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ON THE INTEGRATION OF ASPECTS OF MOTIVATION IN COGNITIVE TECHNICAL SYSTEMS

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ABSTRACT

It is increasingly expected by technical systems that they act autonomously and situation-suitable. A flexible and environment-adaptive action control poses great challenges for the development of cognitive technical systems. This implicates that the technical system is able to adapt the behaviour of one's own according to the situation and to move to desired goals. With the contribution will be describe, how technical systems can be enabled to act motivated, whereby motivation in this context will be defined as a principle deposition to act and to behave. Psychology and cognitive sciences establish a basis for principle describing of processes for motivated acting. The challenge for the engineering sciences consists of transferring these idea's and structural approaches to a technical system.

Keywords: cognitive abilities of technical systems; motivation; mechatronics

1 INTRODUCTION

Developments and innovations in all engineering-scientific sectors have resulted in great progresses, above all in the performance capability of interdisciplinary products. Today, our life is scarcely imaginable without mechatronic systems. The requirement to enable technical systems to act as appropriate according to the situation entails in the consequent further development of those systems towards cognitive technical systems.

By integration of cognitive abilities into a technical system, systems are anticipated with intelligence being significantly higher than it is presently the case with reactive and adaptive systems. Thereby, cognitive abilities are primarily explained and defined by cognition science and by sub-sectors of psychology. Therefore, integration of cognitive abilities into technical systems first of all means that the typical aspects by which cognitive properties can be described (perceiving, recognizing, thinking, solving problems, encoding, motor-functional control, communicating) are to be translated into an engineering-scientific perception. In addition to a highly performing information processing system, integration of cognitive abilities into technical systems also requires an adapted system structure. After all, the system is only capable of such actions that are also accordingly supported by respective actuators. Furthermore, the quality of sensor data and in turn percipience is bound to the technical equipment of the system. The embodiment, so the overall system structure as a unity comprising of the sensor and actor technology are provided, which is anchored in one basic system, is an important prerequisite for representing cognitive abilities. Therefore, the structuring of such systems is initially based on the reference architecture of mechatronics as a reactive system, which is to be extended accordingly. On the basis of cognitive properties, aspects like the system's self-observation, self-amplification, and self-evaluation gain very much in importance.

The scientific progress in the field of sensors permits today the detection of environmental- and system-parameters. Approaches from pattern recognition helps to evaluate these data specifically. Today, the challenge for product development will be to develop a technical system, which is able to generate actions, which are adapted to the situation. This requires an actuator-system which is capable of arbitrarily complex actions. Of course approaches from artifical intelligence serve as a basis for problemsolving [8]. The aim is now, to integrate behavior-based ideas [9, 10] into real products. For product development resulting following challenges:

- The interpretation of the system is carried out based on the specification of the system purpose. From the autonomy of the systems result a number of secondary objectives (depend on the cognitive abilities). At least the engineer has to develop the technical system for the system purpose at the end, but it is necessary to look for a multiple aim system depends on the use situation.
- It requires an interpretation of the actuator component of the technical system that gets possible an arbitrarily fine modularization of actions.
- It is necessary to find approaches to enable the technical system to handle with an unstructured environment without endangering its existence and fulfilling the systems purpose anyway.

The following considerations shall be explained at a simple example, an autonomous vacuum cleaner. Beside the normally systems purpose the vacuum cleaner is able to recognize and to clear away objects up to a defined size. To be able to proceed autonomously, besides its real system purpose the vacuum cleaner moreover must be able to update an inner card, to supervise his energy status independently and to avoid an overload (dust, objects). Both the system purpose and the use environment are kept consciously simple in a first step, however, they can be enlarged.

Associated with cognitive properties is, that systems have to be adaptive since the action is not preprogrammed in dependence of occurring sensor data as it is in the reactive system, but is depending on a multitude of intersystem parameters and an environment specification, by which a situation is described, in which it is essential to act adequately and as appropriate according to the situation.

