Bionic Model for Control Platforms

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The complexity of technical systems in automation is rapidly growing and is causing increasing costs. Research has to identify appropriate measures to deal with the increasing complexity; Artificial Intelligence (AI) and Cognitive Science (CS) already show noteworthy results. However, compared to human intelligence those results can only be valued as modest. In the following the authors will try to verify the necessity of developing new principles to model control systems and will try to show, which technical principles and tools are suitable for the defined requirements. However, the challenge will be to accept a new kind of thinking in the bionic world, which will be in accord with scientists of other specific scientific faculties such as neuropsychoanalysis. The goal must be a formal approach in specifying the psyche. [1]

1 Motivation

Describing and specifying industrial processes is becoming increasingly complex. It is necessary to develop principles that fulfill the new requirements in an efficient and economic way. Examples of such applications exist in all areas in which human beings monitor or control processes, such as in airport security scenarios, the parameterization of thousands of control nodes in a building, or a decision and control tool for mobile robot units in production halls or military fields. In addition, all those developed units must work independently – i.e. in an automated way – and should be robust against unknown states and situations.

A concrete application, in which many different processes are involved, is described in the following example [1]: a child is playing in a kitchen, no adults are present and water is boiling on the stove. Could it be possible to install in each private household's kitchen a small unit or even a household robot to recognize such a dangerous scenario and to alarm adults nearby if the necessity demands? However, such a unit will only be accepted if it can be mass-produced. Another scenario, mentioned above, is the possibility of recognizing dangerous situations at airports: inside and outside of the buildings, when people leave behind baggage or if people linger in forbidden areas. The challenge here is to figure out the unsafe and insecure scenarios [2].

Developers quickly reach the limits of feasibility if machines should analyze complex scenarios and should make decisions. Those limits of feasibility must be exceeded. Scientists have to look for new approaches because traditional methods in Artificial Intelligence (AI) and Cognitive Science (CS) have not provided the promised results.

2 Models in Communication Systems

In the beginning of process automation engineers did not have any knowledge of protocols and abstract layered models. Today, the 20mA interface (figure 1), which is very well established especially in the northern American market, is still an example of a clear hardware oriented definition, independent of the protocol (to handle the communication) and the data valuation. In the following, computer scientists and mathematicians developed the ISO/OSI model for the telecommunication area. In this model they defined seven abstract layers for various communication tasks. The lowest layer describes the hardware, the highest layer the interface function to the application. Very soon, this concept was accepted in automation, but engineers also realized that the seven layers were not sufficient for their applications. An additional layer was introduced for interoperability; later on further layers were added to efficiently interconnect various fieldbus systems [3, 4].

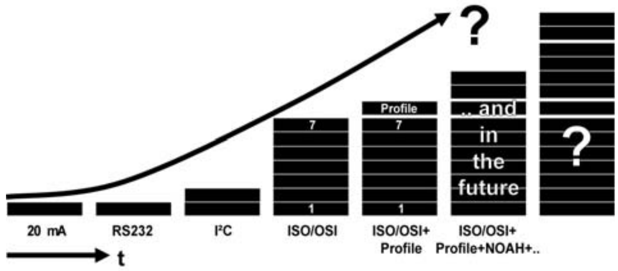

Figure 1: *The increasing number of the abstract layers for communication systems in automation*

[1] This paper is based on results of the European research project SENSE (FP6, project nr. 033279) and the Austrian research project PAIAS (funded by FWF, project nr. P20056-N13).

The addition of these layers is understandable because processes run in an increasingly automated way, which means that they have to exchange information more often. Already today, more than 200,000 computer nodes (Embedded Systems) can be integrated (and networked) in buildings to control the functionality of air conditioning, illumination, elevators, fire alarms and much more. Consequentially, it was necessary to add further layers to make the abstract layer model more transparent and suitable.

The same principle can be noticed in other fields like communication systems, for example in the area of electronic chip design. Here, the Y-diagram from Gajski-Walter is used in a similar way. In its lowest layer one finds differential equations about the physical behavior of silicon. A higher layer describes the transistor network; another layer the electronic circuits with all the synchronization behavior, etc.

