THE ARTIFICIAL RECOGNITION SYSTEM (ARS): NEW CONCEPTS FOR BUILDING AUTOMATION

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Abstract: Building automation faces a development that leads to more and more sensory information available for processing. Existing approaches are challenged by this abundant amount of data, therefore the authors see a need to introduce new concepts for handling the challenges of the upcoming future. Looking at bionic approaches taken from the field of neurobiology, but also psychoanalysis, a system is created that applies neurological principles to get human-like perception, and psychoanalytical principles to evaluate the perceived scenarios.

Keywords: Fieldbus, Sensors, Autonomous Control, Intelligent Control, Cognitive Systems, Bionics, Knowledge Representation, Image Recognition, Evaluation, Behaviour.

1. INTRODUCTION

By reading journals about Building Automation, like *LonMark* (April 2005: Building a Brighter Future), the problems in the future of fieldbus systems become visible. State of the art is to integrate many thousands of networked sensors, actuators and controllers in one system to control various processes in a building – temperature, light, motion, etc. – based on classic control loops with threshold values or similar principles. Higher functionalities, like energy optimizations or security aspects, are solved by similar control systems. It is hardly imaginable that it will be possible to handle – in particular to integrate and to maintain – a drastically increasing number of integrated, multi-functional components in an efficient and low-cost way. But we will be confronted with such high amounts of diverse sensor data in the not so distant future, especially if we consider sensor networks of thousands of intelligent nodes in products like carpets, walls or similar smart parts. We have to think about new possibilities. Of course the performance of embedded systems is increasing as well, but the question remains: Are the classic methods of automatically processing sensory input data enough? The authors are convinced that in order to answer this question we should analyze nature and try to follow its way by copying its solutions.

This paper reports about the bionic approach and the new results of the *Artificial Recognition System (ARS)* project, which was presented in Brainin, *et al.* (2004), or, more recently, in Pratl, *et al.* (2005). There, the authors argued that within the last decade the psychologists and psychoanalysts could verify that our brain does not compute current situations (images) and scenarios by analyzing *all* the incoming data from the various sensors of our body each time again and again. Instead, the human brain memorizes images and scenarios over a whole lifespan. However, this is not the only aspect we pointed out as decisive difference to the traditional thinking of engineers about human cognitive abilities and how to model them technically. The human brain is not able to fully process all incoming data in real time. The brain is only able to perceive and recognize characteristic forms of the outside world. The rest is associated with the aid of the already memorized images (Dietrich, *et al.*, 2004). The association (comparison) of the new images – which creates a mix of computed data based on inputs from the environment and internal, previously memorized data – releases emotions, which, in turn, trigger and guide the actions and reactions of human beings.

The difficult question is how we can technically implement the observed principles. Classic methods, like neural networks, fuzzy logic, knowledge-based systems, etc. are placed on the market. However, although some solutions are quite brilliant, there is no striking application for the area of fieldbus systems. Therefore the authors follow the ideas and principles of the neurologists and psychoanalysts. Of course, it is impossible to artificially construct a system, which implements every functional aspect of the architecture of the human brain, especially if we want to take over principles of the theories of Sigmund Freud. We have to take the "usual" method of engineers and start with very simple parts. A very good example for this approach is presented in a dissertation dealing with an automatic component part sorter for an assembly line (Brenner, 2001), whose realization has been a great success on the market. The first step was to differentiate between only three different components; today the system is able to differentiate between more than 100 learned parts.

This recalls the story of Kaspar Hauser (Hauser, 1995) who was shielded from the outside world throughout his entire childhood and early youth and was kept alone in a dungeon. There, he could only see and, thus, get to know, a very limited set of objects. When he finally saw the outside world with all its complexity, he had the greatest difficulties to accept this “real” world because he did not know it – in our language: He did not have a memorized image of it, and it took him a lot of time and effort to learn how to interpret all the new impressions.

If we define constraints such that our system only needs to "understand" images similar to already memorized ones, and if we only accept a limited set of possible scenarios (applications), then it will be possible to come to a "simple" solution.