Acting as appropriate according to the situation requires a motivation that means, an action is so derived from the sum of sensor parameters that the system can pursue its objectives at the best possible rate. The task is to convert aspects of motivation into technology. The cognitive technical system is supposed to syntonize its behavior caused by own incentive so that it is moving towards a desired target. The high degree of autonomy of such cognitive technical systems resulting thereof demands mechanisms for their self-regulation.

When motivation is considered as target-oriented acting, then for a technical system, motivation primarily results from the system's purpose. In cognitive technical systems, multiple target systems are concerned and targets have different context-depending priorities. These priorities need to be considered in the system architecture in order to enable motivated acting. Motivation as a disposition for behavior respectively acting can be structured and hierarchically classified on basis of approaches from cognition science. The challenge for engineering science now consists in integrating these structural approaches so into the technical system that these "self-properties" mentioned can be lived by the system. Thereby it quickly becomes obvious that a sophisticated information processing system alone will not suffice to implement those properties. In fact, cognitive technical systems work effectively only if the information processing system is combined with a certain embodiment as an overall structure, in which the effectiveness results from the interaction of individual components. Therefore, structural approaches for cognitive technical systems shall be presented in this article that allow for motivated acting of the system.

2 GENERAL STRUCTURING APPROACH FOR COGNITIVE TECHNICAL SYSTEMS

Consequent further development of mechatronic systems yields in the fact that a higher and increasing degree of intelligence is expected of them. A consequent further development of such systems suggests the integration of cognitive abilities. Cognitive abilities in technical systems enable such systems to adapt to a varying conceptual formulation and therewith to act as appropriate to the situation. Since in future, technical systems will be increasingly integrated into the human sphere of action, cognitive abilities are also required for the reason of avoiding constricting the person in his / her freedom of action and freedom of movement and actively supporting the person instead.

Within psychology, very generally the capacities of recognition, perception and knowledge are associated with the of term cognition. So cognitive abilities are bound to the functions:

- Perceiving and recognizing
- Encoding
- Memorizing and remembering
- Thinking and problem solving

- Motor function control
- Using of language.

A prominence of those functions as it is present in the case of the human being as the highest-developed cognitive system can be understood as maximum requirement. Essential however is, that cognitive abilities always have to feature the mentioned 6 functions, those indeed of differently strong prominence, which will decide respectively about the degree of cognition [1]. Cognitive processes can always be characterized as calculation processes. So since they are processes of data processing within which information is gathered, processed, and problem-oriented applied, they can also be assigned to technical systems. A more detailed consideration shows that cognitive processes in principle are based on control loop structures to adapt the system behavior. For that reason, the classical mechatronic reference architecture can be drawn upon as basis for cognitive technical systems.

Hereby to begin with, a purely reactive system is described. Cognitive abilities go beyond reactive systems. The parameters perceived by sensors (sensory perception) and the resulting actions are no longer rigidly interconnected with each other, but modifiable. Such modification is achieved by learning. Essential hereby is that the integration of cognitive abilities requires a reactive system that basically has the function of ensuring the system's existence. These elementary control loops must in any case remain in existence, must not be modifiable. In case of the human being these are reflexes such as regular breathing or the hungry feeling. On such a reactive basis according to [2], a multi-level approach is recommended for integrating cognitive abilities (figure 1).

