CoTeSys Progress
ACIPE - Adaptive Cognitive Interaction in Production Environments

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***Summary*— Fully automated production systems without human workers were regarded as a convincing and useful vision of future production environments. These concepts qualify for repetitive tasks in the context of mass production or where high precision is essential. If it comes to scenarios, e.g. with unforeseeable events, only humans are able to handle these events in appropriate time and with less costs than any technical system available on the market. Regarding human manual workplaces, the ACIPE-project aims at creating an assistive system which is able to give the worker needed information in intuitive ways at the right time and therefore enables a naturalistic interaction between the worker and his environment.**

Among basic research done by the project partners, three major models have been defined during the first project phase. Currently we are working on implementing these concepts.

First of all there is the *process model*, which represents the knowledge about the work plan and contains the required steps to complete the building process of a work piece. To get states of the current work step an *environment model* is needed. It is provided with different kinds of sensor data which are used to give the system status signals about the assembly step the human worker currently is in and how far the work piece has been completed. To know what kind of information the worker currently needs to successfully complete his work, a mental representation of him is also required. This is realized in the *cognitive human model* gained by experimental data combined with knowledge about ergonomic factors.

I. Current Status of the Project

Advancements

In the course of the project, a capacious framework for adaptively generating instructions for humans in manual production environments was defined and partially laid out. Research efforts from neuro-cognitive psychology, ergonomics and joint human machine action were integrated in an assembly scenario within the *Cognitive Factory*.

The overall concept (see Fig. 1) is comprised of three individual models, each yielding a distinct contribution to generating assembly instructions. The design of the system architecture, necessary to map the cognitive loop, features a *process model*, an *environment model* and a *cognitive human model*, as well as the respective interfaces and interactions. The framework offers situation-adaptive worker guidance in regard to:

- the environment of the worker,
- the content and complexity of the instructions,
- the display modalities of the instructions.

The definition of the scenario in which the above mentioned framework is embedded was developed in accordance with the other projects of the *Cognitive Factory*. The key features of the individual models to be implemented are:

- state-based mapping of the product's processing states and a dynamic determination of otherwise sequential steps
- robust multimodal observation of human activities and the production environment
- a methodology for the interpretation of mental states of the human worker, based on remote and non-invasive sensor information
- methods for estimating mental work load and human intentions in an assembly scenario
- adaptive provision of task instructions based on semantic data resulting from the process model

Interaction of the three models provides truly adaptive human worker assistance, as depicted in Fig. 1.

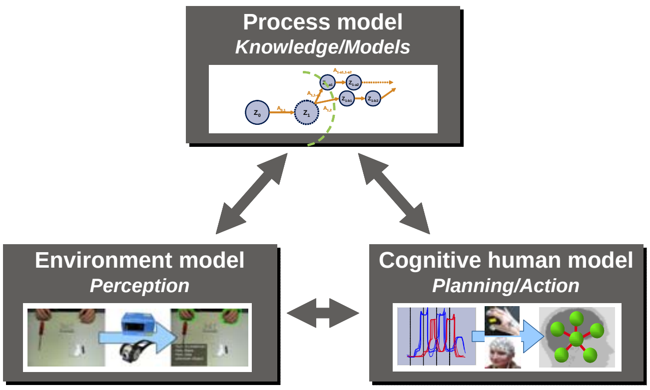

Figure 1 Framework for adaptively generating assembly instructions

In the first year of funding strong emphasis was not only put on methodically defining the above concepts, but on providing a hardware platform and setup suitable for further flexible adaptation and integration of other projects. A manual work place offering various supporting digital tools has been set up as an experimental test bed. Display techniques have been conceptualized and evaluated taking into account the constraints of the production environment. In this context, required tracking technologies have been analyzed and adapted to the given scenario. This also includes the definition of requirements for ergonomic and feasible tracking technologies. The above setup has been extensively reviewed and put to use in experiments with subjects of varying age, capability and prior knowledge of the scenario (see Fig. 2).

Figure 2 A video overlay method for presenting task instruction and registration of a grasping movement using the Polhemus marker system.

The experiments conducted have the following setup:

- mounting objects consisting of multiple parts
- variation of object dimensions and task complexity
- variation of assistance modalities (e.g. contact analog table projection vs. conventional displays)

The subjects are monitored to investigate basic cognitive processes in human manual assembly. A more detailed overview is given in the references.

