# UBIQUITOUS COMPUTING AND ACTION

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Abstract: *Ubiquitous Computing* is an information-view of the world, measuring physical phenomena and human behaviour with intelligent sensors everywhere and hidden procedures of reasoning, judgments and categorisations. We will introduce a concept focusing on visible action as a consequence of concrete continuation of real phenomena into virtuality and vice versa and discuss some consequences for human skills and knowledge.

Keywords: mixed reality, human-computer interaction, ubiquitous computing, ubiquitous action

## 1. INTRODUCTION

Several research communities concentrate on ubiquitous computing, pervasive computing or mixed reality, having in common a certain immersion of the computer into the real world and differ with respect to the relation between real world phenomena and the world of signs within the computer.

One characteristic of these approaches is an information view on physical phenomena and their interrelation to human actions. It is the view of technical semiotics: from a world of physical action-reaction to a world of signs. This is not surprising, because these communities very often have their roots in Computer Science and Human-Computer-Interaction departments. Signs are powerful means of world perception and change, are lightweight and they process on each other on a low energetic level.

From this view an approach can be distinguished which is more oriented towards physical phenomena and has its roots in Cybernetics and the early days of separation of the "analogue" and the "digital". We are aware of some of the multi-facets of pairs like analogue-digital and physical-virtual, which especially arise, if we try a trans-disciplinary discussion. These problems are best documented in the Transactions of the Macy Conferences 1946-1953 (Pias 2003) and have been recently reflected by Pflüger (2005). A media theoretical reflection about translations between different systems of signs and media has been given by Robben (2005). For practical purposes, we will start with a definition of Physical Reality related to the famous controversy between A. Einstein and N. Bohr about "Can Quantum-Mechanical Description of Physical Reality be considered Complete? (Einstein, Podolsky, Rosen 1935, Bohr 1935).

"The correctness of the theory is judged by the degree of agreement between the conclusions of the theory and human experience. This experience, which alone enables us to make inference about reality, in physics takes the form of experiment and measurement …

A comprehensive definition of reality is, however unnecessary for our purpose. We shall be satisfied with the following criterion, which we regard as reasonable. If, without in any way disturbing a system, we can predict with certainty (i.e. with possibility equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this criterion. It seems to us that this criterion, while far from exhausting all possible ways of recognizing a physical reality, at least provides us with one such way, whenever the conditions set down in it occur. Regarding not as necessary, but merely as sufficient condition of reality, this criterion is in agreement with classical as well as quantum-mechanical ideas of reality" (Einstein, Podolsky, Rosen 1935). Bohr (1935) and later on Penrose (1990) used a weaker definition of physical reality more adequate for quantum mechanical phenomena, but we will use Einstein's definition and apply it only to classical concepts of reality.

Another term provoking controversial debates is "virtual reality". Firstly, it is used as "imaginary" in the sense of d'Alembert's *virtual work*, a concept to calculate the physical work of a system if it would be forced to another imaginary state. Secondly, it is used in the sense of "illusion", like Newton's *virtual point* behind the mirror. Furthermore, it is used as an abstraction from some real system, like the *virtual machine* or *virtual manufacturing device* or it is used for some computer internal representation of an illusionary world, *virtual reality*. Having in mind this distinction between virtual as a mental state of illusion and virtual as a computer implementation of a mechanism (which of course is real according to our definition above) to encourage these illusions, we will use the later definition of virtual.

Today, implementations of virtuality are mostly realised on digital computers and they are connected to a discrete or continuous outside world via digital or analogue interfaces. Both types of interfaces operate on a low energy level. They intend to neglect the flow of energy. This makes them powerful for signal processing. Intelligent sensors and actuators are designed according to these principles. They control amplifications to higher energy levels via control cycles, having a feedback from the higher energetic world and a model of this world to operate efficiently and stable. The control mechanism has to "know" the outside world. It should have a model of the whole world, possibly including humans. This, at a first glance, seems to be in contrast with modern developments in computer programming concepts. Object orientation and agent architectures try to operate on local implementations of behaviour. But it is not. These agents or objects interact on a language level according to rules of conversation as long as they stay on an information level, but as soon as they want to change the physical world, at least some of them have to share a common model about the outside.

