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Enabling live data controlled manual assembly processes by worker information system and nearfield localization system

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Abstract

Existing localization solutions cannot be directly integrated into production systems. This article describes a nearfield localization system which can be installed on tools due to its small dimensions. Live data controlled manual assembly processes are enabled. In combination with worker information systems, the manual assembly process can be supported more precisely compared to common systems. The benefits are shown within product-specific assembly scenarios. One benefit is enabling work out of sight (non-visible range) guided through a virtual model on a screen. Error prevention (zero-defect assembly) can be realized by monitoring and matching the actual position to the assembly location. Even without augmented reality devices, comparative 3-D representations of real and virtual world are feasible, supporting employees in mobile workshop with complex repairs. In particular, difficult accessibility can be easily determined when carrying out maintenance work by knowing the complete product structure.

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1. Introduction

Manual assembly processes are very important in today's production as the cognitive abilities of humans are necessary for customer individual products and a rising number of variants per product [1]. There is a lot of research work concerning worker guidance. This results in the creation process of worker information during product development [2]. This is also true for virtual validation [3] and qualification processes [4]. Several ideas lead to a concept of digital information provision instead of paper-based documents [5]. Augmented Reality (AR) was introduced for worker guidance [6][7] as well as web-based systems [8]. In industry, worker information systems (WIS) are widely used. Most systems have a direct connection to the intranet of a company and provide information on a fixed screen next to the workplace. There are little variations of these standards.

1.1. New industrial information concepts

Expressions like cyber-physical system or Smart Factory in the context of the fourth industrial revolution (Industry 4.0) indicate a fundamental evolution in industrial production. Also for manual assembly, the integration of informational flows from Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) to shop-floor and back have to be adapted to the new concepts. There is requirement for information efficiency [9] in order to cope with the challenge of a large volume of information. Another development is the direct access to worker's movements. In planning phase, a Motion Capture System (MCS) can be used for tracking assembly movements [10]. However, this technology is not applicable during series production. An optical method to obtain the worker's postures is presented

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in [11]. Another option is a radiolocation system to have direct access to position and orientation.

1.2. Need for action

Most existing localization solutions cannot be directly integrated into production systems. Either their accuracy is not high enough or their devices are too voluminous and, thus, only suited for mounting on vehicles. Some systems are vulnerable to disturbance in production environments. Based on miniaturized electronics assemblies for radiolocation systems, modern assembly and interconnection technology is able to facilitate nearfield localization in assembly lines. This contributes to a real-time connection between real production and virtual images in corresponding service provision. [12]

To have a concrete example for a production process, screwdriving as an example for a joining technology is chosen. There are discrete screwing locations to evaluate the accuracy of a positioning system. The screwdriving technology needs a distinct mapping between the assembly plan and the real production in order to guarantee product safety and quality. Existing localization systems based on ultra wideband (UWB) can only differentiate screwdriver locations among single workplaces [13]. Further, ultrasonic and optical localization systems have a resolution up to a few centimeters. There are commercially available ultrasonic systems such as Quality Assist from Sarissa GmbH or a corresponding low-cost variant resulting from a research project [14]. The latter is suited for locating the worker’s hand or tools. The functionality is proofed in laboratory environment but not in industrial production environments. In general, ultrasonic systems can be disturbed by sound sources such as pneumatic nut runners. Optical localization systems are commercially available. An example for a research-based system is light-responsive radio frequency identification (RFID) for fastening screws with cordless screwdriver in manual assembly verification [15]. This approach does not only depend on optical sensors but also on inertial sensors. This is comparable with our approach using a Motion Capture System for virtual validation of manual assembly processes [10]. Both approaches are only suited for planning phase, but not for production. Besides, pure optical systems are susceptible to interference by dust, steam or smoke.

Commercially available screwdriving systems consist of a controller, an electrically or pneumatically powered screwdriver and a display for workers. In general, these systems can differentiate among screwing locations by mechanical positioning systems and feature appropriate control programs. Regarding the data representation on screens, text or tables combined with engineering drawings are mostly used, but 3-D models are not usual. An example for the latter is provided by ZF in cooperation with Atlas Copco.

There are reasons for a detailed worker guidance and recording of screwing locations. The screwdriving process is very safety-critical and important for product quality. Data for each screw hole and its relating joining process is relevant.

There is a demand for zero-defect production [16]. This goal can be reached through quality control of raw material, visual control of workpiece and in-process actions such as real-time loop controls [17]. For the latter, all steps of machinery or worker interaction have to be detected. In one of our cases, a distinct assignment of work step to the joining location is necessary. The parameters of the device controller are also available for analysis. Thus, predictive maintenance methods based on these parameters are feasible [18].

In Industry 4.0 respectively Industrial Internet, there is a demand for connected devices. E. g. a screwdriver can be embedded into networks via cable or wireless local area network (WLAN). However, the question for positioning is not solved by that. A localization system for traceability is a precondition so that a screwdriver has awareness of his current status und is able to offer services based on his status. [19]

Manual working processes are in the focus of efficiency improvement. In contrary to machine data recording, the method of analyzing efficiency of manual work is not obvious as some actions are not traced. The travel paths of workers between workplace and central feedback terminals are often long and time-consuming (see Fig. 1). It is not clear how often a worker goes to the terminal and how long he stays there. A personal device next to the workplace spares several travel paths as a worker has access to current information and can immediately give feedback. In this case, the waste of working time is avoided. This finding is a result of industrial practice and contributes to the concept of zero-waste.

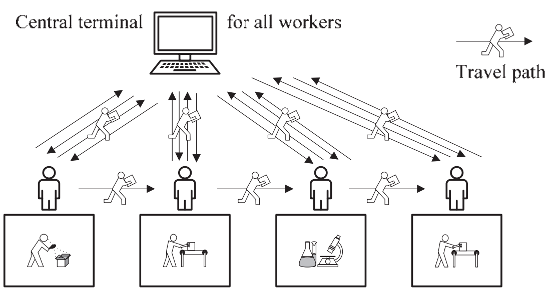

Fig. 1. Frequent travel paths to central terminal for giving inputs.

2. System approach

The use case in the project “Wireless Localization of Systems in Production and Assembly Lines” (abbreviation NaLoSysPro) is a screwdriving process combined with manual assembly steps. Our demonstration scenario is a manual workstation with a manually guided nut runner. The use of autonomous positioning systems based on radar for joining processes within manual assembly is one of the main goals (see Fig. 2). One further objective is the miniaturization of electronics for the transponder on the screwdriver.

The research work also covers an innovative locating with accuracy down to one screwing location as well as an intuitively understandable 3-D visualization of target/actual comparison. In contrary to the above-mentioned, commercially available systems, we derive the actual data sets from 3-D computer-aided design (CAD) models (see Fig. 2). Thus, we do not need to take photos or teach each screwing