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Improving manufacturing process change by 3D visualization support: A pilot study on truck production

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Abstract

In the global market, customer demands changes rapidly. Manufacturing companies need to meet the demands to keep competitive. Therefore, manufacturing processes constantly need to be changed. The process change is challenging because it involves different actors across the company, especially for international companies that have globally distributed operations.

Manufacturing process change is carried out by production engineers and needs to consider the needs and requirement of all actors in the manufacturing system. To this end, guidelines for manufacturing system design and cross-functional team meetings for concept design assessment are utilized. While the meeting takes place, such meetings require resources to be available in parallel and advanced planning to come to fruition. Thus making the concept design iteration loop considerably longer if inputs are to be collected frequently.

This paper presents an approach that utilizes a collaborative tool developed in Unity. It integrates 3D scanned factory data with proposed process changes to provide sufficient context to every stakeholders involved. Thus, to facilitate better understanding and communication of the ongoing changes. It will improve every process change on its design, implementation, and future maintenance. The challenges of implementation and evaluation of the collaborative tool are discussed.

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1. Introduction

In today's increasing global competition environment, manufacturing companies are striving to remain at the forefront through adaption of new technologies, rising awareness of resource cost and environmental concerns [1]. The ability and flexibility to continuous customize the production process according to end user requirements are also pivotal to companies' success in the market. Thus, manufacturing process changes are constantly required to achieve the partial targets. However, changes in manufacturing process will affect operations of every internal and external organisation across the company, such as production, maintenance, logistics and etc. It can stimulate a set of obstacles to a successful process change. Therefore, taking every affected stakeholders into account and effectively utilise their knowledge and expertise before and during manufacturing process change become crucial. Nevertheless, previous study shows a lack of comprehension of the importance for the essential elements and their mutual relationships that can hinder the success of manufacturing process change efforts [2].

3D scanning technologies have developed and matured into an off the shelf method of capturing spatial data with great level of detail [3]. While most prominent in the construction

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surveying and archaeology sector there are many examples of use of the technology in industrial manufacturing [3], [4], [5]. It has been proven as a valid method for capturing current state spatial data for industrial manufacturing systems and can thus be utilised to facilitate computerised modelling and re-configuration activities [6]. Furthermore the captured spatial data can be visualized in a highly realistic and true to life manner, depicting the real system as a digital 3D model [5].

This paper aims to propose a collaborative work procedure through a virtual tool that integrates 3D scanned factory data with the possibilities to design and evaluate different process changes options in 3D virtual context for every stakeholders involved.

The rest of the paper is organized as: section 2 will summarize the literatures of manufacturing process change and 3D scanning technologies used in industry. Section 3 will detail the pilot study at Volvo. Section 4 will present the result of the pilot study and is followed by the discussion and conclusion in section 5 and 6 respectively. At last, suggestions for future research are made in Section 7.

2. Theory

This section gives an overview of the previous studies on the topic.

2.1. Manufacturing process change

Manufacturing companies tend to introduce continuous process changes for various reasons. The experience of manufacturing industry suggests that process changes are needed constantly and in an increasing rate as in response to gain flexibility and efficiency in their operations and to a rising awareness of resource costs and environmental concerns [1]. The long-term competitiveness of any manufacturing company depends ultimately on the success of its product development capabilities. New product development holds hope for improving market position and financial performance, creating new industry standards and new niche markets and even renewing the organization [7]. Resilience is seen as a key capability for sustainability in manufacturing industry. Therefore, for a company to be more sustainable and resilient, the delivery of innovative responses to the market through continuous change and improvement is necessary [8].

However, a successful design and implementation of a manufacturing process change which realises potential benefits is not always attainable in the real world. Due to the complex nature of any manufacturing process, any change made in the existing system will affect stakeholders across the whole company. Often the changes in partial targets will bring consequences to other processes and need cooperation among various sections within the company. It requires a coherence procedure that will enable all the stakeholders involved to effectively put their knowledge and expertise into the design and implementation for the new process [9].

Conventional design of manufacturing process change heavily depends on the expertise and experience of professionals [10]. It takes time and resources to foster experienced professionals and the inevitable personnel changes put companies in a vulnerable position of substantial losses of intangible assets, such as accumulated experience and expertise. Therefore, it is important to integrate knowledge and technology into applications that can be used by every engineer in design and implementation of process changes.

Previous studies show that despite the long term benefit of manufacturing process change, it can also bring serious short term disruptions and the cost might outweigh the potential benefit if the process change is not designed and implemented properly. Short term disruptions like reduced productivity, excessive equipment downtime, and problems in scheduling, materials, quality and maintenance are common by-products of process change [11]. Another study shows that the short term loss in productivity from implementation of new manufacturing equipment is often more costly than the actual equipment purchase [12]. Goodman and Griffith [13] state that managers tend to select and plan process change from the narrow viewpoint of the long term benefits sough. Thereafter, Carrillo and Gaimon [14] identify four common challenges during manufacturing process change: First, disruptions during process change typically reduce short term capacity, although, it may increase effective capacity in the long run. Second, the shrinking product life cycles complicates the implementation of process change. Third, while knowledge may enhance the ultimate benefits derived from process change, the correct timing and means of knowledge creation are difficult to discern. Lastly, a series of trade-offs must be evaluated when choosing a particular process change to implement.

