Chapter 10
Biomimetics in Intelligent Sensor and Actuator Automation Systems

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Abstract Intelligent machines are really an old mankind's dream. With increasing technological development, the requirements for intelligent devices also increased. However, up to know, artificial intelligence (AI) lacks solutions to the demands of truly intelligent machines that have no problems to integrate themselves into daily human environments. Current hardware with a processing power of billions of operations per second (but without any model of human-like intelligence) could not substantially contribute to the intelligence of machines when compared with that of the early AI times. There are great results, of course. Machines are able to find the shortest path between far apart cities on the map; algorithms let you find information described only by few key words. But no machine is able to get us a cup of coffee from the kitchen yet.

Biomimetics, being the application of biological systems found in nature to the study and the design of engineering systems and modern technology, is the promising method. However, it has to be implemented reasonably, which is argued and detailed below. Doing so, a new research field – the alliance between engineering and psychoanalysis – emerged, which is presented in this contribution. The ultimate goal of this research is to create a human-like intelligence for the control of automation systems that consist of sensors and actuators interconnected via field bus systems.

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10.1 Research Field

The core question is: What is necessary to give machines an understanding of the real world? The postulated answer is: The integration of research findings from psychoanalysis, neurology, and engineering was the basis for the foundation of a new research area, which focuses on completely new ideas. Instead of looking for solutions for partial problems, the focus should be put on a holistic model of the human psyche describing all of its functions – up to consciousness. Even if the implementation of machine consciousness is still to come, the model development of necessary functions and requirements gives important hints for further research.

One important research task today is the evaluation of information and the extraction of relevant information. This is necessary for recognizing situations and for decision making. The complex evaluation system of humans serves as a biological archetype: through comparison with a huge number of already evaluated patterns, we can filter and classify lots of information very quickly. Psychoanalytic theory models this evaluation process with the help of emotions, affects, and drives. The human psyche needs to satisfy various requirements from different sources like the own body or the environment while it constantly facilitates equilibrium between those partly contradicting demands. A technological implementation needs to facilitate exactly these mechanisms, in order to have the same capabilities. This task poses many unintended obstacles (e.g., the definition of a technological "body"), but it is seen as the lead to future success.

Researchers face the challenge to translate domain-specific knowledge from foreign disciplines into their own. This knowledge is not edited to be understood by engineers. It has to be "translated." Very often mechanisms are described in terms of their observable function, not in terms of their functional model – as required in engineering.

10.2 Automation

From the early days on, the focus of scientific investigations in the field of automation was on communication technology. Industry quickly identified the enormous market potential of distributing intelligent control units to various fields such as energy production, energy supply, rail transportation, or aviation and space technology. This and the following section intend to review history to better understand the present and how the current research directions evolved.

The term automation was introduced in 1936 by the Ford manager D.S. Harder [1]. Since that time, its meaning has changed remarkably. In the beginning, automation only meant optimization of processes in the production of goods. In engineering today, the meaning of automation has changed to the more general notion of processes controlled by machines. Hence, in the past its major goal was optimization of mass production. Today, no matter whether human resources are additionally required or not, we talk about automation when processes are controlled by machines, though mass production is still an important goal. However, automation today is about more, about process optimization in various respects, e.g., higher quality, safer environments, more security, or better hygiene.

In previous times, the term “hand-made” has been a quality feature. Today, when talking about material goods, it refers no longer to high quality, but rather to the opposite (of course this statement does not hold for artistic craftwork). This is because machines are able to continuously deliver high quality. The quality can be only kept on high levels and standards with consolidated deployment of automation technologies and methodologies. Otherwise, micro and nanotechnology, chip technology, and many other areas of production procedures could not be implemented. Impressive examples of advantages through automation can be found, e.g., in aviation technology. Only field bus technology and the introduction of the fly-by-wire principle made modern aircrafts possible. Another example is cars. Modern upper class cars have some hundreds of embedded systems communicating with each other, drive-by-wire. Both “by-wire” principles imply that the device is no more directly controlled (e.g., with a mechanical bar), but with the use of a field bus system. The term field bus system refers to a communication and computation system where various sensors, actuators, and control units are interconnected with a communication medium, the field bus. The principle is the same as in bus systems in a common computer, but the application is outside of it, e. g. in a factory or a car, that is “in the field.”

