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Standardized coordinate system for factory and production planning

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Abstract

The Institute of Industrial Manufacturing and Management IFF, which is affiliated with the University of Stuttgart in Germany, has developed a continuous factory coordinate system for adaptable production systems and implemented it in the learning factory "advanced Industrial Engineering" aIE. The factory coordinate system merges the digital image of the factory (digital shadow) with the real production process practically in realtime and independent of scale. To achieve this, diverse data acquisition systems are grouped into a classification system on the basis of the degree of accuracy required; depending on the degree of resolution, the data collected is then merged chronologically in a standardized coordinate system according to time. The resulting digital shadow of the complete production plant enables the complexity of tasks in the system to be reduced. Any decisions that need to be made in the near future can be aided by performing centralized or decentralized simulations with realtime data. This enables systems to be adapted to new restrictions faster and more cost-effectively. By projecting the digital shadow onto the real production system, any discrepancies are identified immediately, any problems rectified and downtimes reduced even before they arise. This strengthens and safeguards the competitiveness of networked factories in the future.

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1. Introduction

Due to rising product individualization and shorter product lifecycles, the processing industry is being faced with constant change, particularly in the field of manufacturing [1,2]. This external market complexity can only be countered with an equally high degree of internal company complexity [1,3]. This degree of internal complexity must be high enough to work efficiently, while remaining manageable and cost-effective at the same time. [1]

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The production process also has to adapt permanently to these changing product demands. In order to adapt correctly to the changing demands detailed data on how the factory works at any given time are needed. Therefore, the high complexity of a factory adapting constantly to new restrictions makes it necessary to continuously model the factory digitally in realtime, as well as the changes made. This contrasts with today's typical "stand-alone" solutions [4,5], in which individual elements of the production system are recorded once and digitized. This results in gaps in the digital production model and outdated modeling data. As the subsequent discrepancies between the "stand-alone" solution and the real production system increase in size, the system becomes more and more complex. Decisions become increasingly uncertain due to the lack of information and the risk of making sub-optimal decisions rises. At the same time, due to the high degree of complexity, optimization potentials and problems become obscure, downtimes occur more frequently [6,7] and the efficiency of the production system decreases.

This can only be countered by a realtime detailed model of the complete factory, which enables processes inside the factory to be tracked in realtime. These factory models can then be continuously adapted to the real situation and advance decisions simulated on the basis of realtime data. It is also possible to project simulation results projected onto the real factory. This enables discrepancies that indicate problems to be visualized in realtime, problems to be rectified and downtimes reduced even before they occur.

To generate a consistent model of the complete factory, a standardized coordinate system is needed in which all the elements of the production systems are merged together to form a digital shadow depending on their location, position and time recorded in relation to one another.

In the advanced Industrial Engineering learning factory at the Institute of Industrial Manufacturing and Management IFF of the University of Stuttgart, a system has been developed that can model the complete production system as a digital shadow. Via various sensors, which are classified according to their varying degrees of accuracy and types of task, data are recorded from all objects. As sensor ranges overlap not every single component of the factory has to be equipped with sensors. The data are then digitized and transferred to a model with a standardized coordinate system. The production system is divided into different sub-systems and simulated on different scales. The simulation results are then projected in the real factory.

Based on the method published in 2012 [8] of automatically comparing the real learning factory with the data model, the possibilities of acquiring data in the whole production system were extended. Depending on the production area and task concerned, data acquisition is governed by a range of different restrictions and requirements. A classification system was therefore developed accounts for these restrictions and requirements as data is collected. The system digitally models in realtime all the objects contained in a system in a standardized coordinate system according to their respective requirements. Interdependencies between the models are then determined and filed in the digital shadow. Lastly, if desired, the models can also be projected in the real factory.

2. Recording all elements making up a production system

To aid realtime decisions and continuously improve the production system by projecting the digital shadow, all objects concerned must be modeled in a standardized coordinate system. To do this, objects need to be recorded by different sensors and the various data models standardized and transformed. Dependencies can only be filed and simulations carried out once this has been done.

The underlying acquisition and standardization methods are based on metrological methods, which have always assigned great importance to the standardization and traceability of data from different sensors and coordinate systems. For this reason, measuring systems and measuring objects are addressed in the following section.

The measuring system "production" has to acquire the data from the measured objects at a frequency/speed aligned with that of the object's tasks (realtime) with the necessary degree of accuracy. Furthermore, the separate objects recorded by the various measuring systems must be placed in relation to one another and transformed into a common coordinate system. At IFF, data generated by the production system is supplemented by and merged with data recorded from additional measuring systems installed in the production hall.