In conclusion one can say: Without having such differently layered models complex information systems would never be manageable. The complexity demands abstraction and modularization, two essential methods in the field of computer technology to understand information processes. Why should that not be useful and perhaps even necessary for bionic developments like a technical implementation of principles of the mental apparatus?

3 Constraints

A new approach needs a break from specific previous notions. Therefore, it is important to evaluate the main reasons of why it is necessary to think about new methods and to develop a new bionic model that utilizes an "intelligent system," whatever it means and demanded in this article.

3.1 Hierarchical Model and Top-down Design

As mentioned above, computer engineers are accustomed to working with hierarchical and distributed models of processes. An engineer learns the definition of a computer in the very beginning of his educational program: It is a system (process) that computes (transfers, stores and manipulates) data. If, in this sense, the layered model of the neurologist Lurija [5] is mapped on a hierarchical model of a computer – without working out the details concerning how many sub layers exist in both models and which parts are structured in a clear, strict hierarchy, and which are more evenly distributed – one achieves the comparable modularized columns in figure 2. Of course, in this first step, the figure can only be a rough approach. It has to be differentiated later on.

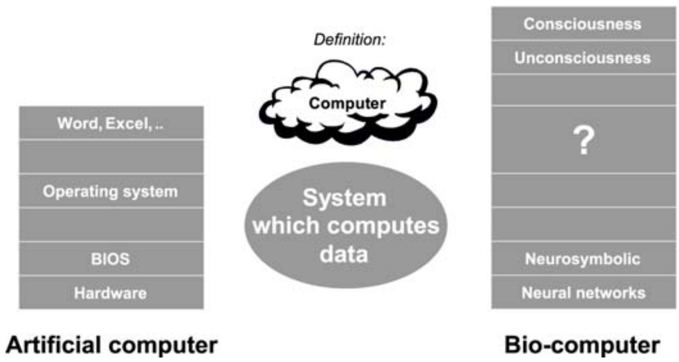

Figure 2: *Possible abstraction layers of computers (on the left hand side the artificial computer, on the right hand side the "bio-computer")*

What does this mean? If one accepts that the brain is an information processing system, which controls the "process" human being, and if one also accepts that software is nothing more than hardware - only another kind of descriptive language to be able to describe this part of hardware[2] - one must come to the conclusion that the neural networks are comparable to the electronic devices in an artificial computer. The hardware of the "bio-computer" is a different kind of technology than the artificial computer, and this first layer includes completely different functions than all other higher abstract layers of the right column shown in figure 2.

Considering the results of [6], in which the author differentiates between the symbolic AI (Artificial Intelligence), the statistical AI, the behavior based AI and the emotion based AI, the general bottom-up approach to develop an intelligent system in the area of AI is obvious. In the beginning of AI, about 60 years ago, researchers first tried to understand how the neurons and the neural networks worked. They then tried to understand the symbolization, and then behavior, which means that they saw the connection between intelligence and the body. Today researchers of Artificial Intelligence and Cognitive Science speak about emotions and feelings, which are seen in the highest abstract layers of an abstract layer model.

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[2] Software is stored in form of bits in the memory of the computer. It is a question of taste at what level of abstraction one starts calling the commands software instead of hardware.

If an engineer develops a computer, he is forced to go the other way round. In the very beginning things like technology or behavior is definitely unimportant, and even distracting. A computer designer needs a specification of the functions that must be fulfilled by the computer (the type of calculations and the types of input or output which needs to be processed, etc.). He needs a functional system. Then he will break it down into a model with different abstract layers, and finally he analyzes which kind of technologies (hardware and software) he will use for which part of all the different layers. In the test phase he is able to simulate the programmed system and to compare the behavior with the requirements of the specification.