Mining companies in Europe were only able to reach the required safety level for road tunnels through interconnection with field busses. They steadily collect data and send it to control stations and central offices. In this case, data collection was not a technical problem at all. It could have been accomplished with decentralized control units or even with widespread internet connections for all sensors and actuators. However, the key advantages of field busses are twofold: first of all low prices, and second and most important their specification of profiles for application areas. Especially the second point, the definition of profiles, is a question of standardization, for which industry, industrial associations, and also governments spent lots of money in the form of grants. In this way, a broad basis emerged, on which most notably the European industry created enormous margins. Without profiles, field busses are worthless; they would be too expensive in development and still more so in maintenance. If countries that do not have strong industries in this area want to use this fundament, they need people who acquire the knowledge about profiles for them. The conception of a field bus being a small computer with long connections to sensors and actuators as well as connections to other computers is no longer enough, since field bus components will be superseded in the next years with developments in the areas of internet technology and brown ware (consumer electronic). According to Moore’s law, the performance of processor chips will increase year by year. Therefore, knowledge in the field bus area does not lie in components; it lies in the functional profiles and interoperability. And still there is more to it. The second large area of knowledge capital, which makes out a field bus expert, can be seen in application-specific knowledge. The collection of billions of data points via a large field bus system is not a trivial task at all; especially if various channels are connecting sinks and sources. But the real challenge lies in finding the information behind the data – which can only be accomplished automatically due to the sheer amount of data [2].

10.3 Intelligence and Communication

Two major issues must be discussed: First, why is it now that automation experiences its phenomenal boost as an essential pillar of economy? Second, a vast number of processes can be found in nature. Which automation principles can be found there and what can biomimetical approaches offer for even smarter control units?

Purely mechanical control systems are always physical compromises. For the control of a process A to use some mechanical system B that is subjected to physical laws and constraints compromises are necessary. The differential transmission of the two front wheels of a vehicle is an example. It must be constructed to support minimal curve radius with various velocities and torques. A differential transmission of a tractor therefore looks different from one of a race car.

If we separate the flows of energy and information in a mechanical process and develop separate electronic control components (which are not subjected to physical constraints), those compromises become almost always unnecessary. Let us assume that the mechanical differential transmission together with the steering column will be replaced by propulsion engines directly integrated into the wheels (which in fact is a goal of the automotive industry, remember fly-by-wire: drive-by-wire). In this case, any desired differential transmission algorithm can be implemented with the drive-by-wire system (field bus). Such a system could also additionally be able to consider road conditions. Hence, compromises regarding control are no longer necessary. Therefore, economic benefits arise. Mechanical degradation is limited to the remaining parts for suspending the wheel. Maintenance will be eased and therefore available for lower prices. The period of warranty can be enhanced, because the failure rate can be calculated more precisely and easily. The overall energy consumption can be optimized; also the wear of tires can be reduced.

All these considerations reveal that with the help of automation and the introduction of field bus systems, production lines can be built more efficiently, in short times, for lower prices. Large portions of energy can be saved. All this was not possible in earlier times without field bus technology. It became a crucial business factor. Smart control units implemented as embedded systems together with communication technology – as learned from nature – are the motors of this trend.

Still, the explanation is missing how evolution tackled those problems. Very old creatures such as the amoeba can be treated like the mechanical systems in the above examples with respect to their control (= information processing), since they act based on physical–chemical processes, which does not allow for any separation of information and energy flow. However, evolution introduced this

