# Concept of an adaptive training system for production

**Barbara Odenthal, Marcel Ph. Mayer, Morten Grandt, Christopher M. Schlick**
RWTH Aachen University,
Institute of Industrial Engineering, and Ergonomics
D-52062, Aachen, Germany
{b.odenthal, m.mayer, m.grandt, c.schlick}@iaw.rwth-aachen.de

## Abstract

The globalisation and the connected relocation abroad lead to a new situation for German enterprises. In order to react to the changing situation, the project "Integrative Production for High-Wage Countries" examines the research question under which conditions and with which methods and measures successful economic production in high-wage countries is feasible.
In order to find solutions, the project focuses, along with three other research fields, on self-optimising production systems. In this field a cognitive control system is emphasized. In order to cope with innovative and complex systems, workers will have to meet new challenges regarding the work requirements. Considering the effects on task performance a special training system is being developed in order to increase productivity and to support employees within the new tasks.

## 1 Introduction

One of the effects of globalisation in public view is the reduction of production in high-wage countries especially due to job relocation abroad to low-wage countries e.g. towards Eastern Europe or Asia [von Weizsäcker 2002, 2003]. Based on this a competition between manufacturing companies in high-wage and low-wage countries typically occurs within two dimensions: the production-oriented economy and the planning-oriented economy. Possible disadvantages of production in low-wage countries concerning process times, factor consumption and process mastering are compensated by low productive factor costs.

In contrast, companies in high-wage countries try to utilise the relatively expensive productivity factors by maximising the output (economies-of-scale). Another way to compensate the arising unit cost disadvantages is customisation or fast adaptation to market needs (economies-of-scope). But the escape into sophisticated niche markets does not seem to be a promising way for the future anymore.

Within the second dimension – the planning-oriented economy – companies in high-wage countries try to optimise processes with sophisticated, investment-intensive planning approaches and production systems while companies in low-wage countries implement simple, robust value-stream-oriented process chains. Since processes and production systems do not exceed the limits of an optimal operating range, additional competitive disadvantages for high-wage countries emerge.

It cannot be sufficient to only achieve a better position within one of the dichotomies "scale vs. scope" or "planning-orientation vs. value-orientation", hence the research question must aim at solving both dichotomies. Economies-of-scale and economies-of-scope must be maximised at the same time, while additionally the share of added-value activities must be further maximised without neglecting the planning quality to finally achieve a sustainable competitive advantage for production in high-wage countries.

## 2 General Research Approach

**Cluster of Excellence "Integrative Production for High Wage Countries"**

To achieve this goal the Cluster of Excellence "Integrative Production for High Wage Countries" was initiated at RWTH Aachen University. The cluster aims at contributing to an extended production theory that describes the interrelations and interdependencies between the single elements of production systems and ensures efficient resource deployment. The four main research areas "Individualised Production", "Virtual Production Systems", "Hybrid Production Systems" and "Self-optimising Production Systems" - are oriented towards the vision of an Integrative Production Technology.

The issues of optimisation and mastering complexity are addressed by the fourth field "Self-optimising Production Systems". Improving the use of cognition is the preferred way to develop and evaluate more rigorous, model based and systematic methods for reducing the dilemma of scale and scope towards an intelligent manufacturing environment.

The essential step is the application of cognitive control mechanisms. Cognitive control should enable arbitrary production processes on different production levels. Such a system will be able to obtain, store, transform and use knowledge for self-analysis and self-optimisation with respect to the mutable optimisation objectives.

**Cognitive Control System**

In order to reduce the personnel costs and to increase the system's availability and reliability, enterprises enhance the automation of the production systems. However, in doing so the flexibility of the system decreases and the expenditure during the planning phase and time of planning increase. Therefore the project part „Cognitive Control Systems" deals with the conception and development of a cognitive and „intelligent" control system for production systems which enables a high flexibility by reducing the expenditure of planning.