In such a way, the computer designer differentiates between two phases. Firstly, it is necessary to develop the function model and then secondly, the phase for the top-down design of the computer. The first part cannot be developed by the computer designer (by an engineer). He is only able to offer support. The main work must be done by an expert who knows the process (application) and has the scientific skills (in the case here, the expert must be knowledgeable and skilled in the mental apparatus, the psyche).

Because this aspect is essential, it should be formulated in further words: The procedure to develop the hierarchical model is based on a method of describing the process "the nervous system of the human being". What are the lowest and the highest layers concerning human beings? If the lowest layer is the hardware (neurons, the neuronal network), then the highest layer must be related to feelings and conscious functions, which cannot be defined (described) by engineers (see section 3.7 and the following). However, that means that the design cannot be started in layer 1 depicted in figure 2, but the other way around, one has to start from the top of the column (how computer engineers are used to develop systems), the layer in which feelings and the functions of consciousness are placed.

In this case, a very important aspect will be obvious: On the one hand, the constraint for such an ongoing scientific approach is the monistic conviction, which means that the brain has nothing mystical. On the other hand we will be able to deduce constraints which in Artificial Intelligence or Cognitive Science were often ignored up to now, and which we will explain in the following.

3.2 Statistical Methods

In human beings a huge number of physiological and mental control loops of different kinds work in an interconnected manner and cross over all layers of the abstract layered model (fig. 3). If we assume that these control loops behave in different ways - some in a quiet, stable manner, while others in an unstable manner (these different kinds of behavior are influenced by many factors coming from outside and inside inputs, and they influence each other as well), it is obvious that this behavior can only be described and formalized if we develop a model of the whole process. A partly described behavior can cover only specific functions, which can be important in different states of the system. Figure 3 shows this phenomenon. What happens at the tip of the arrow? Whether this event X may or may not influence the outward behavior depends on the behavior of all control loops, which are directly or indirectly connected with the parameters of this event X. If the behavior of the whole process is measured by statistical methods, for example in the case of human beings, the experimenter may or may not be successful at identifying some changes in the behavior at the surface of the process. It depends on many parameters.

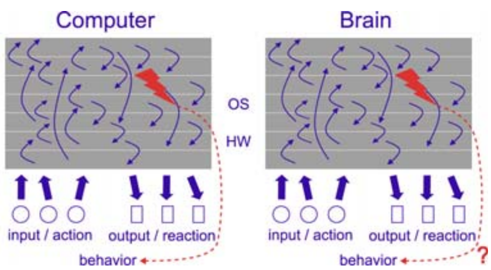

Figure 3: *Layer impact (OS: operation system; HW: hardware)*

This phenomenon can be made transparent by a very simple example. If a computer's text processing application, like MS Word, shows a strange behavior, statistical methods will seldom help to find the cause of the problem if we do not have an idea of the computer's model and the application's model. Questions arise like: Is it a problem with a specific sub-layer of Word itself or is the problem situated in a layer under the Word layers? Is it a problem in one of the layers of the operating system? Is it a problem with the hardware? The expert must have a clear understanding of the abstract layered system to find the cause.

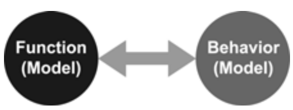

Figure 4: Differentiation between functional capabilities and resulting behavior

In this way, if psychologists analyze human beings with statistical methods, engineers are not able to work with these results because they do not have the knowledge and especially the skills to interpret these results. And if engineers, like people in Artificial Intelligence are accustomed to do so, [7, pp. 243; 8, pp. 201; 9, pp. 21] then the statistical results must always be scrutinized, and it is to take care if they only copy the behavior but do not develop the demanded model (structure) of the mental apparatus, the "intelligent control system" of the human being, which equips human beings with their unique abilities. We have to differentiate between the function model and its behavior (figure 4). For taking over principles following the bionic approach it is necessary to use the functional model and not to copy its behavior.

3.3 Intelligence

The technical terminus *intelligence* should be applied carefully. In early microprocessor development we could observe how many companies competed for designing the “best” (intelligent) microprocessor. The dispute came to an end only when the opponents reached the agreement that a general definition of a "microprocessor performance" is not possible. They defined benchmark tests for different applications with which they compared the performance of those units.

