Follow-Me: Smartwatch Assistance on the Shop Floor

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Abstract. The growing complexity of manufacturing calls for new approaches to support the human workforce with situation-aware information and tools which in consequence ease the process of understanding and applying work related knowledge. With this paper we introduce a theoretical model for a systematic information transfer between assistance system and worker. It defines assistance objectives and reviews the role of artifacts during the assistance process focusing on the cognitive aspects of work. Our approach was implemented using smartwatches for application in industrial assembly environments extending the Plant@Hand manufacturing performance support system.

1 Introduction

In manufacturing we are facing a dynamic work environment and continuously changing work conditions. Streamlining production processes means here to streamline information processes in order to increase not only efficiency but also manufacturing flexibility. Novel interaction and information devices, for example *smartwatches* or similar wearable technologies, allow us the design of completely new assistance systems for a manufacturing environment, specifically for the shop floor.

The paper introduces our concept of *follow-me assistance* which uses a combination of smartwatches and mobile as well as stationary computer displays to guide the worker situation-aware through his work day and through single assembly work tasks. Follow-me uses smartwatches as a means for providing awareness displays, information assistance, interaction opportunities and activity recognition.

With our approach we focus on assisting by improving information processes which finally influence the workers awareness and understanding, and thus work performance.

2 Related Work

With a continuously growing complexity of manufacturing data we witness new challenges in order to work efficiently with this data on all operational levels.

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Emerging assistance technologies address specific scopes. With a semantic enrichment of data and manufacturing information systems [1] propose smarter data logistics which are required to improve the management of manufacturing data. In addition, novel approaches, such as the *cognitive factory*, combine a high degree of self-organization and automation with the individual strengths and flexibility of the human workforce [2]. Although manufacturing efficiency and intelligence grows, it still requires information assistance which integrates manual work into the automated smart factory. Here we can found our work on long-term research which focuses on assisting workers with information and tools helping to understand work tasks and improving work performance and quality. Studies show a direct influence of systematic information assistance and the outcome of work processes. For example, Kokkalis et al. [3] could demonstrate that people provided with generated work instructions completed their tasks more quickly than people without it. Known assistance solutions bring together work related data and documents (e.g. construction plans, assembly manuals or videos) from the product design phase with production work plans, or they analyze work results in order to find quality issues.

3 Approach

Follow-me is founded on a theoretical model which describes the information transfer between assistance system and worker through the use of artifacts. This model helps us to understand the implications and limits of assistance technologies. It consists of:

- hierarchical *information objectives* which define the degree of required information and tool assistance,
- *assistance artifacts* which mediate both information and tool between assistance system and worker, and
- a formal *process model* which describes the dependency of information, knowledge and work process as well as the transitions of data, information, knowledge and the work product.

The next sections introduce basic concepts of our theoretical model followed by describing our approach in more detail.

3.1 Objectives

Similar to formal education processes, information assistance can be understood as an informal way of learning facts (*what*), procedures (*how*) and concepts (*why*) required for a specific task. Here we can apply Bloom's taxonomy of educational objectives [4] and their revision by Anderson and Krathwohl [5] which lead us to more general knowledge objectives with respect to the cognitive processing of information: *remember*, *understand*, *apply*, *analyze*, *evaluate* and *create*. At least the first four objectives are hierarchical. Thus, the objective *apply* includes both objectives *remember* and *understand* for example. They describe basic competences to be achieved by systematic information assistance. In table 1 we show how educational objectives can be applied to the manufacturing work domain for structuring the information process, defining assistance goals and deriving assisting information and tools.

Table 1. Application of educational objectives for supporting assembly tasks

Objective	Description	Example
Remember	memorize and repeat the information	remember a work instruction and tools as well as material to be used
Understand	summarize, re-structure and reproduce the information	understand the sequence of assemble steps of an instruction
Apply	use the information in a new situation	execute the work instruction to assemble in described order using correct tools and material
Analyze	deconstruct and compare the information e.g. for problem solving	adjust the assembly order in case of a modified construction part
Evaluate	review and judge the information	examine the practicability of a new assembly sequence
Create	produce new information from information	define a practical assembly sequence for a new construction design

Depending on specific work situations and the work tasks to be carried out the assistance system needs to vary information objectives in order to provide the worker with required information and tool assistance. Both can be based on assistance artifacts which are introduced with the next section.