Roles within the Project

System ergonomics and human modeling are the Institute of Ergonomics' major research areas. Within the project the institute's focus is on optimizing the flow of information between the human worker and its environment. The institutes' key method of information flow analysis is used to develop novel adaptive human-machine-dialogues, instead of adapting the human being to the machine, e.g. through training. Further, the institutes' competences reside in robust eye-tracking and it contributes to the sensor layer around the human worker. Experiments are conducted to gain knowledge about visual behavior.

The unit of Experimental Psychology provides tools and methods to investigate human performance in complex multitask situations and to relate specific cognitive processes to changes in the environment. In assembly tasks, experimental and neuro-cognitive methods allow for the comparison of performance under different environmental conditions and to draw conclusions about specific underlying sub-processes that are affected, such as attentional selection, working memory storage or action preparation. These measures are needed to define and generate a flexible and adaptive assistive system that provides the worker with needed and relevant support at the right time.

The Institute for Human-Machine Communication focuses its research on different types of human-machine-interaction modalities. In detail, intelligent sensors for generating an environment model are investigated. Expertise in the fields of computer vision and therewith related topics like pattern recognition make it possible to provide surveillance of the work space. The combination of multimodal observations with different kinds of machine learning techniques opens a wide range of possibilities to identify the external states of the human worker, the work piece and the environment.

In the context of the project, the research of the Institute for Machine Tools and Industrial Engineering (*iwb*) focuses on the organizational structures and concepts forming the basis of the assembly of complex goods. The *iwb* provides its vast knowledge of the domains and methods of production, assembly and factory structures for making available a flexible open and integrational framework for adaptively generating assembly instructions. Moreover, in the context of this framework, the *iwb* formulates the process model comprehending the knowledge and domain models.

Integration in the Cluster and Cooperation

The cognitive factory is one of the key demonstrators in the cluster and realizes a complex and advanced test bed, which offers evaluation of the basic research areas' results in a realistic assembly line environment. A major effort in ACIPE is put on integrating its complete framework into the factory, as well as sharing models with other researchers. The individual models and their communication protocols are based on open source software and the overall concept provides well-defined and partly open definitions of its interfaces. As such, the modular structure enables the integration of current and future algorithms (e.g. in the process model for determining the shortest path) and sub-models (e.g. modes of communication via the cognitive human model). Regarding this context, *ACIPE* closely works together with other projects of the cognitive factory: *CogMaSh* (#155), *CoDeFS* (#161), *JAHIR* (#207) and *MOHMIP* (#194).

ACIPE investigates cognitive processes underlying human performance in manual assembly scenarios. Currently behavioral performance, arm and hand motion-trajectories and eye movement are used for experimental data collection. In the future it is planned to expand these methodologies by also using EEG (electroencephalography) recordings. EEG will provide information of the brain activity that accompanies cognition in assembly tasks. The set-up for pilot investigations is currently prepared in cooperation with research group *Memory-based mechanisms in the cognitive control of uni- and multi-modal attentional selection* (#148). Investigating the relation of explicit and implicit memory processes and the role they play in attentional selection, project 148 also provides input for the experimental set-up and the paradigms used in ACIPE. On the other hand, sub-units of the assembly task (such as selecting the next relevant object) are investigated in a more controlled experimental setting in 148. The progress report of 148 gives an example of a selection task with varying context familiarity that was designed from the building blocks taken from the task shown in Figure 2.

Delivering requirements for robust eye-tracking systems in the researched scenarios is one major issue of the cooperation with *EYETRACK* (#121) and the *Ergoneers GmbH*, who are providing such systems for evaluation.

ACIPE's experimental results are the base for human mental models created in MOHMIP in RA-A and RA-E in close cooperation with the junior research group *Cognitive Modeling in Ergonomics* (#127). The human mental model, on the other hand, is combined and embedded with a process model and an environment model in ACIPE, such that a cognitive system is created to adaptively assist a human worker in the manual assembly. The gained insights are shared through participation in cross area working groups and other events.

ACIPE is a member of the working group *Nonverbal Communication* (CA4, 09.05., 12.07. and on 13.09.2007) and *Knowledge and Learning* (CA5, 17.07.2007). The project has also been presented on the CoTeSys Workshops *Cognitive Architectures* (17.09.2007), *Cognitive Factory* (18.09.2007) and *Transfer from RA-A to RA-F* (24.09.2007).

Members of ACIPE participated in the *Haptic Day* at GATE Garching (03.05.2007), *Johnnie* Workshop (11.05.2007), *Justin* Workshop (18.06.2007), represented ACIPE at *Bayern Innovativ Forum - Intelligente Sensorik* in Augsburg (21.06.2007) and presented a poster at the *Interdisziplinäres Kolleg (IK)* in Günne am Möhnesee (16.03.2007). *Transtechnik GmbH & Co. KG* in Passau (25.06.2007) has been visited, and cooperation was established to keep reference with real production scenarios.

