans. This gap is characterized by the performance of consciousness that human only possesses and that science does not currently explain. Many philosophers and scientists work on this subject [3]. Current status is that no acceptable scientific explanation has been found to the phenomenon of consciousness. This evolutionist gap between animals and humans bring us to be cautious about taking such a step regarding the analysis of meaning generation thru evolution. We feel there is some need to introduce an intermediate step in order to progressively take into account the new mental performances that came up with human (subjectivity, language, feelings, imagination, mind reading, ...). These new performances are very different from animal performances and cannot be directly deduced from them.

In order to avoid forgetting or loosing important elements in this evolution of meaningful information generation, we propose to introduce an intermediate step between animals and human (keeping in mind that the problem coming from our lack of understanding of consciousness will still remain). The choice of this intermediate step can be made on a prehuman primate like our early australopithecus ancestor that lived on earth about 4 millions of years ago. This ancestor is gone and has left no remains that could help us to understand what were his mental performances. However, studies based on brain size and skull shape indicate that our early austalopithecus ancestors were probably not much different from modern apes in their behavior or appearance.

This brings us to consider modern great apes, that we can observe, as acceptable representations of this prehuman ancestor. We take the performances of today great apes as representing the ones of our prehuman ancestor. We identify the specific constraints that great apes are to satisfy, and correspondingly define the MGSs based on these constraints. This will give an overview on the new types of meaningful information generation that came up thru evolution at prehuman primate time frame.

Current studies on great apes indicate that they display close to human performances (mirror self recognition, empathy, ...). Recent neurological findings tend to link these performances to a specific brain characteristic that some great apes and humans possess: the presence of mirror neurons. Mirror neurons are “a class of premotor neurons that discharge not only when the monkey executes goal-related hand actions like grasping objects, but also when observing other individuals (monkeys or humans) executing similar actions “ [5].

One of these close to human performances that chimpanzee (and orangutan) display is mirror self recognition (MSR). Gordon G . Gallup conducted in 1970 an experimental test to see if monkeys can recognize themselves in a mirror. Chimpanzees were anesthetized and, while unconscious, a red mark (non odorous, non irritant) was applied to the brow. When faced to a mirror after recovering, the chimpanzees looked at the image in the mirror and guided their fingers to the marks on their face. Other monkeys do not display such self-directed behavior when facing a mirror.

The conclusion was that chimpanzee share with humans the capacity of self-recognition [4]. Discussions exist on the interpretation of these experiences, and some are about the relations between self-recognition, self-awareness and mental states attribution. The interpretation of MSR we will consider here is that the self-recognition displayed by the chimpanzee is a body self-awareness, the ability to have a self concept limited to the body.
There is another performance that chimpanzee seem to possess, it is intersubjectivity (the sharing of meanings and behaviors by actors in interaction). The performance of intersubjectivity seems related to mirror neurons. The discovery of mirror neurons about ten years ago ([6], [7]) has allowed the built up of new conceptual tools for the understanding of intersubjectivity within humans and prehuman primates [8], [9]. Studies in these fields are still in progress, with discussions on the level of applicability of this natural intersubjectivity to great apes where it is considered that "human beings "identify" with conspecifics more deeply than do other primates" [10]. We consider here that great apes do possess some level of intersubjectivity. Correspondingly, we assume that our prehuman ancestor did also possess some level of intersubjectiviy.
We will show that these performances of intersubjectivity and body-self awareness have naturally introduced in the prehuman primates a new type of constraint to satisfy, and has induced the generation of new types of meaningful information.