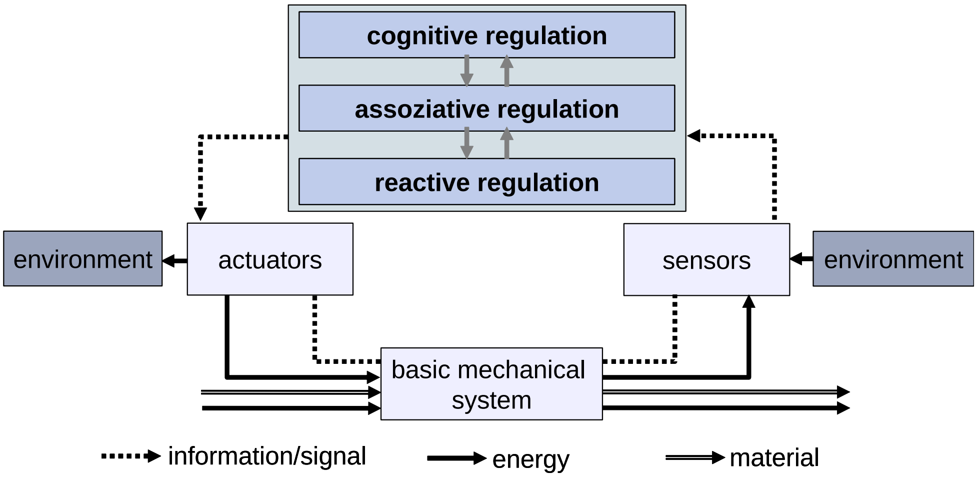

Bild 1: Mehrschicht-Modell zur Integration kognitiver Fähigkeiten in ein mechatronisches System

Basis for cognitive abilities is the above-described reactive basic system. On this an associative regulation layer is based by which action variants in terms of classical and operant conditioning can be realized. The third level of cognitive regulation forms the basis for action and execution planning. It provides deliberative functions [3]. In the example of the vacuum cleaner the reactive level must guarantee, that there is always enough energy that the system still can go to the loading up station. Moreover the overloading has to be avoided. Here also have been included the regulations which update the card, register the actual position, which recognize objects and remember where dust was already sucked. An associative level has the task of deciding, which of the possible aims must be reached at first, to fulfil at long last the system purpose (e.g. objects must be cleared away before you can suck). A cognitive level must actions plan ahead by evaluating information’s from earlier sucking events and based on as a route planning.

The displayed multi-level model can now be integrated into the reference architecture in place of information processing. Such a description however is too coarse and therefore, not very helpful for actually deriving structuring approaches for product development.

A technical system is enabled by cognitive abilities to operate autonomously to the extend possible, because it can act flexible in most different situations. Such flexibility however presupposes target orientation. Here it becomes obvious that a multiple target system develops that cannot be hierarchically structured anymore. This target system results from different realities in specific situations and must not be confused with the principle purpose of the system. Basis for product development still is the finality principle, by which the purpose of the system is defined, and which still is used as starting point for all considerations. For system design now, a rather cybernetic approach is gaining in importance: namely the question, how the cognitive technical system in its behavior is supposed to fulfill the purpose of the system. The multiple target system results last but not least from the thought that for one situation-specific behavior, different approaches must lead to the same target. To define those targets is not only a challenge for the designer but, based on the system's learning aptitude, must be enabled to take place to some extend also by internal activity of the system itself. To satisfy this requirement, corresponding structuring approaches for cognitive technical systems are necessary, which shall be derived and briefly explained in the following.

3 ACTING APPROPRIATE TO THE SITUATION AND TARGET-ORIENTED

According to the above-mentioned description of cognitive abilities, technical systems must substantially fulfill three aspects [2]:

- They must be actively embedded in the environment, thus have the ability to exchange information with that environment
- They must possess flexible and environment-adaptive control of action and the facility for reflecting system-relevant data and the environment
- They must have learning and anticipating aptitude in information processing

Active involvement in the environment is preferably accomplished by the system's sensory equipment. Here it shows that the embodiment of the technical system is playing an important role for cognitive abilities. From the environment after all only such data can be collected that are preplanned by the sensor concept. Also the arrangement of sensors in an overall system plays an important role for the quality and usability of the collected data. Flexible and ambience-adaptive control of actions is achieved to a certain degree by a skillful hierarchic combination of control loops. Typical cascade controls for example are very helpful for realizing parameter adjustments in function of different influencing variables.

These structuring approaches for control loops indeed allow a relatively flexible adjustment of parameters; breaking up of sensor-actor chains however is not possible. To accomplish that at the one hand, corresponding algorithms are required, by means of which for example a search for patterns in the sensor data is executed that are interrelated to corresponding actor actions in terms of classical conditioning and actoric actions are varied or reassembled as appropriate to the situation.

