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Enabling manual assembly and integration of aerospace structures for Industry 4.0 - methods

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Abstract

Digitalization is continuously entering production. However, most concepts are dealing with sensor integration and actuation as well as inter-machine data exchange and communication. They are therefore mainly useful in production areas, which are highly automated already. Aerospace industry is, comparable to the assembly of other large technical structures like railway-cars and machine tools as well as steel and plant construction in general, driven by manual assembly. The aim of the presented research work is to develop methods that make more use of digitalization in these production areas. As a real-time interface to digital planning and numerical decision-making, numerous ubiquitous computing devices such as smartglasses, tablet computer and smartphones are evaluated. Graphical user interfaces for data representation and devices for data input are developed and tested specifically for the needs of production areas. Functioning as a back end, a planning algorithm is being developed, which will be able to answer requests and fault reports by the worker immediately. It is based on graph theory to represent the planned assembly sequence as well as a set of rules that allow real-time decision-making by balancing between alternative actions. The assembly and integration of Ariane 6 upper composite in the Ariane Group plant in Bremen is being used as a case study.

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Keywords: Industry 4.0; manual assembly; smart computing

1. Initial situation and rationale

Industry 4.0 (I4.0) comprises a wide range of new possibilities in terms of interaction and communication within production systems. It is foremost driven by the development of information technology and aims at the increase of efficiency, quality and output by using more and better real-time data, autonomous decision making and coordination.

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Recent research and applications however focus on machine tools and material handling systems, the connection and communication between equipment and planning systems [1,2] as well as sensor data and protocols [3,4,5]. This is reasonable because machines and manufacturing systems are often already equipped with sensors, computing and networking capabilities and represent therefore an ideal platform for the above concepts and aims. A typical field of application is mass production, as it is the case in automotive, electronics and consumer goods industry for example. In a wide range of industrial branches on the other hand production is driven by manual work. Especially the production of large structures, such as aerospace components, railway cars, busses and special purpose vehicles but also machines and machine tools in general is difficult to automate. Reasons are the dimensions of the product itself but also complex assembly sequences, a layered buildup and the difficult accessibility of inner areas. Another main reason for a low level of automation is often a comparably low production rate, which leads to a long period of amortization for non-recurring.

But still there is a large potential for the use of digital support systems, especially in aerospace industry, because of the following characteristics of this industry:

- Complex products, complex assembly sequences, complex work orders and installation drawings,
- Large work-orders processed by skilled workers,
- High effort of quality reports and documentation.

The key question therefore is, how is it possible to connect working staff on the shop floor to real time communication and decision making of computing systems and networks, following I4.0 concepts and ideas. This can lead to several important improvements compared to typical workflows in aerospace production:

- Paper based documents like drawings and work orders must be physically exchanged in case of a new release. An electronic device is able to display the actual data from the database and any earlier version at any time if required.
- If a problem occurs, cause and solution can be communicated in real time. Paper based workflows include manual change and reprint of documents and often take days or even weeks.
- An electronic device has multiple sensors to send pictures, videos, speech and even positional data. Furthermore, it has the ability to display not only text but drawings, pictures and 3D models. This is useful for in-process documentation.

However, a number of obstacles must be overcome to make full use of these advantages. One approach to make I4.0 accessible in manual assembly is presented here.

2. Concept and structure of the developed solution

Two main aspects need to be investigated to solve the described task. On the one hand, data exchange between working personnel and computing networks must be realized in a practical, stable and ergonomic way. Mobile computing devices are broadly available, but handling, display size and user interfaces have to be appropriate for a use within a production environment with varying light and noise levels, dust and dirt. Input and output must be easy and reproducible to maintain user acceptance. The use of any devices should be mostly hands free. This involves the specification of appropriate mobile computing hardware, network connections, its display and operation concepts, graphical surfaces as well as the utilization of sensors such as cameras and microphones. In this research all related aspects are summarized as front end.

On the other hand, the capability of real time communication leads to the demand of real time decision making. If the worker sends any data regarding its status or actual fault reports it should be possible to react automatically by answering for example with a new work order or a solution to the problem. This requires an algorithm based numerical decision making method. An approach based on graph theory is developed and presented. Adequate work flows are necessary to enable real time capability of the overall system. The related aspects are summarized as back end. These two aspects are the initial questions for the research work described in the following paragraphs.