We will present a concept that differs from this approach and discuss consequences on ubiquitous automation, human-machine interaction and human skills.

## 2. FROM INTERFACES TO MIXED ARTEFACTS

Benford et al (2005) give an actual overview about taxonomies for input devices. They argue for a shift of focus from the interface as a mere support of user interaction with a given task designed by the system developer towards a focus on appliances and augmented physical artefacts bringing the design of the artefact itself more into focus. The former regards the physical I/O devices only as peripheral, the later would consider them related to everyday artefacts with all their pre-existing functionality and cultural connotations. They expect that this is a better assumption for smart environments, location-based services, and other interfaces that actively engage passing users and push information at them, where users' intentions may be less clear. They suggest a design framework for sensing-based interfaces as a space of problems to be solved and opportunities to be exploited in relation to expected physical movements and those desired by an application. This seems to be a useful orientation for applications for everyday life, leisure, play and art, not aiming at an increase of productivity. We will support and extend this view, in considering information and energy, sensing and acting in a holistic way, allowing an implementation of the border between reality and virtuality to be arbitrary chosen and distributed. At a first glance, this might look like a focus on the user as being only part of a ubiquitous cybernetic system, but this will depend on the way reality is coupled to virtuality. In fact, it might open up new perspectives of cultural specific and art oriented applications. To allow this, it is necessary to have a different view on interfaces between the real and the virtual world and on physical artefacts and their computer internal representation: a completely local view.

Consider two resistors R1 and R2, two electrical sources of energy S constituted by a high level electrical potentiality P1 and a low level P2, and three connectors T1, T2, T3. We build a system of two disconnected subsystems

P1-T1-R1     R2-T3-P2

Then a small amount of energy flows to reach the steady state within the two separated subsystems. As soon as these subsystems are connected via T2

P1-T1-R1---T2---R2-T3-P0,

a spontaneous reaction of the system in form of energy flow according to the sum of the two resistors is the reaction. But how does one resistor know from the other one? It does not, and does not need to. It strictly reacts on a local physical level, providing continuity of energy flow. That means, the resistor R1, experiencing a difference of energy potentialities at both ends, will react with a flow of energy according to this difference. This will change the potentiality at the ends until a stable state is reached. Thus, the behaviour of the overall system is established by a completely local characteristic of its components. Unless we have some special philosophical view on nature, we would argue that the two resistors are not communicating and negotiating about energy flow on a language or sign level, but on a spontaneous physical action-reaction level.

This structure can be implemented in a concept of mixed reality where only local characteristics of the components are provided. Having such local and non-informed bonds between real and virtual artefacts would allow a free explorative shift of focus between tasks and artefacts within the computer, tasks and artefacts in everyday environments and the interface devices. Chapter 4 will refer to some development in this direction.

## 3. INFORMATION AND ENERGY

Many computer applications use the computer on an information processing level, clearly separated from the energetic level of the outside physical world. If we use a simulation model, we consider it as some abstraction of real world phenomena to allow easy, fast and systematic experimentation with structures and properties of a clumsy reality. If we have a control algorithm of a machine, like a PLC program for an elevator or a CNC program for the axis of a milling machine, we consider it as a sign processing logic calculator connected to the energy process via signal layers supported by sensors and amplifiers. The computer is responsible for "thinking", the process is responsible for the work.

Let us for a moment recall the discussion of the 1940's to 50's when it was not so clear weather the separation of the mechanisms of machines (and animals) into a digital processing logic unit and a controlled electro-mechanical device was the preferable. J. von Neumann, N. Wiener and others (see Pias 2003) had long discussions about the representation of functions in digital or analogue devices. Hoelzer (1994) presents an impressive example of a controlling-controlled device on an analogue circuit level to provide fast orientation and positioning.