An intrasystem control of actions muss be able to revert to an appropriate system structure. Such control has to provide that the behavior of the cognitive technical system is oriented to a certain target respectively target combination. The basis for intrasystem control is a nominal/actual value comparison of parameters that can be derived from the control loop, whereby deficiency conditions can be detected. Two terms are to be clarified: how does a situation define itself, and what from result possible targets for the cognitive technical system?

By a situation, a specification of parameters shall be understood that describe the intrasystem condition as well as the environment condition, which is detectable by the sensors of the cognitive technical system, at a defined point in time. In the process for the designer it proves to be downright difficult to detect a situation completely, as such situation is composed of a multiplicity of elements (parameters), which moreover are networked among each other. A situation measurement so is a snapshot that is measured by collecting all current sensor values at a defined point in time. The coherences between the individual parameter specifications do not emanate from the approach. Up to a certain degree, they are derivable from the control loop structures; environmental influences however remain uncertain. Such situation coverage nevertheless provides the basis for the target description of the des technical system. The parameter values obtained are available to a nominal/actual value comparison. Taking into consideration that control loop architectures are chosen to maintain equilibrium in the system and in the integration in the environment, corresponding action alternatives can be derived from parameter differences. Therewith each situation, in which acting is required, turns into an own goal that aims at the trim of the equilibrium in the control loop architecture. The system has a motive for executing a certain action. For example the vacuum cleaner could be aware of an object which it would like to clear away but the system has not enough energy to fulfil the task. Now the vacuum cleaner has a motive to load the accumulator. The behaviour in specific situations is so directed that equilibrium be restored.

For this reason, motives can be considered as effective instruments that are to support minimizing nominal/actual value deviations within a technical system [4]. To make a motive accessible for the cognitive technical system and therewith utilize it in terms of a target description, it is essential to integrate appropriate approaches into the system structure.

4 STRUCTURE APPROACH FOR THE INTEGRATION OF MOTIVATED ACTING IN COGNITIVE TECHNICAL SYSTEMS

4.1 Development of a triple system

For implementing a motivated behavior in a technical system, to an approach for system description for a motivated behavior according to Dörner shall be reverted. This approach describes how a system generally should be provided in order to possess the capability for internal and external counteraction [4]. This approach from psychology originally was used to model acting in complex situations. Though due to its cybernetic fundamentals, it can very well be transferred to technical systems [5]. The principle thoughts of the system structure of a motivation shall be introduced briefly in this chapter to then derive respective considerations for product development.

The basis for the motivation-supporting structure approach is formed by comparatively complex control loop architecture. Here are cascade-shaped couplings between control-loops are to be preferred as with that, an arbitrarily fine calibration of system parameters is enabled. Naturally, control loop architectures for different functions are established in complex systems, which up to a certain degree also operate peripheral. This function-oriented control loop architecture now is essential to be interlinked by practical information processes.

In order to understand the information process in cognitive technical system better, not only control loops and their structures are contemplated in the following, but also between the essential constituents of the control loop in general are distinguished. Of importance are then the actors that are relevant for generating action and the sensors, by means of which a situation is to be recognized and described. Both of these components are completed to a triple system by a so-called motivatory system. The sensory system combines all parameters, by means of which information is gathered from the environment as well as about the system itself. In figure 2, for this a netlike hierarchic arrangement can be recognized.

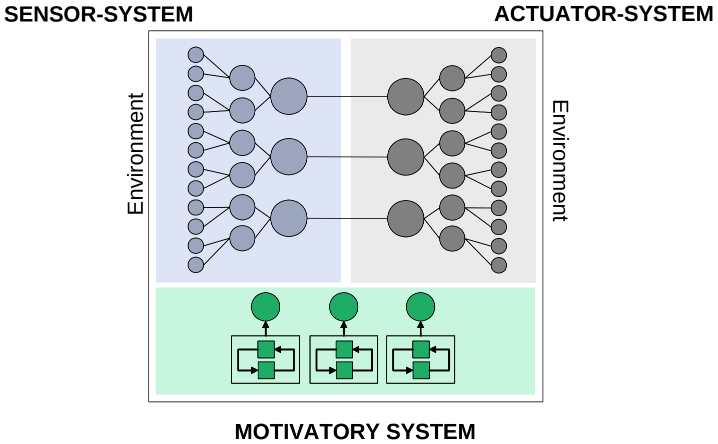

Figure 2: Triple system according to Dörner [4]