3.2 Assistance Artifacts

Each technological system which provides assistance to a user works through the mediation of support by using physical or virtual tools and representations - *artifacts*. In literature, there can be found a wide range of research addressing the nature and role of artifacts in human computer interaction. Bødker and Klokmose [6] give us here a very detailed overview on the lifecycle, dynamics and ecologies of artifacts while focusing on the relationship with human activities. Following their definition, we understand assistance artifacts as any tool or representation which is used as a *mediator* for the purpose of assisting the user. In manufacturing such assistance artifacts can be work orders describing the tasks to be done, additional documents (e.g. construction plans, assembly guides), annotations on material to be used, the work tools themselves, or machine displays with progress details. Even a component to be built mediates information about its' current configuration and assembly state. It depends on the abilities of a worker to perceive, understand and interpret the given information correctly.

Each artifact is used to provide awareness about required information pieces or to support the operational execution of single work tasks. The more artifacts are designed to fulfill a specific assistance purpose within the context of work, the better they integrate with existing work processes and the easier they can be applied by the worker. Thus, it is important to know work context and situation in detail in order to provide suitable tools and representations, especially in dynamic work environments with changing conditions.

3.3 Process Model

We must understand that an effective work process requires first the successful acquisition, interpretation and application of work related information including organizational collection, filtering and provision of data sources [7]. Each physical work activity implies cognitive activities in order to consume and apply available information to the work task.

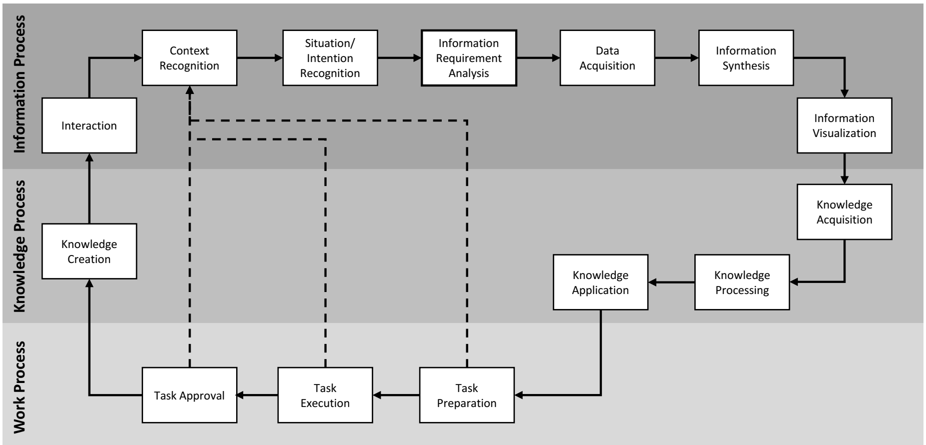

Fig. 1. Simplified assistance process model combining information, knowledge and work processes

We use the relationship between physical and cognitive work in order to design an *assistance process* (see Fig. 1) which provides the worker with required information and influences both his knowledge and work processes and subsequently his work performance. The process model focuses on the information transfer between assistance system and worker. Within the information process *data* from heterogeneous sources is collected, filtered and processed in order to create a situation adequate representation. Then, this *information* is transfered from assistance system to the worker using suitable artifacts. Once it is perceived by the worker, the knowledge process starts, beginning with acquiring and processing *knowledge* from the given information. It ends when the worker is able to apply the knowledge to a work task. The work process consists of preparing the work task, executing it and approving the *work product*. New findings or conclusions from the work process lead to new knowledge which is finally feed back to the information process through an interaction with the assistance system. In parallel, a context recognition acquires data from the interaction or from the ongoing work process for a following situation and intention recognition which is the basis for the information requirement analysis.

The assistance model in Fig. 1 shows a simplified circular sequence of process steps which reproduce the technological and cognitive information transfer between assistance system and worker. There are also direct connections between work steps and information process steps. They illustrate the continuous analysis of work situations by the assistance system.