In the same sense "intelligence" is to be judged, a fact which is well known in psychology. It makes no sense to say "person A is more intelligent than person B". However, if one uses the models in figure 2 and figure 3, the definition of intelligence can be formulated for each layer independent of the other layers. In such a model each layer has a specific task for which an optimized algorithm can be figured out.

If one wants to take the technical terminus *intelligence* over into the bionic world, one has to differentiate the application areas. *Intelligence* can be defined for each of the different layers of the model or for the model as a whole, if we define a reference application (as explained above).

3.4 Choice of Model

Historical retrospect has shown us that the choice of a right model can greatly influence future results. In the early Middle Ages the earth was assumed to be in the middle of the universe (figure 5). The mathematical description of the movements (trajectories) of stars was only possible in very rough approximations by epicycles (Ptolemaic world view). The breakthrough came in 1473. Copernicus assumed that the sun must be the center of our universe, and suddenly the movements of the Mars were easily determined as elliptical.

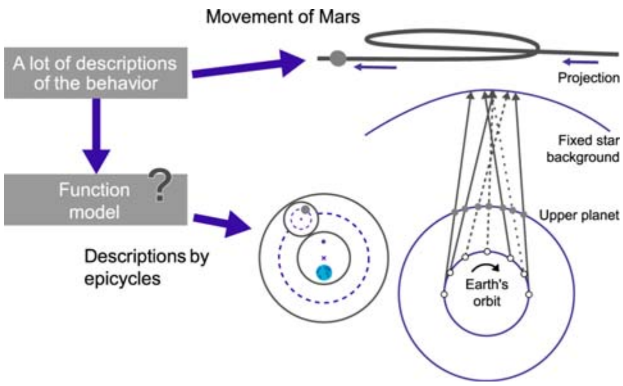

Figure 5: *The earth in the center of the universe*

If we apply this example to apparent observations of human being's behavior, a wrong model would lead to the wrong understanding of the process and thus to wrong conclusions. It is very important for synthesizing the bionic model to find the correct one, and the designer has to verify and modify it till it fits and he is satisfied with the results. This is important for bionic understanding if engineers figure out specific aspects or phenomena of a psychological publication. Before engineers apply those results, experts should evaluate them for interoperability.

3.5 A Unitary Model

While analyzing psychological cited publications in books like [7], a natural scientist must be aware that authors in Artificial Intelligence often use psychological studies from different schools without proving the interoperability of the models underlying the studies. This is dangerous because different schools have different premises and define different constraints, which leads to different opinions and models and in such a way often to contradictions. However, an engineer is not able to analyze such details and will be mislead.

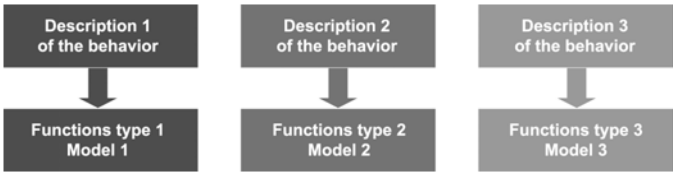

Figure 6: *Different schools lead to different models.*

In the scientific world of psychology the concept of different models doesn't seem to pose a real problem because the main goal is to succeed in helping people and not to formally prove one model or to point out theoretical contradictions in various models. Also, we have to realize that it is often difficult or even impossible to find a proof for a statement. Psychological scientists have had to learn to deal with this problem. However, if the goal is to develop a model of the mental apparatus and to apply the principles of the psyche to another domain, then we have to follow the engineer's way, which means to figure out all contradictions and to find a unitary model. Publications of different schools must be interoperable otherwise we would get a patchwork model. Such a patchwork may still create a device that appears useful and creates a market in which it sells well, but it will not support us in better understanding the mechanisms that lead to refining the model of the human psyche.