With mechatronics, embedded systems research, ubiquitous computing and action, these ideas are getting a renaissance. Mills (1995) developed a new type of analogue computer based on Jan Lukasiewicz continuous-valued logics and Gustav Robert Kirchhoffs experiments with thin sheets of copper to study electrical current flow and heat transfer problems, the Kirchhoff-Lukasiewicz Machine. It is argued, that this type of computer is better suited to process information from thousands of sensors reacting in real time than clocked digital computers.

This concept is interesting as it is a view on computers providing some analogy for real physical phenomena by non-digital means, by non-computing. It is an approach, "turning complex systems into machine configurations without using mathematical equations" (Hedger 1998). A further step could be, to consider a closely coupled real-virtual scenario as a behaviour generating mechanism, of which parts are embodied by real components and others by analogue/digital computers. Reality could be used as calculator or better problem-solver for "stiff" problems (those having very different time characteristics). The question arises, how this coupling of reality and virtual can be realised in a unified and flexible way. We will suggest first steps in this direction.

## 4. HYPER-BONDS SUPPORTING ENERGETIC AND SEMIOTIC COUPLING

Hyper-Bonds are certain implementations of the theory of Bond-Graphs in the domain of interfaces between the computer and its environment based on continuity of energy flows and local information and control mechanisms. Bond-Graphs provide means to represent computer internal models, the interface itself and the outside physical world. A short description is given here, more details can be found in (Bruns 2005).

Given an arbitrary system S described by a bond-graph BG with effort-flow elements: MSe (modulated source of effort), MSf (modulated source of flow), R (resistor), C (capacity), I (induction), 0 (constant effort node), 1 (constant flow node), energy and signal arcs, sensors of effort and flow, we can replace any energy connection by a subnet HB (Hyper-bond) conserving the overall behaviour and providing a mechanism to separate two physical subnets S1 and S2 connected via HB, a network of sensors and generators of effort and flow. Given such a separation of two physical networks S1 and S2 connected via HB, an arbitrary implementation of S1 and S2 as real or virtual system is possible, restricted only by signal transmission time and sensor/generator characteristics.

We can demonstrate the approach in a stepwise transformation of a simple resistor network into two networks connected by a hyper-bond implementation using 20-sim as simulator. A real prototype of this simple network has been built and evaluated by Schwarten (2005). More complex implementations, including a servo-motor design have been demonstrated on a theoretical and simulation level by Erbe & Bruns (2005).

Fig. 1 shows two connected resistors and two sources of effort in an iconic and a bond-graph representation. Applying a sine-wave generator on the left side and a cosine-wave generator on the right side, would result in a certain behavior, which can be preserved in a hyper-bond implementation corresponding to the circuit shown in fig 2. Introducing the characteristics of A/D-Converters at the measurement side and D/A-Converters at the generator site yields an implemented hyper-bond presented in fig 2 and can be extended to more complex networks containing capacities and inductivities. Applications of this technology are free configurations of real and virtual components connected through different energy bonds to form a distributed mixed reality system (fig. 3).

