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Visualization support for virtual redesign of manufacturing systems

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Abstract

Rapidly changing products and market demand call for manufacturing systems to be continuously adapted and developed. The process of modifying manufacturing systems requires large amounts of planning involving contributions from personnel across an organization. These people need a shared understanding of the future system, including but not limited to its design, functions, and expected performance. One common representation in the virtual manufacturing system domain are 2D CAD layouts. Typical problems with such traditional 2D models are that only experts understand the content fully. For increased understanding, 3D CAD models could bridge the gap between different areas of expertise. However, creating 3D models representing the complete system is traditionally time-consuming, resulting in oversimplified models or limited to parts of the system. Furthermore, such models normally contain uncertainty about building-related geometries that could incur costly mistakes if used as basis for decisions, e.g. realizing during installation of a machine that roof-beams interfere with the planned placement. This paper evaluates what type of problems can be solved with better visualization support, e.g. issues concerning workshop-layout, production flow, workplace design, etc. The evaluation is based on two case studies at different manufacturing sites during ongoing system redesign processes. The case studies implemented visualization using a combination of CAD models and 3D laser scanned as-built data of the current system and facility. The vision is to implement the Lean concept of "Go to Gemba" for a future state in a virtual environment. Bringing this concept into the early phases of manufacturing system redesign has the potential to facilitate the creation of a shared understanding of the future system within cross-functional project teams.

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1. Introduction

Manufacturing companies in prosperous countries are continuously struggling against competitors on the global market, which requires manufacturing systems with high margins on profitability [1]. The time-to-market needs to be reduced to fulfill this request by highly time effective development projects [2]. Those projects are normally under tight budget and time schedule, which leaves no room for mistakes and misunderstandings [3]. As a tool, to detect and prevent mistakes and misunderstandings early in the process, companies use virtual representations of products and manufacturing systems [4]. One critical type of project, often initiated by external pressure and changes, is redesign of existing manufacturing systems.

Visualization of manufacturing system layouts is normally done using 2D computer aided design (CAD) data or simplified 3D CAD representations [1]. However, due in part to the time consuming task of modeling, the level of visual detail and accuracy of those representations are lacking in comparison to the real world systems. A potential problem with this lack is the ability to effectively communicate solutions between persons with different areas of expertise to create a common understanding of the future system inside the organization [5]. An improved level of visualization support could reduce the gap in understanding between persons and detect potential problems early in the development process.

To create detailed and realistic 3D models of the manufacturing system rapidly a proposed method is to use 3D laser scanning technology. The technology holds a potential through its speed, accuracy and ease of use [6]. From the 3D scan data it is possible to create a point cloud that visualizes the as-built factory in a photorealistic 1:1 scaled 3D model. Such a model could

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be modified to visualize and evaluate future changes. The evaluation could be based on hybrid modeling where the point cloud model is combined with CAD objects of new factory equipment. Manufacturing environments is so far a relatively undeveloped area in terms of 3D scanning, but the technology holds potential in the area and development work is ongoing [6].

An important research goal is to develop a solution to support cross-functional teams of manufacturing development engineers in the decision process. The aim is to provide a common view of the manufacturing system, which facilities a common understanding to make the right conclusions and decisions at a certain point of time. Within Lean production the ”Go to Gemba” approach to better understanding and problem solving is an important concept [7-8]. The concept stresses the importance of visiting the real place where a problem exists, in this case the shop floor, to get firsthand information and understanding [7-8]. If the team of engineers could “Go to the future Gemba” they would be able to get a better common understanding of what they are about to create and make better decisions.

This paper will discuss the potential contribution of using point cloud models for visualization support when redesigning manufacturing systems. In section 2 visualization methods used for factory planning are summarized along with a description of the 3D laser scanning technology. Two case studies are presented in section 3 detailing how the technology has been used to evaluate pending manufacturing system redesigns. Based on experiences from those studies a discussion, conclusions and future work are presented.

2. State of the art

Developing effective manufacturing systems is a complex process involving and affecting persons all across an organization. Based on their expert knowledge those persons often have different interests in and views of the manufacturing system. To prevent mistakes they need to understand each other and share the same system view during planning and discussions. This is not always possible without support from some type of tool, such as a virtual representation of the system. Creating a representation with realistic visualization could enable everyone to relate to and create the same view and mental model of the system. Such an approach is described in Fig 1 where the relationship between the mental model, virtual model, and reality are presented [9].

This section will discuss the theoretical aspects of visualization in factory planning and give a description of the 3D scanning technology used to create point cloud models.

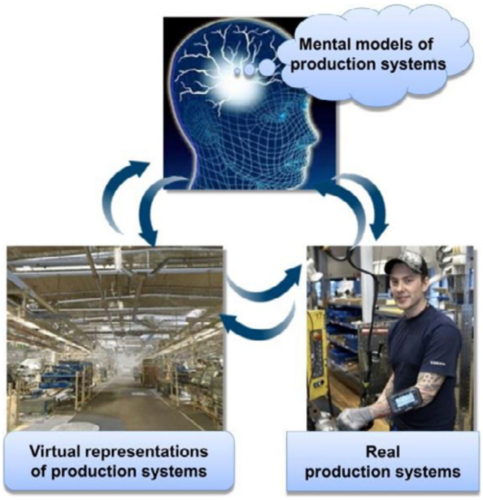

Fig. 1. The three views of production systems [9]

2.1. Visualization in factory planning

Redesigning a factory is a complex process where the solution needs to be optimized and evaluated based on several factors, such as material handling, product flows and factory logistics [10]. A number of different solutions of how to construct the manufacturing system based on a digital factory model has been discussed and presented over the years. Virtual models used to visualize planned factory layouts has shown to be helpful during the evaluating process and to avoid costly mistakes [11]. Users will get better perspectives if 3D models are used in the planning process instead of traditional 2D models [11]. There are several additional benefits from using detailed visualization in those virtual models. E.g. increase in planning speed, decrease in planning costs, and increase in planning quality are some of the benefits that have been discussed [1], [5]. The level of visual detail in those models could however differ as well as how the user interacts with the models.

Virtual reality is an example of a technology used to increase the level of interaction between the user and the model, which was discussed for example by Wiendahl et al. [5] and Menck et al. [12]. In this context the user experience is discussed and how to create a realistic model of a manufacturing system based on 3D CAD objects, where the user could get the feeling of being inside the virtual factory. To increase the user interaction in the initial step of the planning process a proposed method by Dangelmaier et al. is to create a factory model based on augmented reality [3]. The model will then be presented in a virtual reality environment for further discussions. Using the proposed method enables effective cooperative factory planning [3]. A challenge and common problem with these types of tools are how to make them user-friendly and easy to access for a wide scope of users [1].