3.6 Differentiation Between Function, Behavior and Projection

In the above sections the authors have already tried to work out the difference between functions and behavior. If we look at robots like CB2 [A], we have to consider another technical terminus: projection. If we relate the expression *human* to the expression *mental apparatus*, a doll is not human-like; it only looks like a human being because human beings project human characteristics onto this object. It is the same with CB2 (as an example for robots in general). CB2 is a highly sophisticated machine, with very complex electronic systems, highly developed control loops etc.; however, this machine has nothing to do with a human being if we define this expression on the basis of the mental apparatus. CB2 does not show feelings, but we project feelings onto this machine.

3.7 Interdisciplinarity

It is remarkable that psychoanalysts or even neuro-psychoanalysts are not (normally) cited in scientific publications of Artificial Intelligence, Cognitive Science, or robotics. Furthermore, it is remarkable that proposals were made early on to bring together these completely different scientific fields [10]; yet the first scientific project was only published in 2000 [11]. However, the rule exists which states that results from all scientific fields must be considered in a scientific paper as state-of-the-art. Is there anything wrong with engineers not considering scientific papers of psychoanalysts?

If Artificial Intelligence and Cognitive Science use terms like emotions and feelings, it is critical to consider psychoanalysis and neuro-psychoanalysis as well. Psychoanalysis was founded before the First World War and from this time on taught in most countries world-wide. In Vienna the Sigmund Freud University was even founded several years ago. Neuropsychoanalysis must work and be accepted as a natural science. This leads to the next chapter.

4 Why Neuropsychoanalysis?

In [12] the reason was explained why only psychoanalysis is able to offer a model that can be sufficient for computer designers if the constraints, argued in the last chapter, are considered. However, psychoanalysis on one hand focuses its interest only on conscious and unconscious mental contents, which means, in regards to figure 2, psychoanalysis deals with the upper layers and has a good knowledge of that. Neurology on the other hand deals with the lower layers (figure 7). For the layers in-between, for example the neuro-symbolic layer, proposals exist as in [13; 14] which are very rare because the knowledge about this area is very limited. This is exactly the topic that for example the authors of [15] and [16] are talking about. The international organization NPSA [B] has been founded for exactly the following reason: the gap between the higher layers of Lurija's model and the lower neurology layers must be closed. Therefore, at NPSA conferences, scientists from different faculties discuss possible solutions on the basis of experiments and evidence.

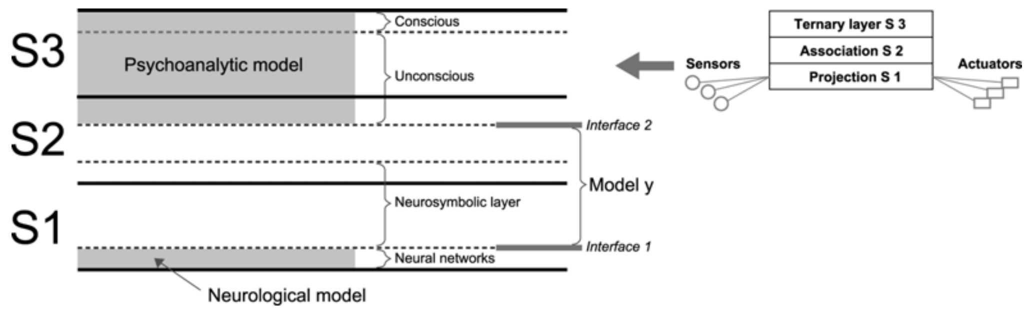

Figure 7: *Hierarchical model defined by Lurija [5] (right), differentiated between areas where more (grey) or less (white) knowledge exists*

Computer designers have another approach. In such a case, they define clear interfaces as presented in figure 7. Interface 1 can be defined by neurologists, and interface 2 can be defined by psychoanalysts. On the basis of the demands of interface 2 it is possible to define the functions which are necessary to get all information coming from the bottom. On the basis of interface 1 it is possible to define the kind of data that is able to be transferred to the upper layers (and the other way round). In this way it is possible to develop the whole layered model. However, the authors know very well how huge and difficult the designer's task will be. As it is already explained in [14] the amount of different functions, which are difficult to solve and that have to be defined is immense, and the number of existing feedbacks is incredible, all of which poses a real challenge for the computer designer. Yet in the end he acquires three models: the psychoanalytical model, the model for the lower part, and a model for the part inbetween, the latter being mostly undefined up until today.

