# Towards a Model to Identify the Need and the Economic Efficiency of Digital Assistance Systems in Cyber-Physical Assembly Systems

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***Abstract*—Digital assistance systems (DAS) in cyber-physical assembly systems (CPAS) encounter the challenge of increasing need for transparent and personalized information that facilitates correct and efficient execution of an individual assembly task. Risks of rising physical and psychological stress triggered by constantly changing work tasks - due to lot-size one - and the resulting issue that work routine cannot be built up prospectively in CPAS can be encountered by DAS. This paper illustrates an approach for a planning and analysis model to clarify requirements of DAS components as well as productivity values of such systems at the same time.**

***Keywords*—digital assistance system, planning and analyzing model, cyber-pysical assembly system, quality function deployment, methods-time measurement**

## I. Digital Assistance in CPAS

Assembly systems in high-wage countries are faced with the challenges of economic tackle of rising product and process complexity in terms of individualized customer needs and an aging society by demanding preservation of efficiency as well as productivity at the same time. Assembly systems as they are established in the industry currently reach their limits when encountering these challenges increasingly. By networking digital data and modern forms of information and communication technology with physical production and assembly processes, altered forms of assembly processes will be possible [1]. Assembly processes will be upgraded in this way to adapt economically requirements of costumer desired products [2].

Thereby, cyber-physical systems (CPS) realize a connection between the physical and the digital world. CPS are composed of embedded systems, which detect physical data directly by sensors and interact with physical processes via actuators. These systems are linked through digital networks and use available data and services globally. CPS are not (technically) closed units. They are defined as open socio-technical systems, which are characterized by a high degree of cross-linking of the physical, social and virtual world as well as by the intelligent use of information and communication systems [3]. By integrating CPS into assembly systems, so called CPAS will evolve in the context of complex assembly systems. It is proclaimed that hereby, assembly systems will meet the demand of volatile markets through producing numbers of different variants (lot-size 1) economically and flexibly while realizing ergonomic and meeting aging-appropriate design requirements at the same time [4].

Against the background of short cyclic changes of work content, information needs regarding the work task and the risk of excessive physical and mental stress experienced by the operator will rise in CPAS [5]. The risk of work situations that are unmanageable for the operator will increase because prior due to the design aspect of "real time", they cannot build up relevant routine prospectively. This risk will further increase in situations of system failures, such as in situations of wrong materials or breakdowns of facilities (tools) in the work station [6].

In this context, an assistance service system has a control function within a CPAS in order to compensate the delta between skill and routine requirements of a work task (performance requirements) and the human (operator) capability (work force). Operators are supported by DAS during the execution of their activities with the aim to minimize or to eliminate the described discrepancy in order to increase the productivity [7] thought-out representation of information. The primary objectives of DAS are reduction of training time, search times, operating errors and improving the work force in stressful situations [8, 9].

The functionalities of modern DAS come far beyond a sheer representation of information, but provide a real-time, synchronous, and thus situational support through networking with the assembly periphery (tools, material, work piece, etc.). This means, work instructions are automatically synchronized in accordance with work progress and without any manual interaction with the system. The assembly sequence provided therein the use of the correct work piece, the correct fastener tools, materials etc. - monitored by sensors and cameras. Through logical relations of these signals with corresponding process data, the right work instruction is provided to the operator. In case of assembly mistakes, appropriate software identifies the correct support and generates a specific information in order to have the mistake corrected right in the moment, at the right location to achieve product quality as desired. To be able to define the advantageous components of DAS already within in the planning phase of complex assembly systems, it is necessary to identify the specific DAS needs and to derive the specific requirements for technical components for an adequate provision and also in regard to evaluate the economic and productivity impact of the assistance service system on the entire assembly system.

## II. PLANNING AND ANALYSING DIGITAL ASSISTANCE

To counter economic challenges in planning and control assembly work systems, the industry followed design paradigms like "Taylorism", "Humanization of Work", "Computer Integrated Manufacturing" (CIM) in recent decades and most recently the philosophy of "Lean Management" [9, 10, 11]. The objective of Lean Management is to avoid all forms of inefficiencies, unplanned variability and overload of operators and resources [12]. Exemplary approaches in regard to increasing efficiency and productivity in the context of Lean Management are planning and control systematics by REFA [13] and Lotter et al. [10] as well as the method of Methods-Time Measurement (MTM) [14, 15]. The trends of the historical development of design paradigms illustrate the necessity to keep attention on a holistic view of the factors *human*, *technology* and *organization* within work systems [4, 14, 15].

While methods and tools currently used in the context of Lean Management are particularly suitable to improve and to evaluate the productivity of existing work systems, they demonstrate significant weaknesses in the context of a technical planning and analysis. The necessity of information provision, communication technology requirements in regard of productivity potential in the context of the complexity between human, technology and organization are not mentioned adequately [4, 15, 16].