In the course of the project, several diploma, master and student research theses have also been tutored.

Publications within the Project

A detailed description of our overall concept is given in [7], which is attached to this progress report. All publications published in line with the ACIPE project are listed below.

[1] Stork, S.; Stößel, C.; Müller, H. J.; Wiesbeck, M.; Zäh, M. F.; Schubö, A.: A Neuroergonomic Approach for the Investigation of Cognitive Processes in Interactive Assembly Environments. In: 16th IEEE International Symposium on Robot and Human Interactive Communication 2007 (IEEE RO-MAN 2007). Jeju Island, Korea, 26.-29. August 2007. 2007.

[2] Vesper, C.; Stork, S.; Wiesbeck, M.; Schubö, A.: Intra- and Interpersonal Coordination of Goal-oriented Movements in a Working Scenario. In: 1st International Conference on Cognitive Neurodynamics (ICCN'07). Shanghai, China, 17.-21. November, 2007. 2007. (in print)

[3] Wallhoff, F.; Ablaßmeier, M.; Bannat, A.; Buchta, S.; Rauschert, A.; Rigoll, G.; Wiesbeck, M.: Adaptive Human-Machine Interfaces in Cognitive Production Environments. In: IEEE International Conference on Multimedia & Expo (ICME '07). Beijing, China, 2.-5. Juli 2007. 2007, pp. 2246-2249.

[4] Wallhoff, F.; Ruß, M.; Rigoll, G.; Göbel, J.; Diehl, H.: Surveillance and Activity Recognition with Depth Information. In: IEEE International Conference on Multimedia & Expo (ICME '07). Beijing, China, 2.-5. Juli 2007. 2007, pp. 1103-1106.

[5] Wiesbeck, M.; Vogl, W.: Der Exzellenzcluster „Cognition in Technical Systems“ (CoTeSys) der Deutschen Forschungsgemeinschaft. iwb Newsletter 4 2007 (2006) 11/2007, p. 8.

[6] Zäh, M. F.; Lau, C.; Wiesbeck, M.; Ostgathe, M.; Vogl, W.: Towards the Cognitive Factory. In: 2nd International Conference on Changeable, Agile, Reconfigurable and Virtual Production. Toronto, Canada, 22.-24. Juli 2007. 2007. ISBN: 9780978318703.

[7] Zäh, M. F.; Wiesbeck, M.; Engstler, F.; Friesdorf, F.; Schubö, A.; Stork, S.; Bannat, A.; Wallhoff, F.: Kognitive Assistenzsysteme in der manuellen Montage. wt Werkstattstechnik online 97 (2007) 9. (in print)

[8] Zäh, M. F.; Ostgathe, M.; Wiesbeck, M.: The Cognitive Factory: A research platform for cognitive automation systems. In: Pfalzgraf, J. (Hrsg.): 2nd International Symposium on Multiagent Systems (MAS), Robotics and Cybernetics: Theory and Practice. Baden Baden, Germany, 1.-2. August 2007. 2007. (in print)

II. Future Proceeding

As described in the previous section, we are currently working on the implementation of the three major models, the sensor layer and the integrating framework. To give insights about the future work packages the following items summarize the next steps within the ACIPE-Project.

Process model:

- realization of process model concept in JBoss architecture
- definition of a common xml-structure for assembly instructions
- provision of an open interface towards other process planning tools
- finalization of weightings for instruction paths, making them adaptable as well
- definition of units, standard lengths and scaling factors
- optimization of shortest path algorithm in process graph
- conceptualization of method for adaptive link generation between product states

Environment model:

- integration of industrial sensors in the current framework
- identification of current state of work piece
- implementation of intelligent sensors
- integration of capabilities for machine learning techniques into sensors
- multimodal fusion of sensorial data to acquire classifiers for different states
- detection of human position and pose

Cognitive human model:

- development of natural interaction procedures with the work environment
- extension of user interface to understand multimodal input
- fusion of atomic user actions in order to gain higher-level actions
- continuation of subject experiments (utilizing EEG in addition to eye and hand motion-tracking)
- adaptive presentation of assistive information
- individualization of user interface based on knowledge gained about a specific worker

During the following period, the common interfaces between the models will be defined and functionally integrated into the overall framework.

In the third year of funding, the models will be extended by learning and reasoning strategies to enable teaching-by-expert, dynamic generation of new assembly steps and adaptation to different individual workers.