As already explained in Tamarit, *et al.* (2001), the base is a hierarchical system where the inputs are symbolized at different levels. The higher symbols are the input for another processing functional unit, where complex functions are defined and actions/reactions initiated. The information flow is evaluated by emotions, generated by comparison between inputs and memorized images. So, we have to separate the ARS project in two different parts: the hierarchical lower level functions, mainly from the point of view of neurologists, and the higher complex functions, where Freud's model is taken over (Brainin, *et al.,* 2004).

2. APPLICATIONS

We focus on the development of a system, termed the Artificial Recognition System (ARS), which makes use of diverse, redundant sensory inputs in a bionic way to create a perception and consistent representation of the surrounding world. This enables the system to perform the desired functions and to attend to the required applications. In order to demonstrate the approach of our system we have chosen four applications from different domains.

Application 1: Human Surveillance System
By making use of light barriers and detectors, tactile sensors in the floor, door contacts, and stereo cameras the system is enabled to know the position of persons in a building. People are considered to be anonymous, which means that the system has no additional knowledge about their identity. That is to say, unless a person is furthermore provided with an identification mechanism (e.g. due to authentication at a security door). The system is able to provide information about a person's current and past location, so that the path of a person through a building can be tracked and monitored.

Application 2: Child Safety System
The second application we consider is a *child safety* system. The system recognizes whether a particular person is actually a child, and can monitor and guard the actions of the child. When it appears that the safety of the child may be compromised due to a hazardous situation, the system alerts a (human) supervisor.

The decision that a particular person is actually a child is based on diverse sensor information, similar to other mechanisms in the system. This includes the use of camera images to derive height and shape of a person, as well as information from light barriers that are mounted at different heights, and weight information obtained from pressure sensors to support the decision. Example situations that are classified as hazardous are: an open fire, a hot stove plate, a cupboard with open doors, or a child climbing on table. There are additional conditions and criteria that have to be taken into consideration. For example, a situation is only classified as hazardous if a child is alone and unattended (meaning that no adult is in the same vicinity). Other conditions include the facts that the fire has to be burning, or that the stove is indeed hot.

Application 3: Geriatric Care System
The third application is concerned with a *geriatric system* to care for elderly people. In this case the system is able to recognize when an elderly person collapses or faints. Furthermore, the system is able to identify and track the location of predefined objects, such as keys, glasses, and books.

Application 4: Theft Protection
The fourth application shall supervise the whereabouts of classified things. In a given room the system monitors a set of objects (e.g. books in a library) that are not allowed to be removed. In case a person takes away such an object, the system shall inform a (human) supervisor.

These applications share a common layout, in the sense that we define a number of rooms on a floor that has a layout, which is identical for all four applications. The sensors that are used are also identical, and mounted in the same position. In this way the symbolization mechanism shares a common set of symbols (although not all symbols have to be present in all applications).

Obviously the system has only a limited understanding of the world it perceives. The fact that cameras are installed does not automatically imply that the system is able to process all the information in a way that is similar to a human operator observing and evaluating a camera image. For example, suppose that a dog enters the room. This could possible be perceived as a "person" (or, at best, as "child"), since the system has no initial concept of a dog. Hence, the system is bound to make incorrect decisions if it is confronted with facts or images that are outside the scope of its capabilities. This system attribute is intentional, since it does not form part of the task that needs to be fulfilled. If we introduce a new application, which makes it necessary to distinguish animals from persons, the knowledge of the system will have to be extended.

3. SYMBOLIZATION

We have to find a way to cope with the vast amount of diverse sensory input that the system has at its disposal. We want to extract relevant information, ignore everything that is not important and use the existing redundancy in sensory information to get a stable and robust perception of the environment. Therefore we break the available information into small chunks and label them *symbols*. A symbol in this context is a concept that the system has means to operate on. It contains information that can originate either from sensory input or from knowledge of different kinds. If a symbol is created only by sensory