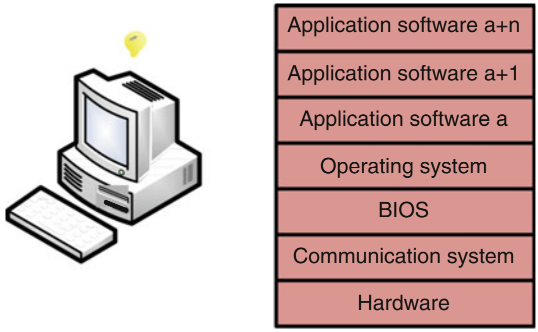

Fig. 10.1 Possible abstraction layers of a computer

principle, e.g., already in worms (which are one example for rather old creatures that have nerves for communication). However, what about humans? We have special information communication channels (the nerves) evolved, which have been the template for the technology of field bus systems (fly-by-wire principle). The information transportation mechanisms are however somewhat differently implemented. Nerves do not exactly work like bus systems. However, this does not contradict the basic principle of separating energy and information flow.

In computers, we differentiate various abstract layers (see Fig. 10.1) from the lowest layer, the hardware (which can itself be divided into sublayers), via device drivers, operation system, up to the application software (which, again, is modeled itself in many further layers and sublayers). The same can be done with the information processing system in living creatures [4]. Nerves and neurons themselves form in this sense the hardware. Higher layers in the brain have been found by the neurologists Luria [3]. In nature, peripherals and centralized oriented information systems can be observed, pursuing decentralized control principles. Because of the actual slightly different functionality of nerves and technical communication systems, it can be anticipated that the principle of the human nervous system needs to be adopted and only implemented in principle, if complying smart automation systems should be constructed. But it can be also useful to look at control mechanisms of various animals to achieve this goal. In this way, bionics gains even more importance, especially with respect to the higher layers of information processing, which are the key enabling factors for "smartness."

10.4 Open Problems: Challenges in Research

The section should highlight that different applications for particular field bus systems require different profiles. A profile is seen as a higher level of abstraction in communication systems. On the one hand, all profiles have distinct properties and justification for particular applications. On the other hand, because profiles are more or less independent of the lower layers (in particular the lowest one, the hardware), the question arises whether it is possible to harmonize the hardware of different field bus systems. Today's discussion is: Can hardware be found that is economically applicable in many different bus systems, allowing for different implementations of the higher layers? One candidate could be Ethernet, which is under constant development and, through its widespread deployment in the PC world, economically priced. Many indicators point at a possible application of Ethernet for field busses, but in the history of field bus technology many technically reasonable solutions have been presented, which were then no longer followed due to economical reasons. The discussion is still open, although the trend goes to Ethernet (and its hardware) to be utilized on a broad basis for the lower layers in field bus systems.

The last point also refers to wireless networks. The developments in this area are also still in progress, especially focusing on energy efficiency while preserving communication abilities. The duration of such nodes reached already some years, but shall be enhanced up to five or more years [5] to allow for cost-efficient applications, as in transportation [6].

Research and development in field bus technology aside the harmonization aspect concentrates mainly on four topics: reduction of installation and maintenance costs, safety, security, and interpretation of the enormous amounts of data. The first three topics are mainly unrelated to biomimetics, while the latter is a clear case of a bionic application and will be dealt with in the next section in more detail.

The problem of reducing costs, especially for installation and maintenance, is of great significance in building automation, since conditions are most dramatic. The physical placement of nodes is usually performed by very cheap, semiskilled workers, and the number of nodes is in a dimension of several thousand up to many ten-thousands of nodes. Another problem of integrating and maintaining such a number of components in an economic way on a PC is left to the integrator. However, this is not only a realization question to an engineer, but also a scientific challenge. This is because modern technology did not find a suitable solution which satisfactory supports the integrator with this problem on the construction site.

Safety (functional safety targets ensuring normal operation even if subsystems fail) is a topic that was rarely tackled in automation and sometimes even in an amateurish way. An example should demonstrate those first, inadequate considerations. It was the time when safety relevant electronic circuits should be realized with micro processors: it was demanded to build up the circuits redundant in a way that one circuit is allowed to contain a micro processor, but the second needs to have a discrete-built circuit. Times changed this fundamentally, but still safety is often avoided since it is seen to imply higher costs, sometimes more than double costs. However, experts know this is absurd, since safety is not about doubling hardware or software, but functionality, which results in additional costs of the product often in a range of 5–10%.