III-2) Meaning Generation for Great Apes

As we consider that the performances of great apes (chimpanzee type) are representative of prehuman ones, we now look at the consequences of body self-awareness (BSA) and intersubjectivity in terms of new constraints creation and corresponding new meaningful information generation.
Many great apes live in group. They perceive conspecifics living in their common environment. This common environment is the place where they satisfy their vital constraints, and more precisely where they manage their 'stay alive' constraint. Avoiding dangers is a key contributor to staying alive. The sources of dangers can be many: predators, natural dangers (fire, flood, gravity, ...), or any kind of threat.
When a subject sees a conspecific submitted to a danger, the performance of intersubjectivity will make the subject feel the danger as if it was on him. And this identification to suffering conspecific may happen every time the subject sees a conspecific exposed to a danger. In such a context, the performance of intersubjectivity will bring a subject to easily identify with suffering conspecifics.
Another element to take into account is body self-awareness. We have seen that chimpanzee type great apes have the performance of body self-awareness, the ability to have a self concept limited to the body. This body self-awareness will amplify the suffering resulting from identification to a conspecific facing a body integrity threat.
We consider that such multiple identifications to sufferings of conspecifics will create an anxiety within the subject, and that his body self awareness will amplify this anxiety. Anxiety, understood as multiple fears with insufficient cognitive identification, is a painful situation that can disturb and impede the basic activities related to vital constraint satisfaction. Consequently, anxiety has to be limited for vital constraints satisfaction. Anxiety limitation becomes a new generic constraint to satisfy.
Fig 3 summarizes the process that positions anxiety limitation as a new constraint related to the stage of prehuman primates in evolution.