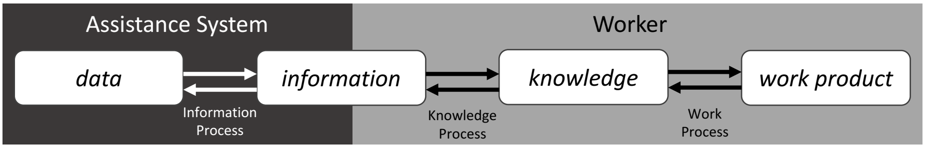

Fig. 2. Transition process of data, information and knowledge between information, knowledge and work processes

The assistance process causes transitions between data, information, knowledge and the work product (see Fig. 2). While an assistance system can only support transitions between data and information, the worker's cognitive processing transfers information into knowledge and through the application of knowledge into a work product. This shows in consequence the need for efficient and effective information processes which finally influence the quality of knowledge and work processes. Here, it is our intention to enrich the information process and assistance artifacts with *contextual information* in order to ease the workers' perception, cognitive processing and application of information and thus to improve his work performance. The next section introduces the assistance design which is derived from our theoretical approach.

4 Assistance Design

In manufacturing we find similar conditions on the shop floor in comparison to ambient assisted living homes. Although the work environment is normally more dirty and noisy, the worker is in continuous movement and not restricted to a single workplace. This leads to situations in which assistance artifacts need to be allocated close to the worker in order to allow an interaction or visualization. Computer terminals can already be found in each assembly group or line. They are used to provide access to work related documents (e.g. work plans, construction details, machine programs). However, with *follow-me* we aim to be much closer to the worker and his surrounding work environment, close enough to assist him while he assembles a complex machine. For this reason, we concentrate on an accompanying form of information assistance at the workplace which:

- *keeps aware* of the changing physical and virtual work environment including information updates,
- *filters and visualizes* required information for current and upcoming work tasks,
- *balances* the information amount and level of detail to avoid cognitive overload situations, and
- *recognizes* work situations in order to improve the quality of the information demand analysis.

Novel developments in general and wearable devices in particular allow us the design of assistance artifacts which stimulate the information transfer and can be worn even at the workplace. We use *smartwatches* in combination with additional displays at the interface between assistance system and worker. They allow us a non-obtrusive work assistance using familiar technologies. Fig. 3 shows the abstract sequence of information and interaction displays to support assembly tasks on a smartwatch.

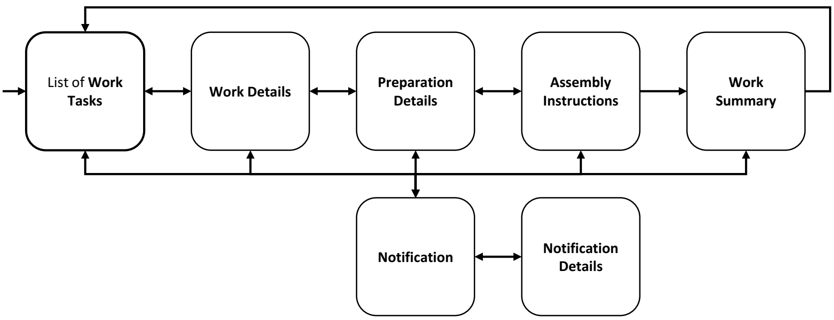

Fig. 3. Information design for smartwatch based assembly assistance

The assistance user interface is designed to provide following assisting functions:

- *awareness display:* emerging occurrences (e.g. new work tasks, incidents) in the work environment which have an impact on the worker or his current and upcoming work tasks are brought to attention by the smartwatch allowing him to align his own activities accordingly.
- *information assistance:* for each work task related manufacturing data, required information and work instructions are collected as well as presented adapted to the given work situation on the smartwatch and an alternative display.
- *interaction:* the smartwatch is used as the main interaction device for working with the assistance system reducing the distraction from work tasks. Hand gestures control the visualization of information (e.g. construction models) or allow simple commands and feedback.

- *activity recognition:* the worker's progress and activities are monitored by collecting and interpreting data from his interaction with the assistance system and acceleration data from the smartwatch (bodily movements).

With *follow-me* we propose an *interaction design* using the metaphor of step-by-step guidance. Work tasks and instructions are generated by the assistance system in advance. It then transfers the information to the worker on two different levels. On *macro-level* the worker is made aware of planned work tasks and occurrences in his work environment which influence his own planning, on *micro-level* he finds step-by-step instructions and related information on how to carry out a single assembly step. Depending on the *work situation* (e.g. task, urgency, impact), *information* to be provided (e.g. instruction, construction plan, how-to media) and the available work *environment* (e.g. tools, displays), we automate the virtual information preparation and physical information distribution at the workplace. Thus, the information follows from one workplace to another not only through the smartwatch, but also by delivering it on additional available displays there.