The case with security is even worse (protecting a system against attackers). In automation, this topic is widely untouched; some proponents even say that a firewall at system border is sufficient. It is certainly not, e.g. in many critical infrastructures, attacks come from active or fired employees, thus from inside. For mechanical systems, this was hardly a problem, but in case of electronic systems it is. Imagine connecting a small hidden device to an internal field bus, which is remotely controlled to terrorize a company. Although the topic is of high importance, in many areas such as industrial automation or automation in transportation this topic is kept behind the scenes these times. Only in building automation some considerations have been undertaken since an attacker could annoy the working or living people in the building a lot. But, as mentioned earlier, it is of no concern today. Research results are present in small number (see [16]) but it is questionable if they will find integration in practice or if they will be further investigated. Maybe other solutions will be found, which are more economical.

After this, the last and maybe most interesting topic is reached: How can the enormous amounts of data in a building, e.g. an airport or a shopping center, be usefully interpreted without the need for massive support by humans? This question already implies that a system is sought that can substitute the capabilities of humans in this respect. But what respect is it when referring to building automation? The applications are HVAC systems (heating, ventilation, air condition), illumination, security systems, and – in the vision of many researchers – context aware systems for many applications to increase safety, security, comfort, energy efficiency, etc. The requirements on a meta level for all applications are similar: perceiving information and interpreting this information with respect to the context of the system. But what is the context? The context is a theoretical construct by humans. Therefore, for a machine to be able to derive the context, it is necessary to give it the same perceptional function as a human. This problem can also be only tackled with using bionic's principle to study nature's solutions. The next section will describe the decision processes that finally lead to the development of the bionic research area at the Institute of Computer Technology of the Vienna University of Technology.

10.5 Intelligence of Bionic Systems

Before presenting the current state of the model development, it is necessary to explain the motivations why this development was essential.

10.5.1 Hierarchical Model Conception

The various approaches of artificial intelligence (AI) over time have been summarized in [3]. Four generations have been identified: symbolic AI, statistical AI, behavior-based AI, and recently, emotional AI. The article very well describes how researchers started to build and understand functions of the human mental apparatus starting with neurons in a bottom-up design methodology, or even with data-driven statistical analysis. Very much emphasis has been put for a considerable time period – sometimes including today – on a behavior-based design methodology, meaning that devices like robots have been built that behave similar to (e.g., move

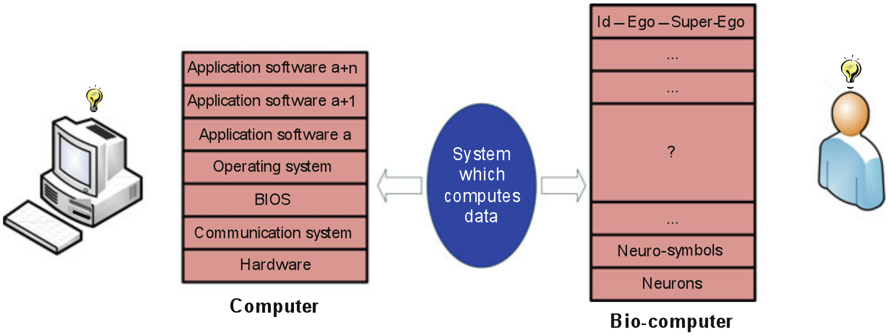

Fig. 10.2 Possible abstraction layers of a computer (to the *left* the artificial device, to the *right* a biological model conception)

like) humans or animals. The term intelligence, however, has never been precisely defined – it has not even been used, except for the title "AI."

However, if engineers are to design machines that should behave "intelligently" as animals or humans, it has to be dealt with the definition thereof. So, what is intelligence? The question can only be seriously answered, if we are able to understand the mental apparatus. It is not enough to know about the behavior, but it is mandatory to have a unitary and comprehensive functional model of it.

For the below presented model development, a number of boundaries has to be defined. On the one hand, appropriate modeling principles and methods from computer engineering, communications engineering, and automation are to be used. Abstract layered models are used there, which are developed in a top-down fashion.