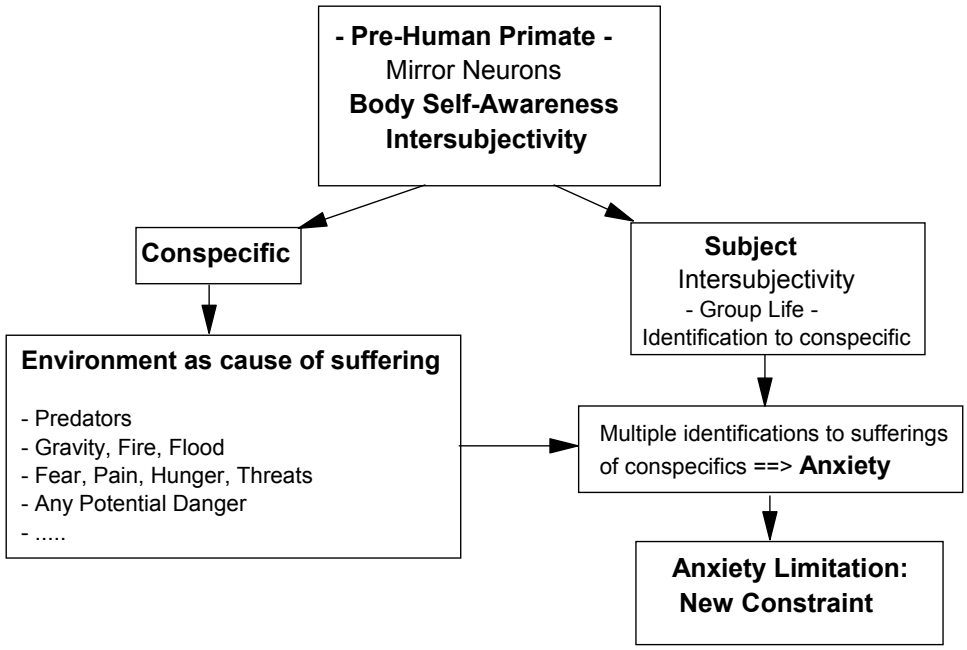

Fig. 4: Body Self-Awareness and Intersubjectivity as Causes of Anxiety

We have now to consider three types of generic constraints to be satisfied at the level of prehuman primates: Stay alive, group life, anxiety limitation.
Each of these generic constraints is to be split up in sub-constraints and be associated to corresponding MGSs.
This 'anxiety limitation' constraint is something new in evolution. We consider that it came up in evolution as a consequence of the performance of mirror neurons at the level of prehuman primates, which is close to the development level of our today great apes. But it is to be clearly stated that this mirror neuron performance does not, per se, call for any kind of self-consciousness performance. Anthropologists consider that Homo habilis (appeared on earth 2.5 millions of years ago) could represent the level of self-consciousness in evolution [11]. The level of prehuman primates we are interested in (early australopithecus) appeared on earth much earlier, at a time when there was no performance of self-consciousness.
This new 'anxiety limitation' is a generic constraint that can be used to build up a very general MGS. But this generic constraint has to be split up into sub-constraints in order to address the content of elementary MGSs. And this is a difficult task. Pre-human primates do not exist any more and have not left remains that can be used to identify possible sub-constraints to anxiety limitation. Great apes could be studied in terms of anxiety limitation, but not much literature is currently available on this subject.
In order to proceed ahead, we are going use an evolutionary scenario presented elsewhere [2] that uses anxiety limitation in great apes/prehuman primate as an evolutionary engine. This scenario identifies components to anxiety limitation that can be used as sub-constraints to the prehuman primate 'anxiety limitation' generic constraint.

This evolutionist scenario includes Fig 4 anxiety generation and addresses anxiety limitation possibilities. The scenario is articulated as follows:
1) Subject anxiety limitation begins with :
- Reduce suffering of conspecific.
- Reduce group vulnerability to environment.
2) These two types of action bring the development of:
- Empathy, imitation, communication (language).
3) These performances lead to the development of:
- group life, body self-awareness, emotions/feelings.
4) A positive feedback loop takes place on body self-awareness development, and so generates some anxiety increase that will have to be limited again. Anxiety limitation becomes the engine of an evolutionary positive feedback loop.
5) Development of body self-awareness, group life and emotions/feelings opens the way to the emergence of self-consciousness, then considered as a by product of body self-awareness development via the anxiety limitation engine (keeping in mind that we currently do not understand the nature of this by product).
Fig 5 describes this evolutionary scenario.

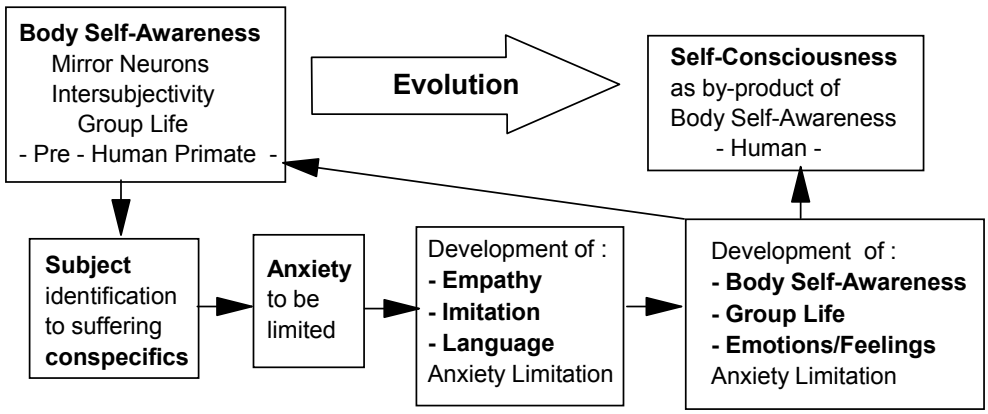

Fig. 5: Evolution from Body Self-Awareness to Self-Consciousness

This scenario makes available three sub-constraints of anxiety limitation for great apes/prehuman primates:
- Development of empathy.
- Development of communication/language.
- Development of imitation.
These sub-constraints have to be satisfied in order to allow limitation of anxiety. Each can become the constraint of a specific MGS related to meaningful information generation within great apes/prehuman primates.
These MGSs will generate meaningful information each time a prehuman primate receives an information from the environment that has a relation with one of these constraints. (perception of a conspecific facing a problem, displaying a warning, braking a nut, ...).
These constraints can in turn also be split up in sub-constraints, and so on. The identification

of bottom sub-constraint is beyond the scope of this paper. (we remind that there is no philosophical development available for the concept of constraint that can be used).