One additional remark is necessary: As mentioned in the beginning of chapter 3, it must be emphasized that all three main layers in figure 7 show *functions*. The technology behind these functions can be chosen later on. For this reason it makes sense to develop the lower lever on the basis of modern computer technology and not on the basis of neural networks.

5 The Psychoanalytical Model

Concerning [5], the model has to be developed as a hierarchical system as the attempt in [13] shows. On the other side, on the basis of the explanations of [15, 16], the psychoanalytical part can only be a completely distributed system, which means that this part has to be seen as one and the highest layer of the hierarchical layered model in figure 2. This one functional layer was worked out by psychoanalysts, supported by engineers and will be presented in [18] in the form of a psychoanalytical explanation. The technical explanation is presented in the following.

On the basis of control principles there are inputs in figure 8 (E1, E10, E12), coming from the left, which initiate a drive and therefore the desire to wish-fulfillment, further a plan of actions, emotional and feeling-based decisions, and finally the action, which is the output on the right side of figure 8 (E32). To get one simple unit for the first step of development, the lower two levels are depicted with functional blocks (E1, E2, ...) and are not considered further more.

The principle task of the mental apparatus (the psyche) is to find a synthesis between three demands [1, pp. 12]. The first demand is coming from the drive (E3), which is derived from the body - physiological conditions. The second demand is constituted by the conditions of the reality, its possibilities and limitations. (E9, E25). The third and last demand is the limitation by the outer world[3] (E14). The third demand is part of the Super-ego (E7, E22), which is the socially founded rules and prohibitions. These three forces should be drawn in their conclusions and consequences concerning the mental apparatus as a whole.

Physiological imbalances arise in the organs of the body (E1) and initiate organic demands (needs) over the neuro-symbolic layer in the form of a drive tension (E3). So, the drive is the first representation of the bodily condition. Life-saving drives are mixed with aggressive drive-tendencies (E4). Their contents will be transferred as thing presentation (I1.4) and build basic affects: pleasure and unpleasure (E5)[4]. Affects and thing presentations represent drives, in which the affects are the quantitative valuation of the thing presentations. Both, the thing presentation and affects (I1.5) are transferred to the defense mechanism (E6), which assesses by the influence of the bids, bans and gratuities of the Super-ego (E7) and by the internalized reality claims (E9). These assessment decides, if, and in which form, the thing presentation and affects are transferred to the Ego. Thing presentation and affects, which are rejected by the defense mechanism because they are not allowed to become preconscious or conscious, are memorized in the Id in a kind of a container and are repressed as psychical contents (E15). Thing presentations and affects, which have gotten access to the Ego, will be processed in the following by the secondary process (E8). This means they associate and are bounded with word presentations, are

[3] The outer world is in psychoanalytical terms the physiological part (outside the psyche), the inner world the mental part.
[4] In opposition to the broad differentiation of all the affects like fear, happiness, etc.