On the other hand, for comparing the platforms, we utilize the definition of a computer after which it is a data manipulating, storing, and transferring device. In this sense, an artificial computer and a biocomputer can be compared (Fig. 10.2). There are many abstract layers defined in an artificial computer in the left part (from hardware to application software) – which can be also imagined in the biological model that is shown in the right part, where many layers are not yet defined due to lack of knowledge. Neurologists also second this structure [3].

Figure 10.2 expresses moreover also the monist conviction – also along with the natural science view of the world – that the brain is a control system based solely on the laws of physics, with no principally unexplainable mechanisms, no mystics [18, 19 p.51].

10.5.2 *Statistical Methods*

A large number of feedback loops of all kind both physiologically and mentally (hence, in all layers of Fig. 10.2) are active in humans (Fig. 10.3). It can be easily imagined that specific propositions about particular feedback loops in such

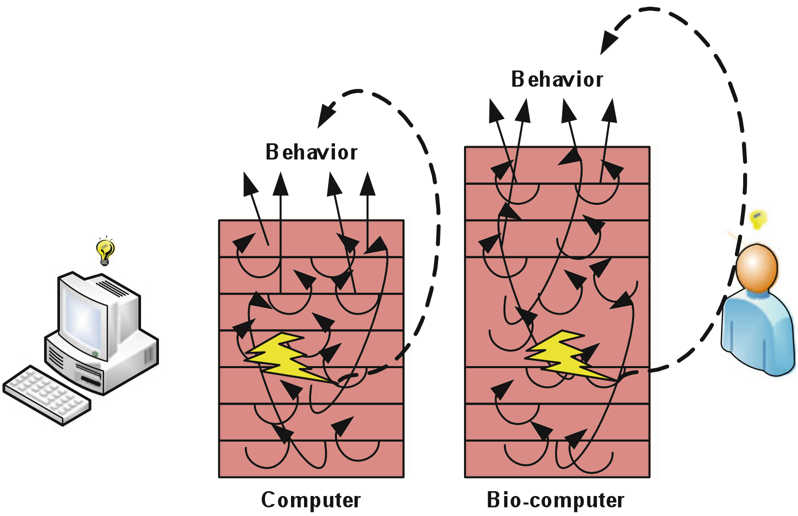

Fig. 10.3 Effect of layers: different behavior of the whole process

an arrangement can only be stated, if there exists a concrete conception about the whole process. In the layered model, two completely different errors in different layers can result in the same behavior. Or, a substantial error in one layer can be compensated by actions in other layers.

So, if the behavior of the whole process is under investigation from the outside, observed phenomena can only give indications about feedback loops inside without having an accurate description of all feedback loops.

For a better depiction another small example is given (Fig. 10.3, left). If there is an instability or error in the operation system, the observer who works with the application software may see only that crashing and believes the error occurred there. This is due to lack of knowledge about the correlations.

This description should elaborate why computer engineers (and chip designers) do not use statistical methods of behavior for synthesis. They need an explicit model description. However, AI often uses behavior-based methods, based on statistical analysis for synthesis as can be seen in the example of [7] – a principle, which has to be questioned.

10.5.3 Definition of Intelligence

The terms intelligent and intelligence have to be used with care. Some two or three decades ago, there have been severe discussions about which processor is the more intelligent one (they spoke about architecture and computing power). However, it was understood soon that this is the wrong kind of question. Computing power