Within the sensory network, individual nodal points are linked to on/off elements that effects the nominal/actual value balancing for these parameters (according to Dörner classificators). When the corresponding parameter is within a specified range of values, the switching element is switched "on". Higher-level classificators are switched on when all subordinate classificators are in "on" status. Thereby, spatial as well as temporal relations between the situation-describing parameters are represented.

Structuring of similar type is used for the actuators. The individual possible actions are arranged in a hierarchically organized network. Each nodal point again is coupled to a switch for which similar applies as for the sensory network. Subordinate actions are exactly then activated, when the superior nodal point is switching over to the "on" condition. Important is, that for the motor-functional network it is not aimed at the individual actors themselves, but at the potential behavior patterns that can be executed by these actors.

The elements of the motivatory network in turn are simple switching elements. These provide the actual supervision of control loops. When a control loop is unbalanced for a longer period of time, the switch is activated. This indicates that the control loop is unable to adjust to a defined setpoint value and is requiring support by higher-level control loop structures (within the scope of cascade control or by behavior adaptation). Motivators can thereby be linked with the sensory system as well as with actor system. To convert the approach from the psychology in a technical application for the design and interpretation research results from designing sensors and from pattern recognition can be used. The illustration of the motivatory system as well as the description and interpretation of the actuator system get more complicated. Now an approach will be introduced for this.

4.2 Action schemata

What advantages now offers the triple system for the system architecture and the behavior description in a cognitive technical system? This is first of all to be seen in comparison to the conventional control loop architectures. By cascade control today it succeeds to correct parameters over a wide range in almost arbitrary fineness. Thereby must only be reverted to the dependencies within control loop architecture. By cascade-shaped interconnection and by purposeful coupling of flows of information, one is able to consider several influence for one parameter.

The possibilities of generating action and for action control go far beyond that by implementation of the triple structure. To equilibrate system parameters, defined actions are needed. Coupling between the sensory and the actoric system happens via so-called action schemata with the following fundamental components:

- **Expectation part**: An action a by the actoric system, which may be arbitrarily complex by its arrangement in the hierarchy
- **Conditional part**: The action is executed subject to a condition b, which is specified by the sensory system and which also can be arbitrarily complex, depending on its position in the hierarchy.

In addition to serial linking of conditional and expectation part, also parallel types of linking are possible. By combinatory coupling of elements of the actoric system with the ones of the sensory system, already with a few elements a multiplicity of action alternatives are obtained. This enables arbitrarily complicated sensorimotor regulations. Through this type of linking it is made possible to adapt actions to the most diverse situations. Action control is hereby not restricted to a simple nominal / actual value comparison. As one condition can be linked with a number of expectations as a result, actions can be adapted to different situations. In addition are the effects of the cognitive technical system on the environment ascertainable via action schemata and can be allowed for in subsequent actions.

For complex action control as described here, hierarchically structured coupling of the sensory and the actoric systems would be satisfactory. Adding the motor-functional system is the prerequisite for realizing targets and describing situations. The basic consideration according to Dörner [4] rests upon the interlinking of a motivator with the elements of the sensory and the actoric system.

A connection of the sensory system with a motivator occurs only then, when the motivator is switched "off". Under this condition, the motivator is interlinked with all those classificators, which are "on" at that moment, thus the control parameters are balanced. That condition to aspire is essential. Herewith a target condition is described, which is memorized and so available for future comparisons. Dörner calls such connections appetence relations. Described are specifications of environmental and internal conditions, which to aspire is essential. They serve as targets for the technical system.

A counter-directed type of relation as represented in figure 3b is marked by a reverse arrow for better discrimination. Now the motivators are so connected with the classificators that an active motivator is interlinked with all active classificators, thus with all those that are in the status "off". So a magnification of the disequilibrium in the technical system is registered. Thereby a situation that is to be avoided is described as an aversion relation [4].