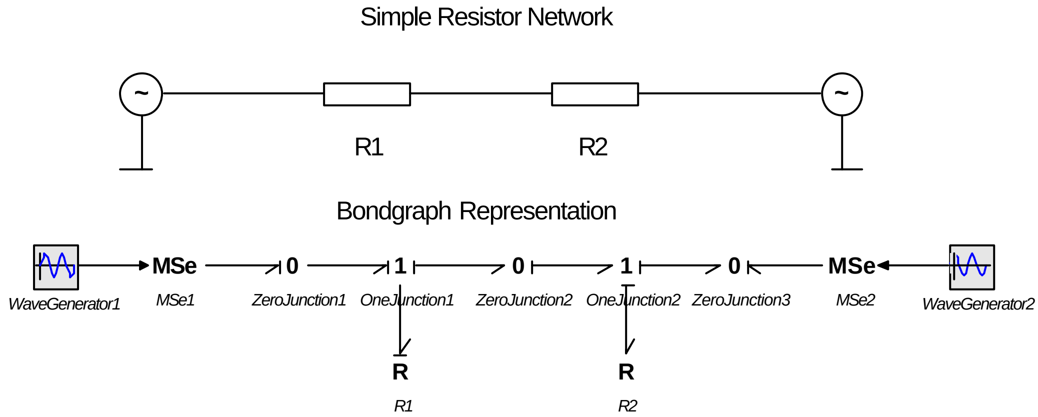


Figure 1: Resistor Network in Bond-graph Representation

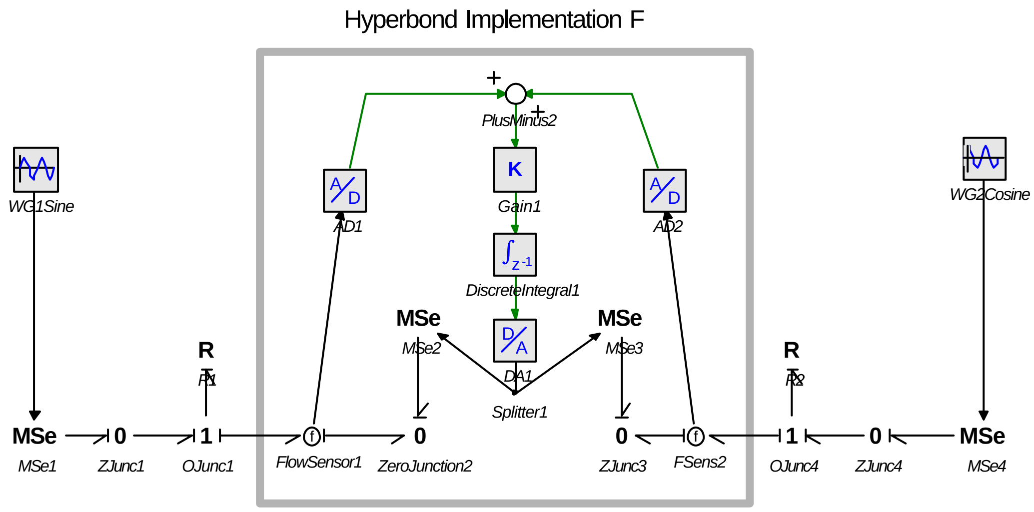


Figure 2: Implementation of Hyper-bond F (sensing flow, generating effort)

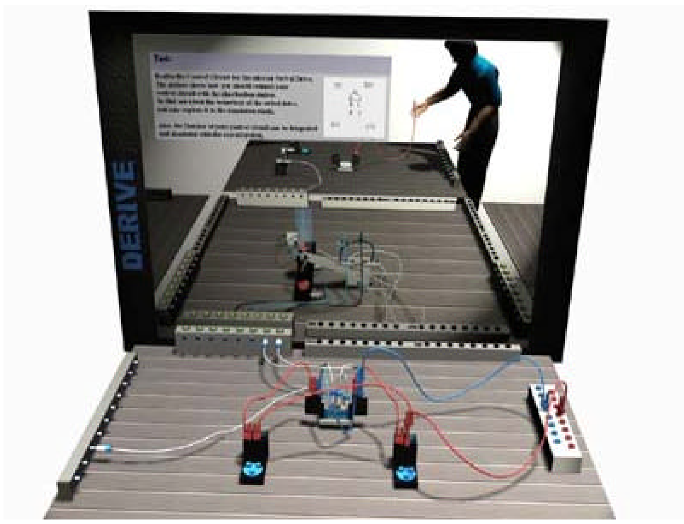


Fig. 3: Mixed Reality System

An interesting question in automation technology is: can sign processing computers replace physical phenomena and vice versa: can physical phenomena replace mathematical calculation. Of course, in a sense, the digital computer is based on physical operations and as such, any computer-simulation replaces physical phenomena by others. But that is not meant in our question, as it is not on a physical analogues level, but through some abstract symbolic representation and calculation. Our problem can be split into two parts.

