Microsystems on their Way to Smart Systems

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ABSTRACT

The aim of this paper is to discuss possible innovation paths from Microsystems to Smart Systems.

Microsystems combine several micro-techniques (Electronics, Mechanics, Optics, Fluidics, etc.) to new and often highly miniaturized products. In the future pure miniaturization will in many cases not be sufficient. As a next step of the technical evolution the implementation of a certain intelligence or smartness into the Microsystems has been considered. This would transform Microsystems into Smart Systems.

Therefore this paper deals with three core questions:
1. What are the requirements of Smart Systems when Microsystems evolve towards Smart Systems?
2. How will the development of Smart Systems influence the future of Microsystems Technologies (MST) and what are important fields of action?
3. What can MST learn from cognitive sciences and how can MST interact with cognitive sciences?

Keywords: Microsystems, Smart Systems Integration, Cognitive Sciences, Convergence of Technologies

1 REQUIREMENTS OF SMART SYSTEMS

Smart Systems in the sense of the European Technology Platform on Smart Systems Integration (EPoSS) are possessing self-diagnosis and sensory and actuatory capabilities. This enables them to describe and to evaluate situations. They can therefore decide and communicate with their environment. Overall these are qualities like self-organization, adaptation, individualization and personalization as well as certain autonomy.

These qualities can only be reached by using new integration technologies. The following techniques and technologies have to be integrated in a miniaturized manner:

- Autarkic energy supply
- RF technologies
- Signal recording and processing
- Preparation of own decisions

The necessary integration technologies consist out of a multitude of single technologies. Regarding the EPoSS Strategic Research Agenda [1] they are marked by:

- Heterogenity e.g. of materials and processes used
- Complexity (in the sense of its reduction!) e.g. of user interfaces and data volumes
- Scale comprehensive demands
- Autonomy e.g. by autarkic energy supply
- Multidisziplinarity e.g by convergence of technologies from physics, chemistry, engineering and cognitive sciences

For the implementation of the qualities mentioned above in future products the use of technologies from nano- and biotechnologies is not enough. This leads to a miniaturization and ubiquitous use of these functions only.

A good example is mobile phones integrating cameras, stereo systems, calendars, maps etc. today (figure 1). This will not make telephones smart in the sense of Smart Systems as noted above! Today the user has to be smart to use a mobile phone.

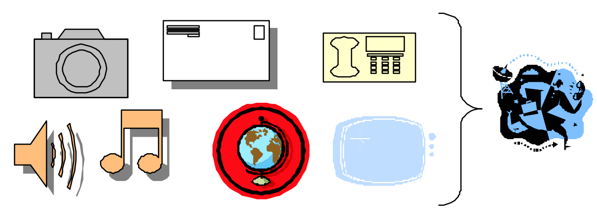

Figure 1: Today's miniaturization needs Smart Users

The same kind of problem exists for at least the majority of today's Microsystems: They are very well miniaturized but need a lot of smartness of the user e.g. when they are applied in the area of process control.

Certain intelligence and smartness may be brought to these systems by using results from cognitive sciences to solve this issue. Otherwise the development of Microsystems Technologies might end in a miniaturized dead-end alley.

On the other hand the implementation of cognitive abilities will lead to complex problems which have to be solved by cooperation of multiple disciplines like micro and nanotechnologies, cognitive sciences and micro-nano integration. This interdisciplinary approach might heavily influence the evolution of MST.

2 FUTURE DEVELOPMENT OF MICROSYSTEMS TECHNOLOGIES

How will the Smart System's demands influence the future development of MST? MST has integrated a fixed set of micro technologies (electronics, mechanics, optics, fluidics etc.) very successfully for more than 20 years. This has lead to many new and highly innovative miniaturized sensor and actuator systems. New independent engineering disciplines were born from the interdisciplinarity of MST in the past. MST is therefore considered as a motor of Convergence for Engineering Sciences. [2]

The above mentioned requirements of Smart Systems lead to the necessity to create a new knowledge body which overcomes the borders of classical Engineering. This new knowledge body has to incorporate fields like Biology and Cognitive Sciences. In consequence Engineering Science has to undergo not only quantitative rearrangement but also reinvention by using convergence processes. For the achievement of Smart System qualities the integration of several technologies and sciences is necessary. They are summarized by the term Smart Systems Integration (SSI). In fact MST will develop by integration of Biology and Cognitive Sciences towards SSI – and might be transformed into SSI in the end (figure 2).