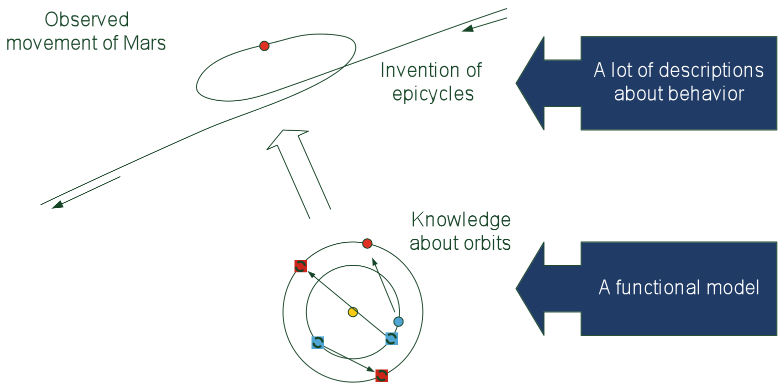

Fig. 10.4 The earth as the center of the universe

cannot be defined in general but only application specific in terms of problem solving. Thus, if a hierarchical model as in Fig. 10.2 is assumed, such kind of question can only be applied to a single layer. Or the range of applications has to be entirely defined, which are performed by the computer. So, to define intelligence one has to be aware to which layer he is referring to. For the synthesis of a model, a computer designer needs a conception for every single abstract layer.

10.5.4 Choice of the Right Model

Here is an example that shall point out the importance of the right point of view. In medieval times, it was assumed that the earth is the center of the universe. The description of Mars' orbit (Fig. 10.4) was therefore mathematically problematic and only possible in approximation with the help of epicycles (ptolimeic world view).

The breakthrough came in 1543 as Copernicus saw the sun as the center – so all orbits could be easily modeled as ellipses.

Transferred to observed human behavior, this means that descriptions based on an erroneous (or from the wrong point of view) model tend to give misleading conclusions. For synthesis of a bionically-inspired model, one needs the right model.

10.5.5 Top-Down Methodology

For computer design or chip design, it has to be distinguished between behavior and function. This means that if a particular potential behavior is sought, one needs a model of the device under development, which can then be iteratively enhanced to reach the desired behavior.

Furthermore, for model development, it is mandatory to use the top-down methodology, because otherwise the optimal circuit design cannot be found. If, for example as in [7], two inconsistent behavioral models would be used as basis, it seems obvious that inconsistencies arise. Here the authors understand top-down as being the design process that starts on the top most abstract functional level – the main function, which is then divided into subfunctions and modules in the consecutive next lower hierarchical abstract layers until a specific description is reached, which can be actually implemented, and on the lowest layer synthesized in real hardware.

10.5.6 A Unitary Model

There exists an abundant amount of psychological theories as has been tried to review in [7]. In this book, the attempt has been started to collect all psychological studies. However, they are taken and publications are cited without having checked their compatibility (interoperability). At least, it is not reported. However, interoperability is essential in the area of interdisciplinary science when taking other theories as template.

In case of psychological schools, they are often based on different premises. The approach to theory-making of psychology cannot be compared with natural science practice where it can be seen as major goal to eliminate inconsistencies. Additionally, in the psychological area, it is very hard or even impossible to formally proof a theory. Therefore, more empirical procedures have been applied. However, on the one hand, if the goal is to compile the mental apparatus in the bionic sense with methods from computer engineering, one cannot simply accept inconsistencies, but needs to search for solutions or particular application cases. If, on the other hand, results or statements from different psychological schools are used, which are not interoperable, the resulting model will be only a patchwork.

10.5.7 Differentiation Between Function, Behavior, and Projection

In previous sections, we already distinguished between behavior and function. However, there is one additional distinction necessary: projection. When looking at quite famous developments such as the CB2 (a robot looking like a human child of 4 years) [W1], we realize the way how reports about it are formulated. A lot of analogies to children are endeavored. However, from a functional point of view, a robot has nothing in common with a human because it simply lacks the functionality of the psyche. Behavior created from the robot is driven by (very sophisticated, of course!) computer algorithms that work very different than the human psyche. The one thing that makes people call it human-like is its appearance. Thus, observers project human behavior into the robot. It is the same as with a doll. Even if a number of actuators remarkably affect CB2's facial expressions, there is no machine emotion behind, only observers perceive the expression of an emotion. Hence, it does not smile because it is amused; there exists no concept of amusement in the machine or doll. Once again, it simply lacks the psyche to generate any kind of human-like behavior. It is only the observers that project human-like emotions and behavior into the robot.