IV) Meaning Generation for Humans

IV-1) Linguistics and Meaning

When speaking about meaningful information as related to humans, we have to consider that an important part of the xxth century philosophy, the analytic tradition, has been preoccupied with questions related to linguistic meaning (the meaning of words and sentences). The analysis of linguistic meaning does not take evolution into account. The performance of human is taken as a given. Human language is a starting point, and what may have existed in terms of meaning of signs in less complex organisms is not considered. The concept of evolution with associated levels of increasing complexity is not taken into account, as it was considered that "biological theories of evolution had little or nothing to do with philosophy" [12]. The approach we propose here is different. We do not take humans as a starting point to analyze the notion of meaning. We choose to follow an evolutionist path that starts with simple living organisms, and follow the path of evolution up to humans.
If there can be some perspective to link the MGS bottom up approach with linguistics and analytic philosophy, we believe it will have to go thru an understanding of consciousness and a sufficient conceptualization of the notion of constraint.

IV-2) Evolution and Meaning Generation for Humans

Considering the case of human in an evolutionary approach assumes that we take into account all that has been considered for the lower stages of evolution. The case of humans takes as granted the constraints identified for animal life and for great apes/prehuman primates:
- Vital constraints (stay alive as an individual and as species)
- Group life constraints (cooperation, hierarchy, responsibilities, ...)
- Anxiety limitation constraints (development of empathy, communication/language, imitation, body self-awareness, group life, emotions/feelings).

In addition to these lower evolutionist level constraints, we want to identify some constraints that are specific to humans.
The problem we face at this step of evolution is that we do not know the nature of human. The nature of consciousness is still a mystery. So what can be done in order to identify new constraints that can be considered as specific to human? We feel two directions can be investigated: use the closed loop process of Fig 5, and dig in today available information on characteristics of human. But we need to keep in mind that other constraints, other MGSs, may have to be introduced later when the nature of consciousness will be understood.
The closed loop scenario where we propose to look at self-consciousness as a by-product of body self-awareness evolution via the anxiety limitation engine can be developed. We can consider that evolution from prehuman primates groups to human societies went thru several stages of social organizations that were developed to offer anxiety limitation tools, but also created new anxieties that had in turn to be limited/compensated. It is easy to consider that a more structured relational life can bring more security resulting from group synergy, but also generates new sources of anxiety as related to the perceived state of belonging to the group. Development of emotions/feelings does also bring new sources of anxiety and ask for new modes of anxiety limitation.
So the domain of anxiety limitation for humans is vast, as an amplification of anxiety

limitation processes that were already existing in previous steps of evolution. And we can probably consider that the process is still active, adding again that self-consciousness may also be a source of new anxiety and of new meanings generations.
These evolutionary stages may have been many and their analysis is beyond the purpose of this paper.
Some characteristics of human are known today. Digging in the books and trying to put together what could fit with 'constraints corresponding to human nature' would lead us to a rough list of items like:
- Principle of pleasure/reality
- Valorize ego
- Avoid frustration
- Life/death drives
- look for happiness
- All the consequences of the positive feedback loop on anxiety limitation.
- ...

These constraints have a wide horizon and are to be looked at as generic constraints. We can build up MGSs containing the above constraints if we accept that sub-constraints levels have also to be taken into account for finer tuning in meaning generation. Human language has some important contribution to meaning generations in terms of build up of network of meanings. These networks of meaning can be represented with the MGS structure (see II.2). But we have to keep in mind that the lack of conceptualization of the notion of constraint and our ignorance of the nature of consciousness significantly impede an exhaustive identification of the MGSs existing at human level.