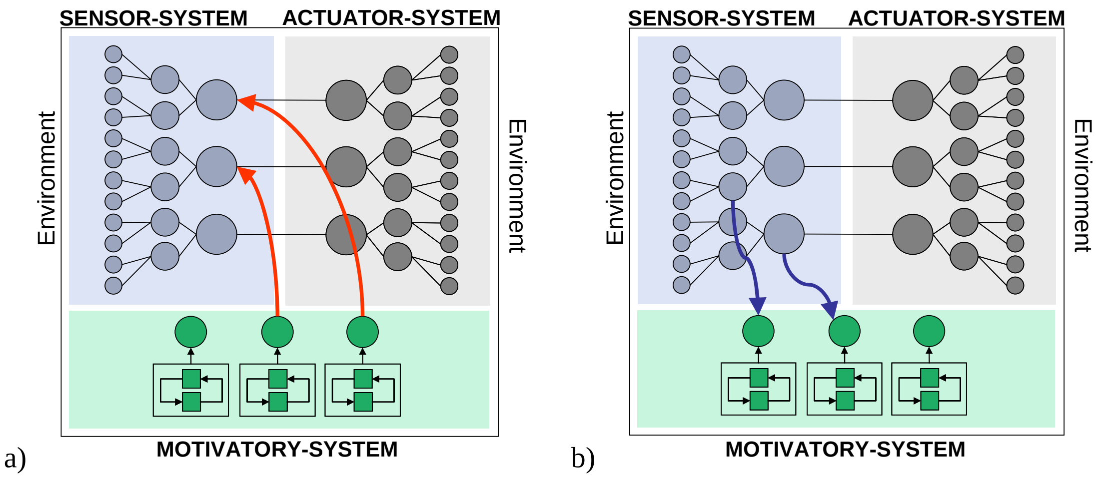

Figure 3: Appetence relation (a) and aversion relation (b) according to Dörner [4]

For the transfer into a technical system the motivatory system will be replaced by priority list, in this one the engineer describes several problem definitions, which can be occurred at the fulfilment of the system purpose. Moreover a weighting is used to guarantee the existence of the system. The partial aims are assigned to special actions. One takes this into account in system architecture the technical system can now react adapted to the situation (figure 4).

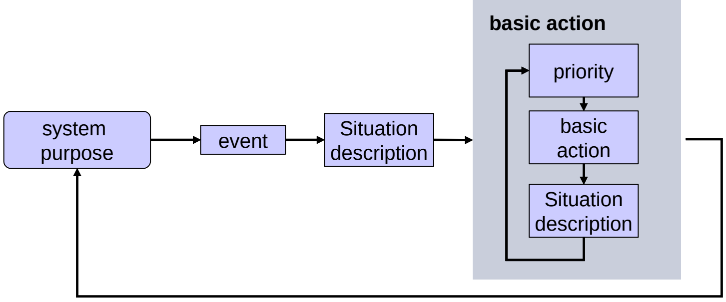

Figure 4: Descriping motives by priorities

Basic actions for the vacuum cleaner are for example the objects clear away, sucks or drives to the loading station. The basic actions which are assigned to the partial aims of the priority-list are already complex plots. The action "clear away an object" contained the actions detect object, raise the object put it into a collecting box. To refine the reaction of the system, it needs the possibility to dissolving these base actions into elementary actions (figure 5).