10.5.8 Indispensible Interdisciplinarity

In science, there exists the principle that all relevant scientific results worldwide have to be incorporated to serve as the state-of-the-art. However, when developing human-like systems, it seems that this principle has been avoided since psychoanalysis – which is as their core competence concerned with the topic for more than 100 years – has not been considered.

To emphasize this point and weaken arguments toward possible self-studies, another hint is necessary: the education of an engineer at a university in Europe lasts for about 6 years, a psychoanalysts needs about 9 years [W2], [W3]. This means that an engineer, on the one hand, will probably not have time to undergo this education, and on the other hand, conducting self-observations without such education will probably not lead to any useful template for implementation.

Having a look at international working groups on the issue of Artificial General Intelligence, it can be noted that hardly either psychoanalysts or neuropsychoanalysts are actually involved. Only some suggestions to bring together psychoanalysis and engineering have been made. The first investigations in this direction were presented in [4] and [8–12].

In other parts of AI, it has become common practice that engineers interpret and utilize psychological literature. But then an engineer would be quite astonished if a psychologist or even psychoanalyst came to the idea to interpret technical research articles. The conclusion is clearly that in such kind of working groups interdisciplinary work has to be more emphasized [13–15].

10.6 The Psychoanalytical Model

Finally, this section presents the developed model. This model is intended to be used in decision units of various technical devices like robots or automation units. It functions according to the psychoanalytical description of the functionality of the human psyche. Therefore, it incorporates terms such as drive, wish, emotion, affect. The following description is very dense and should give the reader only an overview of the topic.

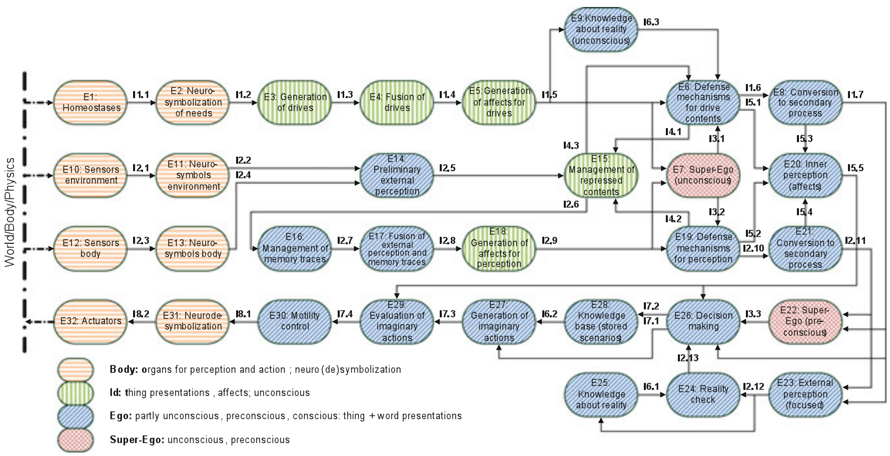

Fig. 10.5 Functional model of the psychic apparatus

A functional model (Fig. 10.5) has been developed, which describes with the help of psychoanalytical concepts how a motivational moment generates a wish, then how decisions are taken, actions are planned, and finally conducted (a detailed description can be found in [17]).

It is the task and function of the human mental apparatus to synthesize the demands of three instances. These instances (Fig. 10.5) are the drive demand (E3), which bases on bodily-physiological requirements (E1), the reality demand, composed of internalized knowledge about the facts of the outer world, its possibilities and bounds (E9), and the subjective consequences developed from perception of the outer world (E14). The third instance represents the demands of the Super-Ego (E7, E22), which is composed of socio-cultural founded bids and bans, i.e. rules.

These three instances and the consequences of their demands for the mental apparatus are to be comprehended. A physiological, hormonal imbalance that develops in an organ (E1) triggers via neuro-symbolization of that organic requirement (E2) a drive tension (E3), whereby the drive tension is the first psychic representation of bodily circumstances. Life-sustaining drives are mixed with aggressive drive tendencies (E4). Their content in the form of thing presentations is further transported (I1.4) and gets rated by an affect of more or less unpleasure (E5). Affect together with (thing) presentation form the drive, whereby the affect is the assessment thereof.