2.2. The 3D scanning technologies

3D laser scanning is a laser baser ranging technology used to capture spatial data from the real world. It utilizes either time-of-flight or phase shift method to determine the distance travelled by a laser beam which is emitted and reflected back into the 3D scanner after striking the nearest surface along its trajectory. By mechanically translating the laser beam trajectory, typically by means of a rotating mirror, during the data capture, data is mapped throughout an area. Most 3D scanners built for this purpose translate and rotate the laser beam to achieve a near 360 degrees field of view around the scanner.

The technology has many applications at this time, the earliest to break through were construction surveying and archaeology. The main benefits can be said to be the ability to rapidly digitalize spatial data, a: for documentation or b: for sharing it remotely with others in different locations. Documentation can be used to verify the adherence to building plans or to track changes over time due to load application or changes in external conditions. A good example of an archaeology application is the Smithsonian X 3D, a web platform where anyone can go and interactively explore artefacts from the Smithsonian museum collection in 3D [15].

There are currently more and more application examples in the industrial production area. Some applications are machine vision, virtual commissioning, visualization, validation/verification of installation, or use in production flow simulation [3], [5], [16], [17].

3. A pilot study in industry

Given the background introduction and the theories we have above, a pilot study was conducted in the company which a collaborative tool is developed using the Unity [1] platform that integrated 3D scanning data from a factory plant. The tool and proposed work process are evaluated by five different stakeholders within the company.

3.1. An automotive industry case

In this study, we collaborated with an automotive partner. It is a global automobile producer based in Sweden. Facing the increasing global competition in the industry and the growing environmental concerns, the company has great internal and external needs to make constant and continuous upgrades of manufacturing process and it has become a necessity for its success.

While applying new technologies or designs through various manufacturing process changes to its products and services, there are certain problems and challenges that prevent it from fully achieving the potential benefits. For instance, during each process change, various stakeholders such as production planners, maintenance, logistics, operators, etc. are involved. It is pivotal to understand and consider every stakeholders' needs and knowledge of the system, in order to obtain maximum benefits from process changes. However, the current methods and work practice are not adequate enough which limits the improvements that process changes can make

3.2. Capture 3D data

To incorporate the current setup of the production system in the model, 3D laser scanning was used to capture spatial data of the system. The data capture was carried out on site by a group of virtual manufacturing engineers at the company. The data was relayed to the researchers who conducted processing and formatting to enable incorporation into the modelling software Unity. Processing consisted of reducing the density of measurement points in the captured data, to facilitate faster rendering in the model. There is a trade-off between the data density and the visual appearance to be made and if the density is reduced too far the visualization will appear faded and transparent. The area designated for change in the demo tool was also cleared of any measurements to allow inserting of virtual equipment into the model. Finally the 3D scan data was converted into .off format which is possible to read into Unity.

3D CAD data was gathered for some typical industrial production equipment such as robots, conveyor belts, and assembly stations. These objects where later used and arranged in different ways to represent a set of possible future configurations in the test phase.

3.3. The collaborative tool

In order to improve the current work practice and demonstrate the possibilities of design and evaluate manufacturing process change in a collaborative 3D environment. We chose Unity [18] as the development platform to integrate 3D scanning data and implement the desired functionalities. Unity is a flexible and powerful development platform for creating multiplatform 3D and 2D games and interactive experiences.

In the demo tool, the possibility of creating new layout proposals is presented with a picture prototype, as shown in Fig. 1.

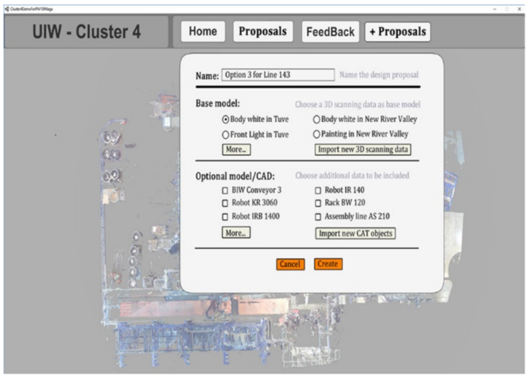

Fig. 1. Create a new layout proposal.

There are three preprogramed 3D layout design of the production cell for the stakeholders to easily switch, visualise and navigate through. The realistic visualisation of the production cell on a laptop or desktop computer, as shown in Fig. 2, will give much more detail information that stakeholders need to make concrete assessments. Thereafter, each stakeholders' comments and feedback are gathered for further discussion and decisions.