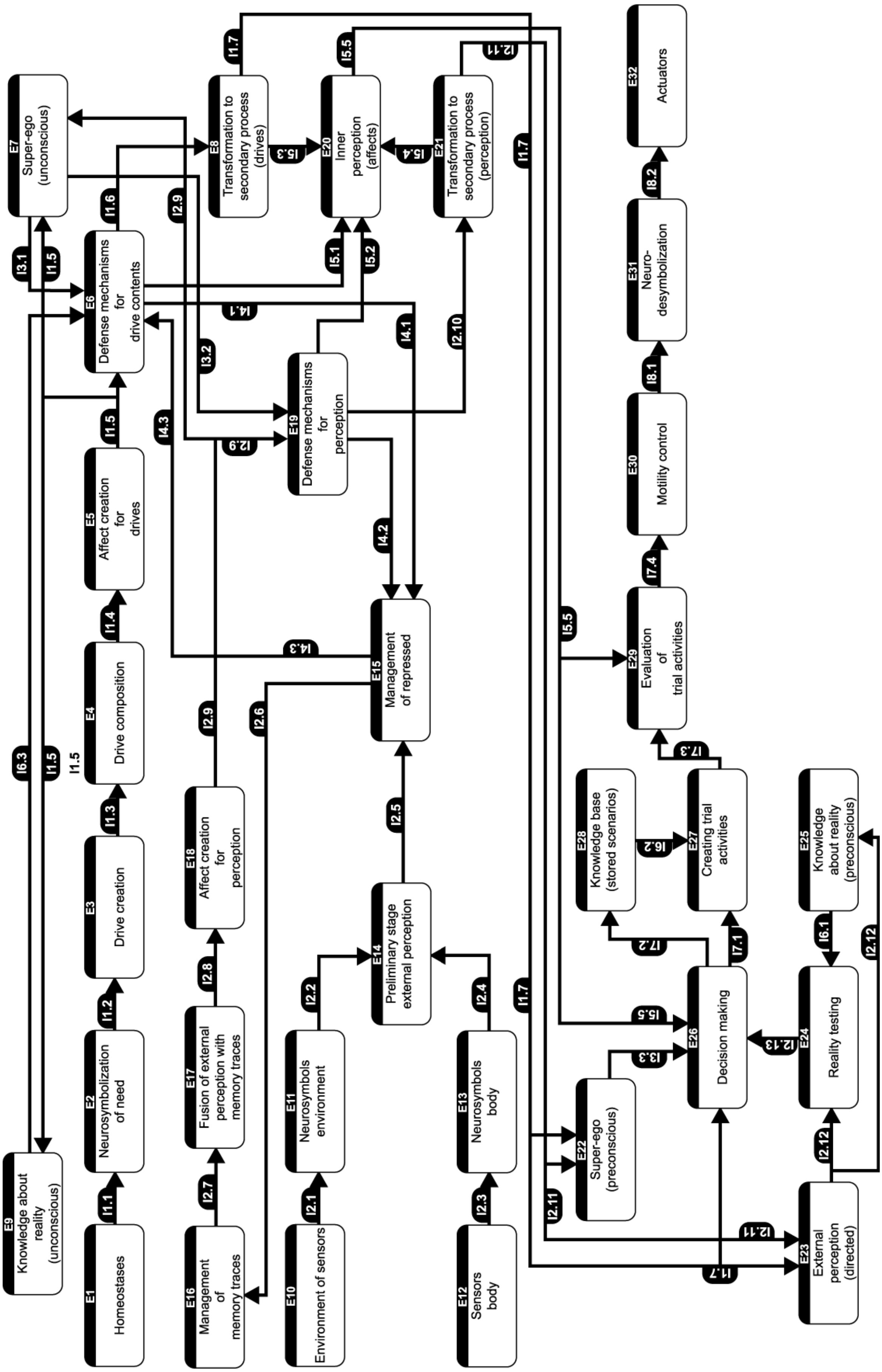

Figure 8: *Functional model of the mental apparatus (psyche)*

logically sorted and valued in a way that they get spatial, (three-dimensional) temporal (chronological), and logical notions.

The outer world gets the information from two sides, the sensors for the external perception of the world around us (sight, smell, touch, …) (E10) and the sensors for the external perception of our body (pain, hunger, localization of the muscles, ...) (E12). The raw data is transformed into neuro-symbols (E11, E13). The human being recognizes these signals unconsciously. These symbols are objects, called thing presentations, which come from the inside of the body (E11 and E13) all the time to inform the mental apparatus about the condition of the body and world in space and time. They activate the administration of repressed contents (E15) and memories (E16). All of this information, the thing presentation and affects and the repressed contents will be computed by the functional block "fusion of external perception with memory traces" (E17). In the same way drive tension leads to affects; they are also built by the perception of the outer world (E18).