1. Can a simple real technical component, like a resistor, be replaced by its virtual representation in a way that preserves the behaviour of a more complex system of which the simple component is a part?
2. If so, what are the limits of complexity and dynamic characteristics of such virtual components regarding the integration into complex real systems?

We can contribute to the first question by demonstrating a running prototype (Schwarten 2005). The second question opens up a new research field for control engineers and system theoreticians. Based on first results with simulations, we expect a broad application area of the concept (Bruns 2005, Erbe & Bruns 2005).

## 5. CONSEQUENCES FOR HUMAN FACTORS

From a human skills point of view, systems described so far and presented in fig. 3, allow the handling of abstract artefacts on a level which is closely related to the world of action and reaction and vice versa. They could support a paradigmatic shift of focus on functionality: from a clear separation between hidden information and control level running on a computer and a visible action and sensory level taking place in reality, to a unified view on a close coupling of both sides. The Theory of Bond-Graphs and its implementation in mixed realities seem to be promising approaches. Although there is a growing demand for "holistic" and flexible functional thinking in mechatronic systems design (v. Amerongen 2000), it is difficult to develop methods and tools to support students of systems design in thinking "bi-ocular", considering software and hardware, controlling computer and controlled environment as equivalent and interchangeable or reversal. The approach presented might ease the shift of focus between these two perspectives and lower the barrier to implement a function in one domain or the other.

*Ubiquitous Computing* is related to the perspective of the invisible computer, of transparency, making the system independent of size, location and physical implementation: computing power everywhere at every time. If the surrounding system of sensors yields unrecognisable observation and artificial reasoning, the possibility of misuse increases.

*Ubiquitous Action* on the other hand does not only require more knowledge about control theory, it also opens up a broader perspective on systems feedback to the user. The feedback should not only intend to improve usability (Zühlke & Wahl, 1999) but also keep the user informed about background information layers. This will be a major challenge for the education of systems designer.

A world full of sensors and actuators, controlled by distributed local devices and central computers, requires thinking in new categories of time, location and space. Although we are used to apply distributed algorithms via fast network connections, the open situation of every day surroundings poses a new challenge for adequate and adapted reaction **times**, suitable not only for deterministic automata and machines but also for human beings and natural objects. Real-time problems in machine environments are somehow easier to determine but often hard to implement. Real-time problems with humans and natural objects are more difficult to determine, they have a grey zone of possible implementations, because humans and nature are very flexible. This allows the designer to shift the burden more or less on or from the user. Domains like *Ergonomics* and *Human-Centred-Systems Design* have been related to these situations for long time and contributed to handle this dilemma: how much determinism and freedom of the machine is desirable for how much determinism and freedom of the user. But who is the user in ubiquitous computing and automation? From the consideration of well determined **locations** and persons (as if that is possible) we even have to shift our attention to open, unknown and changing locations. Mobile automation devices will be carried around in the future. Physical and social contexts are changing in an arbitrary way and have to be foreseen in some engineering sense. This requires new forms of abstract design **spaces**: physical phenomena, changing their relevance from one situation to the next, demand for unified abstract description languages like Bond-Graphs. Physical phenomena could be closely coupled to virtual phenomena to provide some means of distributed handling and control. Hyper-Bonds (Bruns 2005) are means to proceed in this direction. Awareness of privacy, safety, security has to be considered in the design and operating of these systems. All these topics are of course subject of a good engineering education, but in ubiquitous automation they get a new relevance.

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