V) Meaning Generation for Robots

V-1) Artificial Intelligence, Chinese Room, Symbol Grounding

The ability for robots to think and deal with meanings like humans has been a question to philosophers and scientists for decades. The question is still open and can be focused on Artificial Intelligence (AI) where supporters of strong AI consider that "computers given the right programs can be literally said to understand and have other cognitive states".
This position is challenged by opponents to strong AI. Several debates have taken place on subject and are still active. We first present some positions on this question and then look at how the MGS approach can be used.
John Searle's Chinese room argument challenges the strong AI position by a thought experiment showing that computers cannot understand symbols [13]. Suppose that you do not speak Chinese and that you are in a room where you are to apply correspondences between Chinese symbols, following a look-up table. By a window, you receive a Chinese symbol and you make it correspond to another Chinese symbol via the look-up table. You make this other symbol available at the window. With a well designed look-up table, an outside Chinese speaking observer could conclude that the Chinese room does understand Chinese. But in reality, you inside the room do not understand Chinese.
A computer processing symbols does not do more than you in the Chinese room. So, like you, computers cannot understand symbols because "no program by itself is sufficient for thinking". But this position does not exclude the possibility for intelligent machines, as only special machines can think: the "very special kind of machines, namely brains and machines with internal causal powers equivalent to those of the brain".
Stevan Harnad challenges Searle's position by the "symbol grounding problem" which

addresses the intrinsic aspect of a semantic interpretation: “How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads? How can the meanings of the meaningless symbol tokens, manipulated solely on the basis of their (arbitrary) shapes, be grounded in anything but other meaningless symbols?” [14]. A candidate solution is sketched by proposing that symbolic representations must be grounded bottom-up in non symbolic representations.

V-2) Meaning Generator System and Grounding In/Out.

We apply the MGS structure to the symbol grounding problem by considering that a grounded symbol is a meaningful information. The MGS structure can bring some detail and discrimination when applied to the grounding problem. As presented in II.2, the sources of the meaningful information are two types relatively to the MGS: an external source (the incident information), and an internal source (the functions internal to the MGS). These two types of sources can be considered as ‘groundings’ in the Harnad sense, and worded as ‘grounding in’ and ‘grounding out’ of the meaningful information. Grounding in: the meaningful information is grounded in the functions internal to the MGS (reception, constraint, identification of connection). Grounding out: the meaningful information is grounded in the incident information that comes from outside the MGS.
Fig 6 summarizes the groundings in/out.

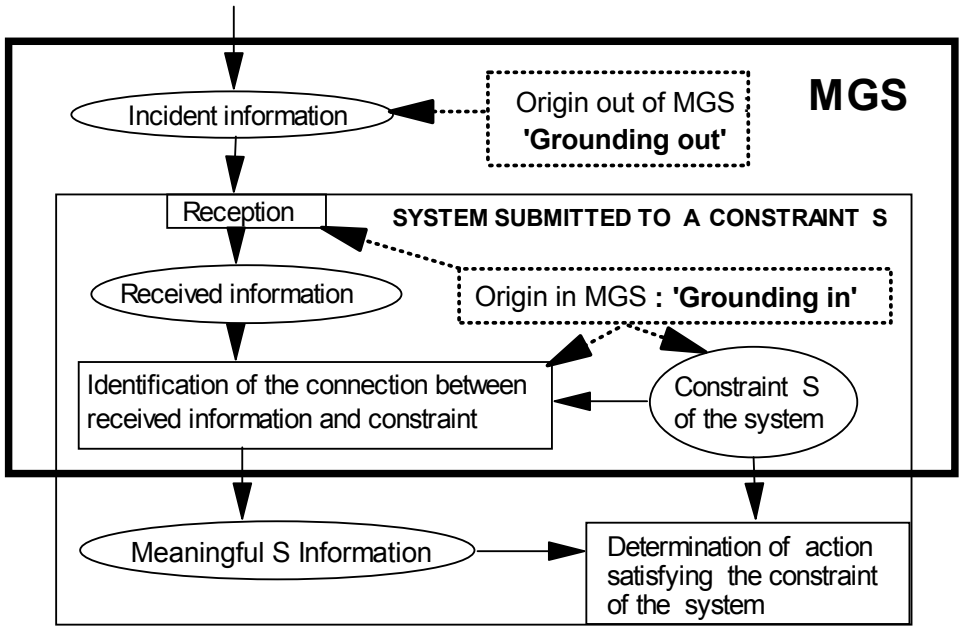

Fig. 6: 'Grounding in' and 'Grounding out' of Meaningful Information

When we go back to the introduction of the symbol grounding problem by Harnad, we find difficulties to identify what are/could be the constraints related to the groundings in/out of a symbol like a word or a sentence of our human language. To see clearly this point, we have to recall that the MGS approach is a bottom up, evolutionist, approach and that the