In this way the presentation and affects which come from the outer world - the preliminary stage of the outside awareness (E14) on one hand and on the other hand from the Super-Ego (E7) - will be computed in the function block defense mechanism (E19), and this leads finally to the transformation into the secondary process (E21) for the Ego. This is the introduction for the inner perception (E20) of drive demand and contents of external perception coming from the outside world. The inner perception means in this case the preconscious/conscious perception of affects as feelings, because the affects can be nominated by word presentations In this way, E8/E20/E21 is the first point where contents can be conscious or preconscious.

These word representations (including thing presentations!) and affects will be transferred over the interfaces (I1.7/I2.11/I5.5) to three different function blocks: the pre-conscious Super-Ego (E22), the decision making (E26) and to the watchful outer perception (E23). The preconscious Super-ego has in principle the same contents as the unconscious one, the difference is that contents are able to become conscious and influence the decision block (E26) in what is to do with the desires coming from the lower unconscious part, the drive tension or the Super-Ego.

The external perception block (E23) as well as the knowledge about reality (preconscious) block (E25) have the task to check the desire against reality (E24) which decides if the desire could in principle lead to success or not. After it comes to a preconscious/conscious decision (E26) to fulfill some particular desire, different images and scenarios (about previous fulfillment) are initiated and lead to various potential action programs (compare [15, p. 85], there they are called concurrently playing mental imagery (visual films)), which are the simulation of plans, mainly unconscious (although it is possible that one of them becomes conscious during the dream state), in order to know what to do (E27). The decision, i.e. which plan will be carried out, is based on feelings (I5.5) perceived by the inner perception (E20).

The last three blocks of figure 8 are the reverse functions as in the beginning: first, the type of movement must be decided (E30), then this demand must be broken down into single symbols (de-neuro-symbolization) (E32) and finally the single actuators must be activated (E31).

6 Further Approach

The first concept and realization of modeling the mental apparatus was presented in several papers, but at great length in [18]. The second draft is discussed in a broad way in [1]. The presented approach here is the third stage of development. The developed simulator will run within the next months. Then the previous results will be tested and evaluated in extensive experiments in the upcoming years. The work will differentiate into two directions: verification and validation. For this reason a software agent platform is under development. In each agent the model of figure 8 will be implemented and individualized by parameterization.

The software agents live in a defined artificial environment, in which they bound to specific demands. Of course, the authors are aware very well that the model of figure 8 is a dramatic reduction of the whole psychoanalytic model and not completely differentiated. This would be impossible in the first step. In the same way the lowest layers of the model, represented in figure 8 by the function modules E1, E2, .., E10, E11, .., E31, E32, .., are reduced in their functionality to the necessary minimum in order to achieve a comprehensive functional process between sensors and actuators. The emphasis is on the psychoanalytic part, not the lower layers of the hierarchical model, but on the distributed functional part of layer three concerning Lurija's three layer model.

The goal of the verification must be to prove that the model in figure 8 works. The authors expect many challenges. First of all, there are several principles like breaking down all the functions in sub units to be able to program them without coming to a contradiction in the psychoanalytic thinking. Which will be the most efficient way? Which is the most natural one? Following psychoanalytic knowledge it is a fact that the whole process *psyche* is very instable. One finds a lot of feedbacks in figure 8. Is it possible to get a stable system? Figure 8 is an abstraction of the whole mental apparatus. Did the researcher forget a main function that would make the process run in an instable form? In this sense, many further questions will arise until the process will run in an acceptable way.

However, as soon as the system works, it is necessary to evaluate the model by psychological experiments where we have to invite psychologists to work out test procedures. And beside all these activities we are able to derive from all these results and interim results practicable solutions for today's demands as it happened for different projects like the European project SENSE [2] mentioned in the beginning.

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8 Web Links

[A] http://www.youtube.com/watch?v=bCK64zsZNNs

[B] http://www.neuropsa.org.uk/npsa