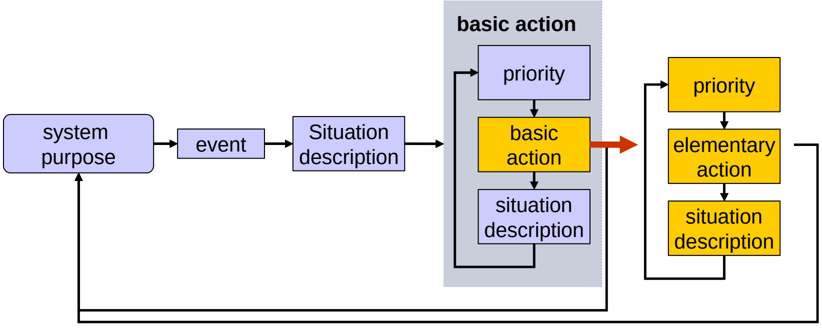

Figure 5: Reduction of basic actions into elementary actions

If the autonomous vacuum cleaner not able to clear away an object (for example the collecting box is full) it would be conceivable to fulfil this action till gripping the object, however, break off the process and vacate the object in elementary actions from the road.

4.3 Integration of learning aptitude in cognitive technical systems

As motive Dörner defines an active motivator, which is connected with a number of classificators by an appetence relation. Motivated acting means then that a behavior is stimulated, which is working towards a certain situation; other situations in turn are to be avoided. There it becomes obvious that in addition to the target description also conflict situations are acquired and can be accounted for a generation or selection of possible actions. So the triple architecture supports the system in gathering and saving of knowledge. The knowledge about targets as combinations to be aimed at of environmental conditions and internal conditions and situations of the systems to be avoided respectively manifests in the nature of linking between motivators and classificators. Can action schemata be attributed to those; knowledge about the achievement of possible goals is simultaneously representable (expectation part in the action schema). [7]

In order to implement cognitive abilities in a technical system, it is furthermore required that this system possesses learning and anticipating aptitude (see chapter 2). This indeed is not possible with the triple architecture on its own, however, this architecture approach is providing an important requisite for it. Via the definition of appetence relations, learning following the principle of classical conditioning is enabled. Classical conditioning presents itself as input-oriented type of learning, by which sensor parameters are detected and evaluated. When additional parameters to the known parameter combinations appear, they will be interlinked among each other. Thereby the action interrelating to the known parameter combination is extended by another perception parameter. This in essence corresponds to the procedure in generating appetence relations. The process can be executed as far as possible independent by the system.

Definitely more complicated will be the representation of operant conditioning, which may be described as output-oriented learning. This means that a defined parameter combination is coupled to sensor data with varying action procedures in order to optimize the achievement of objectives. So the new target situation to be achieved should faster result in an equilibrium condition of the technical system, which finally is only made possible by a modification of means (action) for the achievement of objectives. For natural cognitive systems as the human being is, this is realized by a "trial-and-error method" or by a notional running-though of possible actions. The technical realization requires systems that on the one hand operate in real-time in order to end up with a relevant action alternative within acceptable times. In addition the system needs the computing capacity for comparatively elaborate simulations, which in turn must proceed in real-time to generate and exemplarily test action variants. The triple structure is indeed in principle suitable for realizing operant conditioning (e.g. also for setting up an internal representation); however further considerations are necessary here to analyze, to generalize, and to implement typical system-internal processes in learning.

To enable deciding on basis of action repertoires, which actions reasonably are to be applied in a situation and respectively, which are possibly imperative to be avoided, mechanisms of amplification and punishment are needed, which equals a weighting of appetence relations and aversion relations.

Another rudiment for operant conditioning is on the one hand a number of action schemata and their couplings and on the other hand the knowledge about appetence and aversion relations. Therefore are action schemata of importance here because of their connections with a potential expectation. Pure actions are not sufficient, feedback to systems and the environment are needed. Also here it shows that the described triple architecture indeed is providing an efficient approach. Finally however, methods and algorithms for an effective generation of actions are still missing.

Recapitulating can be noticed that the described triple architecture according to Dörner is a decisive prerequisite for implementing cognition in technical systems in consideration of their embodiment. However, this approach requires absolutely the expansion and the customization on the technical conditions. However particularly the situation-appropriate generation of actions and with it operant conditioning for the associative regulation respectively learning by insight still require a considerable need for research.

5 CHALLENGES FOR PRODUCT DEVELOPMENT

For product development, the development of cognitive technical systems poses a number of new challenges that are imperative to be solved. By means of the integration of cognitive abilities in technical systems devices should result, which are characterized by situations-appropriate acting for the fulfillment of the purpose of the system. How system architecture may look that realizes a therefore necessary generating of goals and is able to recognize situations unambiguously and to execute actions accordingly was introduced by the triple approach.