The comparison of different variants of assembly process planning approaches demonstrates that planning and analyzing of DAS and their components, especially in regard to answering the question, what the impact of DAS on the performance of the operator and on the productivity of the assembly system (and of CPAS in particular) will be, is currently one of the key problems [17, 18, 19, 20, 21, 22]. The reasons for this are mainly based in the lack of practice proven research findings with regard to relations between the characteristic of assembly tasks, taking into account their complexity and corresponding requirements of DAS [22, 23, 24].

## III. TOWARDS A MODEL

The specific objectives of the model are focused on planning (prospectively) and analyzing (retrospectively) DAS needs in complex assembly systems in CPS environments, while taking into account, individual work tasks as well as operators' individual skills, qualifications and performance levels. The model supports the definition of technical and functional requirements for the conception and design of a DAS, concerning quantitative statements with regard to expected productivity effects on the work system. In this way, the model can be used for decision support in regard to an investment project (Output Factor). Therefore, the model is based on the systematic of MTM (Input Factor).

MTM is a system of predetermined motion systems [15] in the context of Lean Management, which allows prediction of process times within a manual work system through the analysis of motion sequences. MTM declares that the time for performing a specific work task depends on the method used to fulfill this task. The time required for the execution of a particular work task is influenced by positioning, orientation and by the weight of the provided assembly objects. Results of a MTM analysis are structured movement sequences based on 17 basic motions (e.g. reach, grasp, move, position, release, press, turn, separate, visual functions). Each basic motion is assigned to standard values, which are governed by a uniform, internationally accepted standard of performance and are predetermined in their value through acquired influence factors. MTM is a tool for the description, analysis, planning and design of work systems using standardized process modules. A process element is a sequence section with defined work content (sector neutral) and clear use, for which a time standard applies. The use of MTM provides a valid basis for the evaluation of productivity - taking into account the human capability and supports the identification of deficiencies in (manual) processes [15, 25].

Planning and analyzing of digital assistance needs, encounter methods like MTM, and related methods to their limits currently, because they do not consider requirements of modern information and communication technologies and also they do not address operator characteristics or performance capabilities sufficiently. The lack of consideration of individual actions of the production worker and the limited knowledge of the production environment (context) make it difficult to plan and to analyze DAS needs adequately in regard to the individual characteristics of the production worker [8]. Despite the lack of relevant factors, MTM is chosen as input factor for the model, in accordance with the assumption that MTM is applied already in industry and addresses, in addition to the standard time relevant indicators to derive digital assistance needs, such as information of positioning, orientation, weight and length, gripping and also indicators for the human work load [8, 9]. Furthermore, the methodology of MTM illustrates an adequate tool for a detailed analysis of work tasks and sequences of varied work tasks.

The model is based initially on two perspectives of complexity - product complexity and workplace complexity [22, 26, 27]. These complexities are calculated qualitatively and quantitatively based on the individual information from the MTM process elements and their description. by using algo-ed in the work system. The analysis is performed along the consideration areas of sensor components for information recording (e.g. sensor components for local positioning of tools and human), for information reproduction and utilization (e.g. instruction forms, signals and events, tool control, etc.)