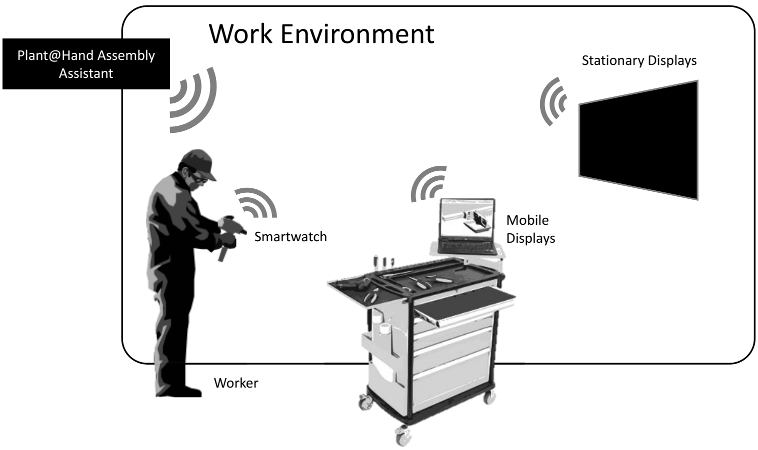

Fig. 4. Schematic setting of industrial application scenario

5 Industrial Application

Our proposed follow-me assistance approach was implemented using different smartwatches (Metawatch STRATA, Sony Smartwatch) as an functional addition to the *Plant@Hand* manufacturing performance support system [8]. The *Plant@Hand Assembly Assistant* collects information from the work environment and distributes required visualizations to the smartwatch an available displays (see Fig. 4).

From analyzing sensory input we make estimations on current activities of the worker and a forecast on his next intended work step. This is the basis for displaying helpful assembly information (construction details, assembly instructions, etc.) in his physical environment. In [9] we describe the formal models and our technological approach for this situation aware information provision in more detail.

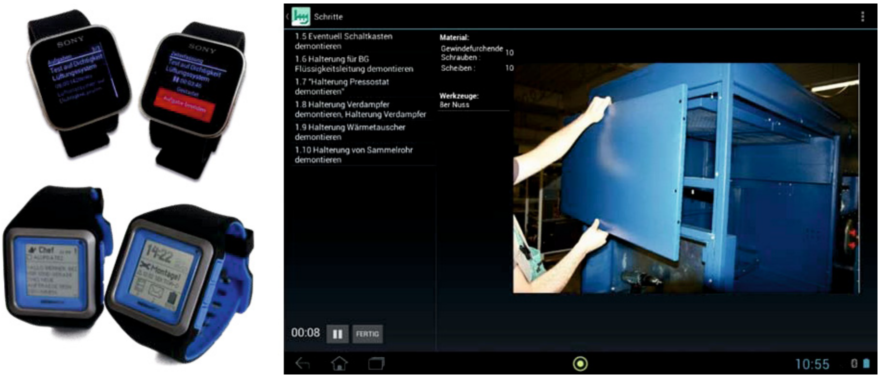

Fig. 5. Plant@Hand assembly assistance application on Sony Smartwatch, Metawatch STRATA (left) and on display (right)

We use both, stationary and mobile displays to enhance the limited abilities of showing information on smartwatches. The smartwatch display is used to provide a small subset of situation-dependent information (e.g. planned start time of next work task, instruction detail) in addition to larger displays which provide more details. If the worker changes his workplace, the provided assistance follows him to his next location. Additionally, we use the smartwatch in this setting as main interaction device with information. Thus, information can be changed and submitted using hand or touch gestures.

6 Conclusions and Future Work

The Plant@Hand Assembly Assistant was designed to support all assistance objectives as described in section 3.1. It supports the step-by-step instruction of single assembly steps as well as the creation of new assembly sequences. Both smartwatch and additional display can be understood as maim assistance artifact used for the information transfer between assistance system and worker which follows our introduced process model (section 3.3). Further work is required to evaluate the influence of our proposed assistance methodology on the overall work performance in comparison to alternative approaches.

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