Affect and thing presentation together are carried (I1.5) to the defense mechanisms (E6), which with the rules about bids and bans from the Super-Ego (E7), resulting fear, and under the internalized reality demands (E9) decide, if and in what form affect and presentation are handed over to potential conscious processing in the Ego.

Affects and presentations, which are entirely defended through the defense mechanisms, as they are not allowed to get conscious or even preconscious, remain in the Id part of the mental apparatus in a container for repressed mental contents (E15).

Affects and presentations that gained access (in what any kind of form) to the Ego become processed in terms of the secondary process (E8). This means that thing presentations become additionally conjunct with word presentations. In that form thing presentations can be ordered and assessed logically, meaning they become consistent with temporal and spatial conceptions.

As has been already stated, the work of the mental apparatus is influenced by drive demands (E3) arising from bodily needs, perceptions of objects, and circumstances of the outer world (E14). The outer world is represented in sensor data of two kinds: one targeted to the environment (E10), and one solely targeted to the own body (E12). These raw sensor data are transformed into neuro-symbols representing body and environment (E11, E13). These are the content of unconscious perception before any kind of psychic processing or assessment. The perceived (thing) presentations come into contact with repressed mental content and together activate memories (E16). As a result, a combination of perception from the outer world and memory is constructed (E17). This means that not some kind of copy of the outer world is psychically processed, but a subjectively and individually assessed and associated presentation thereof. Just like the drive tensions, the presentations of the outer world produce affects (E18). Presentations and affects on this level originating from outer perception and demands are similarly treated by defense mechanisms (E19) as it has been described for drive tensions. Again, perception content that passed the defense mechanisms and therefore gained access to the Ego (in what any kind of form), become processed in terms of the secondary process (E21).

At this level for the first time, preconscious or conscious inner perception (E20) of drive tensions and perceived content from the outer world is possible. Inner perception includes also preconscious/conscious perception of feelings and affects that are related to the combined thing/word presentations.

The thing/word presentations and related affects are carried (I1.7, I2.11, I5.5) to three further processing entities: the preconscious Super-Ego (E22), the decision unit (E26), and the attentive outer perception (E23). The preconscious Super-Ego in principal contains the same content as the unconscious one. However, its content can be accessed consciously and has influence on the decision unit (E26). It controls how the wish – resulting from drive tension after secondary processing – is to be treated. In other words: if and how wish-fulfillment can be achieved.

Both, the attentive outer perception (E23) and the memorized facts about circumstances of reality (E25) affect the reality check (E24), which tells the decision unit what in terms of wish-fulfillment can realistically be achieved and what not – without moral assessment.

After drawing a preconscious/conscious decision that wish-fulfillment is to be achieved (E26), with the help of memorized scenarios (E28) potential action plans are composed (E27) and assessed (E29). The decision for conducting a particular action plan is thereby mainly influenced by feelings (I5.5) resulting from inner perception (E20).

Finally, the action plan is decomposed into instructions for motility control (E30), which are neuro-desymbolized (E31), meaning that mental content is translated into physical signals, which control the actuators (E32). The feedback loop is closed via the sensors that perceive the actual affect on the own body and also the actual affect on the environment of the conducted actions.

10.7 Conclusion

Communication and automation technology have evolved from simple mechanical systems over systems with simple automation and communication abilities to technologically complex solutions that implement all levels of the ISO/OSI communication model and even more abstract levels above and perceive and affect their environment in particularly very advanced ways. The academic questions to be solved in this context have changed from classical electrical engineering issues to problems, which are more related to computer science since the emphasize on the informational part in automation systems continually increases. The demands and requirements for automation systems are steadily changing. In the context of smart future automation networks, it is of major importance to add smart functionality to devices. In the long run, only human-like capabilities will allow for automation of many fast, dangerous, and demanding processes. This goal can in our perspective only be achieved with interdisciplinary scientific efforts between engineers and psychoanalysts in a bionic fashion.

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