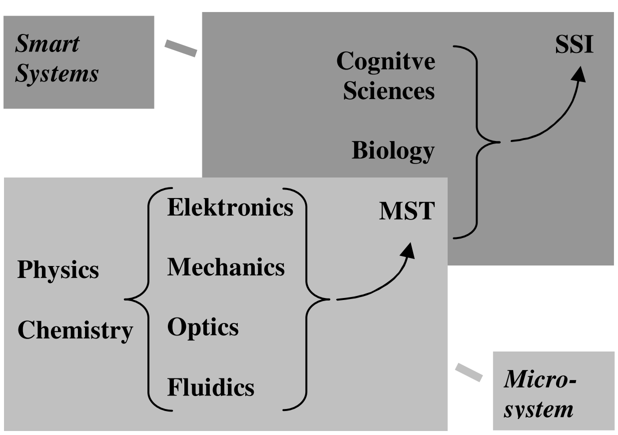

Figure 2: Advancement of MST towards SSI by Convergence of Technologies

From the above mentioned considerations about smart systems six action fields for MST may be derived:

- Integration Technologies
- Autonomy
- Networking of Autonomous Smart Sensor Systems
- Sensory Abilities
- Complexity
- Smartness & Cognition

In the following paragraphs current examples for specific topics are given out of the German Framework program Microsystems. [3]

2.1 Integration Technologies: Micro-Nano-Integration

The integration of nanostructures into micro and nano level as well as the application of effects based on nanotechnology is known as Micro-Nano-Integration. [4]

Activity areas of Micro-Nano-Integration are

- Processes e.g. for contactless assembly (self assembly, self organization) and low-temperature processes (reactive contacts ….).
- Nanomaterials- and stuctures like nano-based materials (e.g. underfiller, glop-top, solder paste, adhisives, ..), Carbon-Nano-Tubes (CNT), nanowires, nanolawn, etc.
- Equipment/ tools for the handling of nano-objects, e.g. cantilevers and grippers.

Results from research done in this activity areas will provide technologies necessary for the highly miniaturized hardware base of Smart Systems.

2.2 Autonomy and Networking of Autonomous Smart Sensor Systems

Autonomous Networked Sensor Systems (ANS) consist of single Microsystems (nodes), which are characterized by integrated sensors, local data (pre)processing, integrated (mostly wireless) communication (broadcasting and receiving) und autarkic energy supply. Often a large and scalable number of sensor systems are involved.

- Sensor networks are restricted by space and energy and self organizing.
- Cooperative data processing delivers precise results and new fields of applications.

Currently the most important problem of real autonomy is the question of energy supply. The energy needed for the receiving and broadcasting of data and information is collected from environment from light, vibration, heat etc. in the ideal case.

In Europe plenty of research is done on wireless sensor networks also with industrial partners. In general the focus lays on miniaturization and optimization towards targeted applications.

ANS will deliver the technologies for the networking of Smart Systems.

2.3 Sensory Abilities

A current topic of sensor technologies is the use of magnetic micro- and nanotechnologies using magnetic materials and effects on the level of micro- and nanostructures. They offer a lot of possibilities for the realization of sensors and actuators and autonomous magnetic Microsystems. Magnetic effects are very useful because of their robustness in harsh environments. In addition they might use much less energy and easy to miniaturize. Well established application areas are:

- Automotive e.g. with magnetic sensors for process control
- Magnetic sensors and contactless data transmission for traffic control
- Automation and process control using magnetic sensors and actuators
- Medicine technology e.g. using magnetic Nanoparticles for Bio-Analytics

Such new sensor systems are necessary to supply smart systems with "eyes" and "ears" to make them smart.

2.4 Smartness & Cognition

For the development of MST towards SSI it will be crucial to use cognitive abilities like thinking, learning and communication (speech). Systems will become smart only by using such abilities. In addition the ability for self organization and at least a certain autonomy are the base for smartness.