In order to find a solution for this research task, the challenge lies in the developing of a control system which will be applied to a concrete use case in the area of production. Under variable conditions based on insecure and/or incomplete information, the cognitive system should be able to optimise the concerned production processes either autonomously or in cooperation with the (human) operator. In figure 1 the basis of an architecture of a cognitive control system is presented.

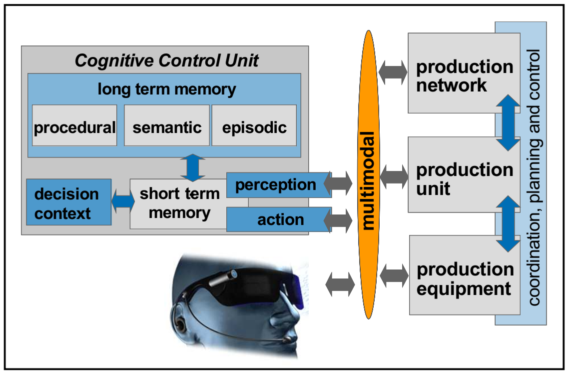


Figure 1: Architecture of a cognitive control system

Cooperation between human operators and autonomous systems in direct interaction or supervisory control requires an adequate system transparency so that the operator is able to build up a mental modal of the system's behaviour and to comprehend the system's actions.

Therefore the basic framework of this system represents an architecture which is similar to well-known models of human information processing. To enable the human operator to interact with the cognitive control system, a multimodal human-machine interface is provided.

Nevertheless, to obtain a full understanding of this novel technology, new concepts and methods are essential to improve and to build the required competence and qualification of the operator. Because of that, the project includes the development of an adaptive instrument for embedded training in order to impart the essential knowledge and the competence to the operator. Since this training functionality shall be integrated in the working process, it is essential to provide the worker with situational relevant information in an intuitive way. One solution to achieve this is the use of technologies from the field of augmented reality (AR).

## 3 Adaptive AR-supported Training System

In the field of production especially in manual assembly, there are already several AR based systems to support the worker by providing detailed instructions. That means common print out handbooks can be replaced by the use of AR-based assembly guidance (Wiedenmaier, 2004). But these systems have not been accepted in practical applications in production yet. One possible reason for minor acceptance is the fact that the system provides the same information in an identical way respective sequence for each user without taking into account the pre-knowledge, the experiences and the individual capacity of the user. Hence an adaptive Training-System shall be developed. This system will be able to adapt to the individual way of learning of each user. In order to achieve this, a modular structure is essential.

Several categories have to be taken into account developing a modular Teaching-/Learning-/Training-System (TLT-System). On the one hand the focus is on the learner with certain qualifications, competences and capabilities related to the task subject to learn, whereas each learner has individual strategies (learning type) to learn in an effective way. On the other hand, based on the task subject to learn, there are certain requirements to the TLT-System, e.g. the content of learning. The task and the learner combined with the technology used to carry knowledge, have a significant influence on the design of the learning modules. Figure 2 illustrates an integrated approach (technology and learning modules, learner and task) which finally shall result in an adaptive TLT-System.

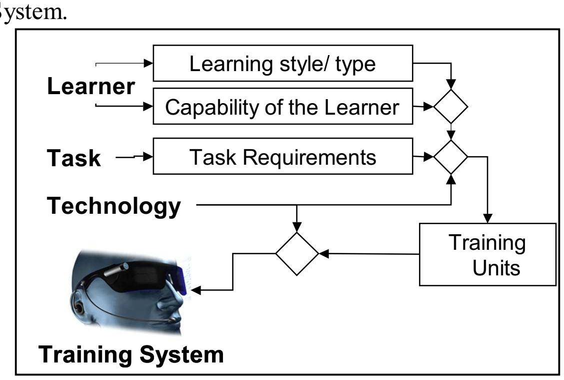


Figure2: Teaching-/Learning-/Training-System

**Learner**

Different learners often achieve different learning results under equal learning conditions because of differing previous knowledge, motivation and intellectual abilities of the individual learner. Existing/previous TLT systems, especially in the production area, provide standardised learning conditions which are independent of individual user's abilities. This implies the adaptation of the user to the system. Within this project, a TLT system will be developed which adapts the technology to the user. Because the success of the learning process is dependent on the abilities of the individual among other things, a classification of the users must be developed by means of certain attributes of the individual learning process. In the psychological and the educational literature as well as the literature of the cognitive science validated classifications of learning types and styles can be found (see e.g. Cassidy 2004). To improve and optimise the learning process, a process oriented classification is considered to be reasonable. The human learning process can be divided in four cyclic steps:

1) **Making experiences:** collection of data and information from tests and personal experiences
2) **Reflection / cogitation:** observation and reflection lead to an analysis of the meaning of the data
3) **Drawing conclusions:** abstract formation of concepts generates abstract models and mental patterns
4) **Testing of the drafts / concepts / action:** executing new operations, maximising desired effects, proofing the models, planning further steps

The learner classification according to Honey und Mumfort [1992] is based upon the fact, that each learner passes through the four steps of the learning process. However, according to the individual learning type the learner prefers different steps which are used with differing intensity in order to learn.

**Task**

Regarding the above described cognitive control system the main tasks of the operator in a production area are:

- initial start-up of the system
- monitoring system's operation
- intervention in the case of system errors

In order to support the worker in the above mentioned areas by means of the TLT-system, it is essential to present/teach not only the knowledge but also the strategies for using the knowledge during the decision-making process. The essential knowledge to perform the occurring tasks will be raised by means of a task analysis. A cognitive task analysis is applied to identify the relevant mental processes, requirements and strategies to successfully cope with the task. During the human information processing differing types of behaviour occur depending on the user's standard of knowledge and practise which can be classified by Rasmussen [1987] who differentiates between skill-, rule- and knowledge-based behaviour.

Skill-based behaviour represents the sensomotor performance of operations which occur without a conscious regulation as an automatic, uniform and highly integrative pattern of behaviour. Rule-based behaviour is defined as follows: in known working situations the cognitive subroutines are consciously regulated by stored rules. In unknown, new situations, for which no known procedures exist, the knowledge respective model-based behaviour takes effect. The action goals are formulated explicitly based on a probalistic situation analysis and personal preferences. A strategy is then developed by evaluating alternative plans with respect to their fulfilment regarding the action goals.

In order to teach and train each type of behaviour, different manners of presentation are required. The results of the task analyses are used in order to identify the best manner of presentation and to allocate the requisite knowledge, the strategies of the decision-making process and the required behaviour to tasks.

**Technology**

To integrate the learning process in the working process and to offer the possibility to work simultaneously, one possible solution is the use of augmented reality technology in the appearance of head-mounted-displays (HMDs) because with this technology the user's attention is not distracted from the object of interest when additional virtual information is supplemented in the field of view [Azuma et al. 2001; Genc et al 2002]. The superimposed information extends the reality in a way that the required information reaches the user at just the right time at just the right location.

In order to identify the specific application, different requirements must be fulfilled. For example, it is essential to know how much information and in which form the information shall be integrated, because this determines the required field of view. Beside this, the distinguishing features of the HMDs are for example the representation of virtual objects (e.g. resolution) and mechanical attributes like weight. Hence an analysis regarding those attributes has to be performed. Furthermore, ergonomic aspects have to be taken into account.

**Learning modules**

The learning modules of the modular system must be adapted to the content, the learning process and the technology applied. In order to evaluate the system, laboratory tests will be executed. The aim is to compare the success of the learning process supported by the developed system to conventional learning in order to make a statement how the success of learning can be increased effectively.

## 4 Summary

This paper describes a proposal for the development of an adaptive, AR-based training-system which is embedded in the working process. Based on an overview of the initial situation the overall research questions and the general research approach were described.

The relevant aspects of the training system like user, task and technology were discussed and the general approach for evaluation was pointed out.

## Acknowledgements

The depicted research is funded by the German Research Foundation DFG as part of the Cluster of Excellence "Integrative Production Technology for High-Wage Countries".

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