understanding of 'meaning generation' within humans needs that we know what are the constraints related to human. As already said, the lack of conceptualization of the notion of constraint, and our ignorance of the nature of consciousness significantly impede an exhaustive identification of the constraints related to human, and consequently make difficult a today usage of MGS for humans.
The above introduction of groundings in/out makes available another perspective on the grounding problem. We believe that using bottom-up evolutionary approach (and widening the symbol system definition) can make the symbol grounding problem easier to address by using the continuity of meaning generation thru evolution introduced in II.2. The continuity of species thru evolution can be duplicated into a corresponding continuity in MGSs thru evolution, complex meaning generations with complex constraints being grounded thru evolution in simpler meaning generations and simpler constraints. This could lead to a regressive grounding of meaningful information thru evolution supported by an evolutionary networks of MGSs.
Developments beyond the content of this paper are necessary to take advantage of such evolutionary perspective on symbol grounding.
If we now compare the usage of MGS for robots and for animals, we can compare the 'grounding in' and 'grounding out' in both cases. Taking robot and animal as being in the same position vs the environment, the 'grounding out' can be considered as identical. Regarding 'grounding in', we can detail the comparison by looking at the content and the origin of the constraints (reception and identification of connections can be regarded as mere data processing). The content of the constraint for the robot is what has been programmed by the human designer. The content of the constraint for the animal is "stay alive" coming from evolution. So with the above hypothesis, the ultimate difference in meaning generation between animals and robots is with the constraint of the MGS. This brings us again to the need for more conceptualization on the notion of constraint to correctly position robots vs living organisms.

VI) Summary and Related Themes

- An overview on meaning generation for life, human and robots is proposed by using a systemic modelization of meaningful information generation already presented [1].
The definition of the Meaning Generator System (MGS) is reminded with its characteristics. (it is based on a system submitted to a constraint that generates a meaningful information when it receives an information that has a relation with the constraint - Fig.1-).
- The notion of constraint is a key item in the proposed systemic approach. We show that the usage of MGS at different levels of evolution is dependant upon a clear enough understanding of the corresponding constraints. Several generic constraints are identified depending upon the level of evolution: life (stay alive, group life), human: (stay alive, group life, limit anxiety). The fact that the nature of human is unknown (the problem of consciousness) significantly impedes an exhaustive identification of the constraints and corresponding MGSs. Also, the current lack of philosophical conceptualization of the notion of constraint makes difficult a formal application of the MGS to various stages of evolution and to robots.
The split of generic constraints into corresponding sub-constraints is identified as necessary in order to avoid ambiguities in MGSs applications. Conflict management functions need to be considered in higher level systems in order to define priorities among conflicting

meaningful information.
Anxiety limitation being used as an evolutionary engine of the positive feedback loop toward self-consciousness, it may be interesting to consider its specific impact on consciousness emergence and on a phylogenesis of emotions/feelings. Another point to address is that the proposed evolutionist scenario assumes implicitly that the anxiety increase is always accepted by the organism. That may not always be true. Other cases that have produced other evolutionary outcomes are to be looked at [2].
- The structure of the MGS allows to introduce the notion of 'networks of meaning' for communicating systems, as well the notions of 'grounding in' and 'grounding out' when applied to the 'grounding problem'. The groundings in/out of meanings can also be used to introduce a continuity of meanings generations thru evolution. The grounding out of a MGS can be a meaningful information coming from another MGS. Duplication of the continuity of species thru evolution into a corresponding continuity of MGSs can lead to an evolutionary grounding of meanings thru an evolutionary networks of MGSs.
- When applying MGS to robots, we show that the difference in meaning generation between animals and robots is with the content of the constraint of the system. More conceptualization is needed on the notion of constraint in order to go beyond this status.

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