By understanding process of thinking and their application of technical system an interesting potential for the implementation of cognitive processes might arise.

Currently a lot of research is done to understand human brain and thinking. In the next step the results have to be transformed to machines where the restrictions in space and energy are not as hard as in miniaturized systems. First steps into this direction become visible in the research on cognitive robotics.

3 MST AND COGNITVE SCIENCES

The author sees in this action field the biggest challenges on the way to SSI because of the efforts which will be necessary to bridge the gap between MST as an engineering science and cognitive sciences as humanities.

A possible path for MST to start implementation of results from cognitive sciences might be the collaboration with the new field of Cognitive Robotics. Examples for Cognitive Robotics might be seen in the work of the German Cluster of Excellence CoTeSys [6] or the European Expert Platform "Feel Europe" [7].

In the shortly created cluster CoTeSys cognitive features for technical systems such as vehicles, robots, and factories are investigated. The aim of the project is to realize cognitive technical systems by equipping them with artificial sensors and actuators and let them act in the physical environment. The systems envisioned shall *"differ from other technical systems in that they perform cognitive control and have cognitive capabilities."* In the European project "Feel Europe" a European expert platform was created for the measurement of human feelings and emotions.

From the above mentioned thoughts the question arises: How might MST interact with Cognitive Robotics? The implementation of cognitive features might be realized either by soft- and/or hardware whereas the software might be seen as the "intelligent" part of the system and the hardware act as the sensory and actuatory part.

It is obvious that Microsystems will be necessary to provide miniaturized sensors to make such systems small enough for common use. An example from automotive industry might be the introduction of lane-keeping assistance systems with miniaturized CMOS cameras where it took over one decade until systems were miniaturized enough for common use. [8]

On the other hand today's Microsystems are small but often lack of smartness. To provide a path to Smart Systems it might be helpful to learn from cognitive robotics. Most common robotic systems have more than enough room for the implementation of software. Therefore it is very good platform to test and implement cognitive abilities into technical systems. The next step will be the stimulation of research for the implementation of cognitive elements into Microsystems.

The target of such research might be seen from figure 3. Until today Microsystems may be seen as structured into a sensory and an actuatory part which is connected by a signal processing unit.

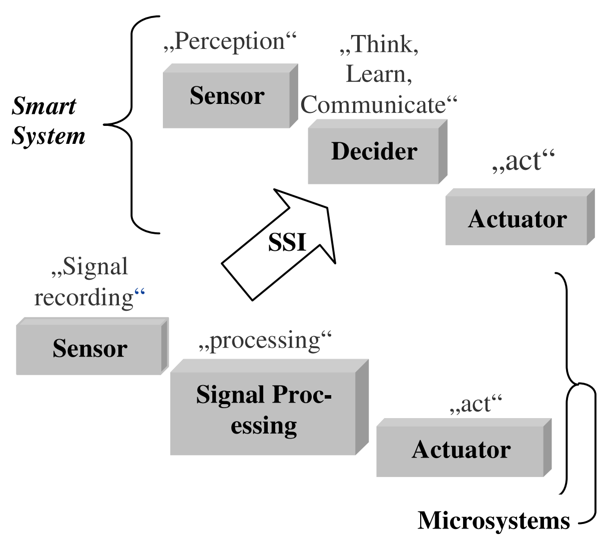

Figure 3: Influence of Cognitive Sciences on the development of Microsystems towards Smart Systems

This signal processing unit is programmed in a more or less fixed manner and therefore relies completely on the smartness of its programmer.

In the future smart system should contain a kind of "decider" unit instead which shall be able to think, learn and communicate. The development of this "decider" will be the central future challenge for the evolution from MST to SSI.

4 SUMMARY

Overall the development of Microsystems towards Smart Systems gives a chance to open a new field of research and innovation based on a bridge between Engineering and Cognition Sciences. This will promote the advancement of engineering sciences towards Smart Systems Engineering. This presentation reflects the possibilities and efforts connected with the convergence of MST and cognitive sciences. It is proposed to start the implementation of cognitive abilities by learning from and supporting cognitive robotics. The central challenge will be the development of a "decider" as cognitive heart of future Smart Systems.

5 ACKNOWLEDGEMENT

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