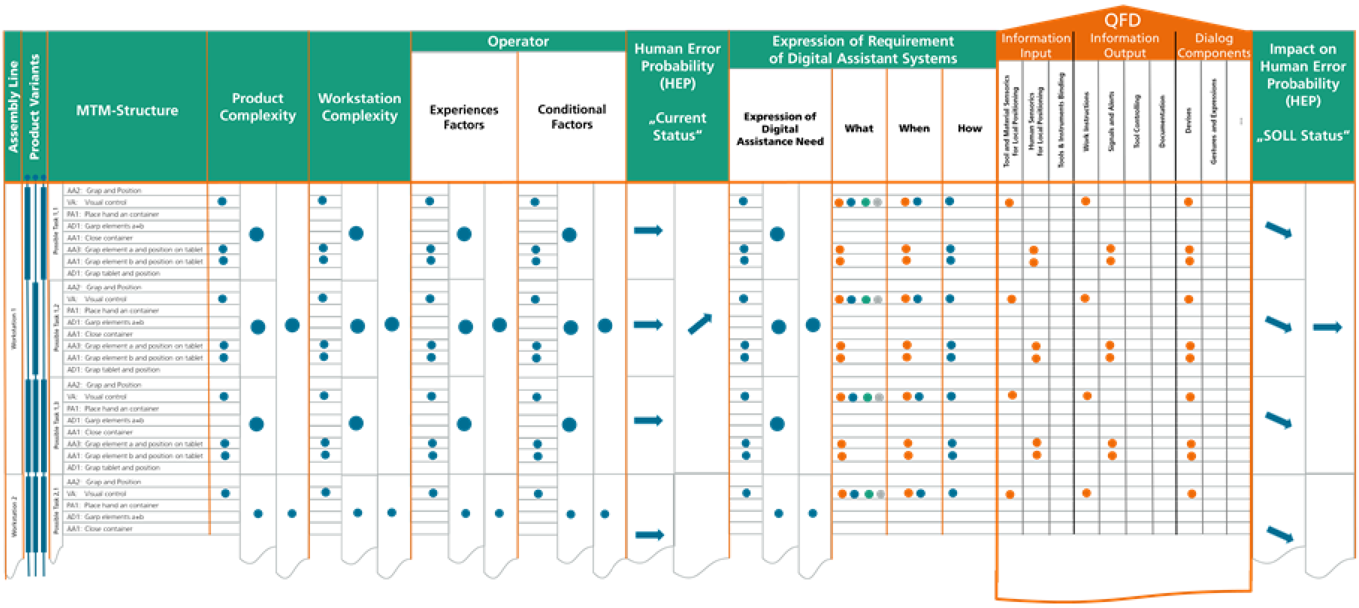


**Figure 1:** Schematic structure of the Model

rithms of data and text mining. Thereby, the analysis is carried out focused on the performance of the work task based on single steps as well as on sequenced steps - workstation specific and workstation overlapping. The level of expression provides an initialize reference to the need of digital assistance service.

In addition to this "extrinsic requirement consideration", a further analysis of "intrinsic demand consideration" is performed [22, 28]. Here, an analysis of the individual MTM process elements and the described methodical execution takes place in terms of experiences of the operators such as skills, knowhow, dexterity, etc. as well as in terms of ergonomic stress situations. In addition to the use of data mining and text mining algorithms, existing ergonomics analysis methods are applied (e.g. EAWS, KIM, etc.) [29]. Based on single steps as well as on sequenced steps of varied work tasks, an analysis of the probability of human caused failures takes place by applying the method of "Human Error Probability" [30]. Above, the connection between the MTM process elements, the probability of human errors is evaluated as a function of time and regarding monetary consequences.

Through an integrated technology database, required components of DAS will be determined in accordance with the identified needs for digital assistant services. Here, it will be derived *what* kind of digital assistant service (instruction, additional information, etc.), *when* (on demand of the operator or automatically) and in *which form* (mobile, semi-mobile and static) is required [31]. Based on this knowledge, the different features and technical components of DAS will be implemented and dialogue management (e.g. devices, controlling, etc.).

Above, a final analysis of the influence of the identified components on the human error probability and the impact on the temporal activity execution (e.g. search processes) productivity by the use of DAS in the work system are measured.

In regard to an adequate structuring and correlation analysis of the inspection fields, “Quality Function Deployment” (QFD) can be used. QFD is a method for supporting a customer oriented product development by means of a series of matrices which work similar to the cost-benefit analysis. Based on the general scheme of the "House of Technologies", different innovation and technology decisions can be derived in a holistic way [32].

## CONSULION AND OUTLOOK

This paper illustrates an approach for a model, based on MTM and QFD to plan and to analyze individual needs, components and potentials of DAS in CPAS. The concept focuses on a systematic consideration of the various process components of working methods according to cause and effect relationships along the target dimensions of DAS and in regard of individual operators’ properties and performances, in regard to identify the effective digital assistance support service level and the adequate system components. Based on the methods of MTM and Human-Error-Probability (HEP) calculations, it is possible to deduce the potential for productivity by integrating a DAS into a complex assembly system. By using the method of QFD, it is possible to create a decision support system to investigate economic advantages and disadvantages of a DAS for individual work tasks in early phases of the assembly and production system planning process. Therefore, cause and effect relationships - within selected use cases - are obtained and quantified by specific studies. The results are intended to provide conclusions to determine which findings can be derived from classical MTM work descriptions regarding a possible use of digital assistance services, as well as which information MTM process elements are needed to be supplemented. Furthermore, specific analyses are carried out in regard to cause and effect relationships between the individual process element of the MTM process construction system and the humans' (production workers') individual characteristics and capabilities. Based on these results, cause and effect relationships are appropriately analyzed and quantified within the individual MTM process element - and their sequences - in regard to the needed requirements of DAS. Finally, the results are summarized into a framework of rules, which will be described mathematically by heuristic algorithms in relation to an economic examination.

## ACKNOWLEDGMENT

This paper is supported by TU Wien research funds. This financial support to the respective authors is gratefully acknowledged.

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