Product development today means that the designer predefines a number of situations, in which the technical system may be employed. For these situations then, the sensory and actoric abilities are designed. Exactly here the greatest difficulties also have arisen in the context of the development of the example vacuum cleaner. Of course the designer can already think many specific situations ahead, however, a complete ahead description doesn’t get possible. Every recording of a situations means, that the technical system will be interpreted for exactly this situation. With the recording are generally accompanied a simplification (e.g. only objects of a defined size are taken, nothing else). With that the technical system loses flexibility, small deviation at the size of the object makes that the system purpose is not fulfilled. In the most unfavourable case a deviation can lead a deviation of ahead imaginary situations to a failure of system. Aim of the designing process of the technical system should rather be to provide only the action limits which it mustn't exceed.

This mastermind thinking by the designer is equivalent to a structuring of the environment since in addition to a pure description; certain occurrences are also precluded in the first place. For today's development projects, in which increasing intelligence is demanded for technical systems, this method of pre-structuring turns out to be more and more problematic. If technical systems are able to recognize, to evaluate situations and to generate respective actions out of this, a material benefit for the user and a significant simplification for product development in the definition of boundary conditions of the utilization of techniques are achieved.

This facilitation admittedly is replaced by the additional effort in the selection and structuring of system components. First of all the question arises, which parameters from the environment are at all necessary for representing the system purpose and to guarantee the performance of functions. Moreover approaches are necessary that allow comprehending the complexity of the perception as well as of the capacity to act and thereby to develop a better understanding for that what the system will be able to perceive at all. This aspect also gains then in importance when one considers that it must succeed to represent spatial and temporal relations with few sensors in a way that the operational conditions can preferably completely acquired.

For considerations regarding function support it is helpful to contemplate the behavior coupled with the respective functions. As behavior may be defined that an input is gathered (via sensors) and modified in terms of a step response, whereby the starting condition is conveyed in a target condition. This target condition must have a function for the behaving system (sub-function) [6]. The cognitive technical system needs for this purpose corresponding sensory, actoric, and information-processing components. However with regard to the cognitive abilities it does not seem to be sufficient conclude in the conventional way from properties on the design of components. More interesting seems be to focus on the behavior, thus on the equilibrium situation in the control loop.

Another point must be clear to the engineer of cognitive technical systems: the capability for acting as appropriate for a situation ultimately entails in the fact that the system will react in a way and by courses of action that go beyond the ones determined by the designer. Thereby reactions come up, which are not offhand comprehensible. The engineer initializes the system, then this system develops further, detached from the designer. That means on the one hand that in order to guarantee the existence and safety and with regard to the user and to the environment it is necessary to cap parameters. Additionally the technical system must be enabled to build up its own representation and the one of the environment. This is first of all a challenge for information processing, but also for the designer oneself. Today customary hard-coded technical systems virtually see the application environment with the eyes of the designer. Things, which the designer had not foreseen, cause faulty reactions. The view of the designer on the application environment is provided by the definition of an initial condition. The cognitive technical system however sees the environment with its own perceptive organs. It requires approaches for objectifying of different perceptions.

From the contemplations referred to it furthermore becomes apparent that ethical aspects of the application must not be neglected. At the moment where the technical system shows behavior patterns, which the engineer had not thought ahead anymore, the question of responsibility for the action arises.

Recapitulating one can say: for product development, a number of new possibilities open up by the integration of cognitive abilities, however it also shows that previous methods and approaches in development will no longer suffice. With the introduced approach of a triple architecture, an important cornerstone is laid for considering the embodiment of cognitive technical systems. It is demonstrated that the properties like situation recognition, target forming, and motivation of the system are in principle supported. Approaches for the integration of learning and anticipating aptitude are prepared, higher mechanisms of learning such as operant conditioning or learning by insight however will require further considerations to also enable their technical realization.

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