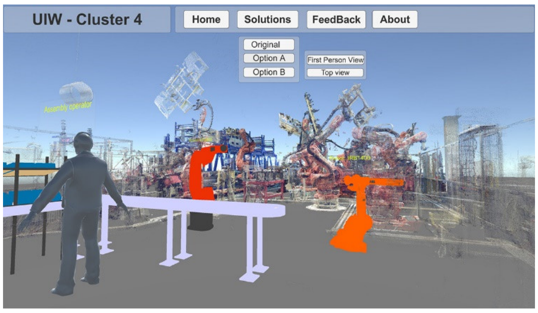

Fig. 2. First person view of solution A.

3.4. Interview

Semi-structured one-to-one interviews were conducted with five stakeholders within the automotive company, which are:

- Layout Engineer
- Logistic engineer
- Lean Manufacturing Specialist
- Assembly Operator
- Virtual Tool Specialist

Each interview was carried out at the stakeholder's office and lasted around 45 minutes. The interview consists of three parts. It begins with questions regarding the interviewee's role and responsibilities in the current manufacturing process change as well as their comments and reflections about the current practice. A demonstration of the collaborative tool and work process is followed, which presents the 3D visualisation of the three layout designs for assessment. At last, it is the discussion concerning how the presented tool and work process could help improve the current work practice and what are the limitations.

4. Results

After further analysis of the interview recordings of the five stakeholders, we have the following result.

Each stakeholder agrees that it would be helpful to their work when 3D realistic visualisation of the production site is accessible from their desktop computers. They also believe that it would help prevent potential errors or conflicts early in the design phase when all the stakeholders could have evaluated the plan in realistic visualization.

Nevertheless, each stakeholder also expressed their doubts and concerns:

The layout and logistic engineers questioned how to keep the 3D data of plant always up to date. It is not uncommon that minor changes and movements would be made continuously in the factory and in the presented work process, it is difficult to reflect the latest changes of the plant. The lean specialist pointed out the accuracy of the 3D visualization might be the problem in actual work and higher quality of 3D data is needed. While the operator is more interested in work task design and balancing of stations than solely layout planning. The virtual tool specialist would like the collaborative tool to include features, such as evaluation task allocation and even augment reality for operator task design and balance.

In short, all the stakeholders think it is promising to have a 3D collaborative tool aiding the manufacturing process change. However, it will take time before it could be used as a day to day basis tool in the actual work.

5. Discussion

The study has shown the possibility to aid the frequently needed manufacturing process changes with a collaborative tool which developed from 3D scanning data of the production site. It brings certain benefits, at the same time, some limitations are also found in this study.

Compared to text description or two dimension data that are widely accepted in current work practice, 3D realistic visualisation of production site gives much more context to engineers to help engineer understand the situation and make decisions.

The collaborative tool with realistic 3D visualisation data would significantly reduce the number of factory visits. The detail of production site could be accessed and visualised right in the engineers' desktop. For companies with globally distributed office or factories, it would be a big step towards the sustainable manufacturing goal.

However, certain problems and limitations have been identified in the study. For instance, the accuracy and data quality is a tough balance with computing capability. In industrial cases, the 3D scanning usually covers a large area with the whole plant or building. As a result, the high quality 3D data in industry scale would make the data file too big for concurrent computers to process. While on the other hand, by decreasing the data density would sacrifice the realistic values of the virtual data.

Another challenge is to keep the 3D scanning data up to date. Factory environment is changing constantly and continuously, shorter intervals of factory scanning could improve the situation, but not entirely. A further point should be noticed is that most changes are minor in a factory scale, therefore, it is not a good idea to think an update as replace the old data with the new one. An effective and efficient way to update existing data is missing.

Last but not least, clean the 3D scanning data and make it ready for further development is not an easy task. In our study, the 3D data of a production cell is acquired as one single file. For the purpose of manipulating different layout design, each object in the production cell should be able to act independently. As a result, every objects such as robots, conveyor should be separated from the single file. The work cannot be done smoothly with current automatic recognition and processing methods. It requires manual processing which is not acceptable for large scale projects.

6. Conclusion

In this study, we have discussed why manufacturing process change is needed as well as the problems and challenges during this process.

Furthermore, in a pilot study with a partner from the automotive industry, we attempt to incorporate 3D scanning factory data with further development in Unity to aid the manufacturing process change. The interview with 5 different stakeholder within the automotive company showed that the approach is promising with realistic 3D visualisation and easy accessibility to the factory environment. However, there are still problems with the 3D data quality, update and object separation which need to be resolved before industry can benefit from adopting it.

7. Future work

The next step of the work will be study the trade-off balance between data quality and computing capability as well as 3D scanning auto-update. To achieve the goal, further search and review of similar studies need to be done. More case studies in the industry are also needed to verify new methods and technologies. The vision is to have a complete solution for supporting manufacturing process change based on 3D scanning technology and further development.

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