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Virtual Reality, laser scanning

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VIRTUAL REALITY IN PRODUCTION LAYOUT DESIGNING

Abstract

Information technologies allow for improving production systems functioning especially thanks to a possibility of solving complex production problems in a very short time. The production system designing is increasingly based on virtual reality, and more specifically on the concept of a digital factory. It enables to create virtual models of real objects and use them for visualization of products and manufacturing processes. The presented examples of new information technologies, which are used in production practice, are the main object of this paper.

1. INTRODUCTION

Today, competitive global markets require high quality, quick production and low cost. Such markets requirements create the need for collaboration of all professions, from engineers and managers to shop floor workers. The future success requires sharing knowledge and experience (Gregor et al., 2007; Plinta & Więcek, 2012) with the use of new information technologies. The highly competitive environment requires in production practice new software systems for designing, testing, process planning, manufacturing and assembly (Tatarchenko, Lyfar & Tatarchenko, 2020).

Another decisive factor for further development is quality of its engineers, who are responsible for innovations. The evolution of production systems mainly follows the development of innovative technology and its direct environment, like machines, devices, methods and tools aiding the work related to preparing technical documentation, including description of product models, processes and production resources (Gregor, Herčko & Grznár, 2015). This can be achieved by introducing shorter production cycles, new products and manufacturing processes development, minimization of the supplies level, more efficient logistics, and the usage of effective and innovative ideas of production realization, like Lean Production, JIT (Just in Time), Total Quality Management, and particularly, Digital Factory Technologies (Davis et al., 2012; Gola, 2014).

The main types of software, used in production enterprises, are linked in PLM solutions, which control different parts of the manufacturing cycle. CAD systems define what will be produced, Manufacturing Process Management defines how it will be manufactured, ERP informs when and where it is created, whereas MES provides shop floor control

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and simultaneously manufacturing feedback (Danilczuk & Gola, 2020). The stored information generally aids communication and improves making decisions, but also removes human errors from the design and the manufacturing process. Nowadays, Industry 4.0 has become a very popular concept, which in its assumptions integrates various software applications (Bučková, Krajčovič & Edl, 2017; Kolberg & Zühlke, 2015).

2. VIRTUAL REALITY

The Digital Factory concept bases, which enables to create virtual models of real objects and use them for visualization of products and manufacturing processes (Westkaemper et al., 2001).

It is possible to use Virtual Reality technologies to design 3D spatial models and 3D modelling and examination of properties of real objects. Virtual Reality can be used for different kinds of analysis connected with product development, designing production processes, workplaces, production systems, etc. The use of Virtual Reality for design and optimisation of production processes and systems is often called Digital Factory application (Dulina & Bartanusova, 2014; Furmann & Krajčovič, 2011; Krajčovič et al., 2013).

Digital Factory can be described as a virtual picture of a real production. It represents the environment integrated by computer and information technologies, in which reality is replaced by virtual computer models. Such virtual solutions enable to verify all collisions and critical situations before real implementation of the proposed solutions. Digital Factory can support planning, organization and optimisation of complex production, and simultaneously creates right conditions for team work, providing quick feedback among designers, technologists, production systems designers and planners (Furmann, Furmannová & Więcek, 2017).

From the perspective of spatial arrangement optimization, the most important decision criteria include minimization of transport activities, material flow, suitable connection between external logistics chains, minimizing the need for space, minimizing inventories and production cycles, fulfilling the requirements regarding health and safety at work, flexibility and possibility of future changes.

For the above mentioned reasons, production layout design requires implementation of a few following basic steps:

1. Collection, processing and analysis of input data.
2. Designing an ideal layout.
3. Constraints specification and creation of a real system and its evaluation.
4. Visualization of the proposed solution.

Real layout design in the virtual environment requires the following steps:

1. Preparation of 2D/3D objects – can be performed as follows:
   - usage of libraries of 2D/3D objects from the used software,
   - acquiring new 3D models using reverse engineering methods,
   - creating new models using CAD applications with application of 3D scanning method.
2. Modelling of the production system - this phase comprises:
   - saving objects from the library on the projection surface,
   - defining relations between objects,
   - designing transport lanes and networks.

3. Layout optimization – with the usage of analytical tools.
4. Visualization of the production system – 2D or 3D layout of the production system, which may be presented as classic visualization by computer monitor, using a projection table, or using virtual technology and augmented reality.

The result is a realistic layout of workplaces, which respects all the existing constraints in production presented in 2D or 3D view (Fig. 1).

a) 2D layout **b) 3D model**

Fig. 1. The real layout of workplaces

3. PROJECT STAGES

The purpose of this paper is to present parts of procedure implemented to develop models of objects. Models can be used in design and reorganizing processes in production halls, staff trainings and validating workstations ergonomics using VR technology.

There are several ways of extracting 3D models of equipment in production halls. The first one is to adopt Factory Design Suite asset library used in designing factories. Factory Design Suite delivers a registry of machinery, units and facilities layout and is compliant with Inventor and AutoCAD. Production halls equipment, architectural building tools, transport devices, mannequins, storage machines, industrial robots and safety equipment can be found within.

The second method is to source the models directly from the manufacturer. It is becoming a common practice for vendors to share 3D models of their products as it allows the customers to save time that otherwise would have to be spent on creating the model.

The third approach allowing to obtain precise geometry data of a production hall and its facilities consists in 3D scanning of a given object and, subsequently, creating its 3D model. There are couple of steps involved in this action, presented in figure 2.

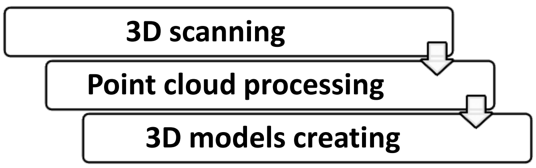

Fig. 2. Project stages

3.1. 3D scanning

3D scanning is a technology that develops rapidly and allows to collect geometric and measurements data of a scanned object quickly and precisely. Essential characteristics of mentioned technology are described below:

- Speed – expressed in the amount of points registered in xyz coordinate system within a second.
- Accuracy – indicated by measurement error observed within a determined length. In the case of FARO LS 880 phase based laser scanner, mentioned in the later part of this paper, the measurement error amounted to ±3 mm within 25 m distance.
- Resolution – the higher resolution the greater amount of points constituting the point cloud representing the projection of scanned area. It is a compromise between the accuracy of a scan and the time of measurement which is directly proportional to resolution.
- Scanning area – totals to 360° horizontally and 320° vertically, therefore the surface under the stand on which the scanner is placed will not be included.
- Color scanning. In case of FARO LS 880 scanner, connecting a camera is required to achieve such result as it takes a series of pictures constituting a groundwork to color the point cloud extracted in the process of scanning.

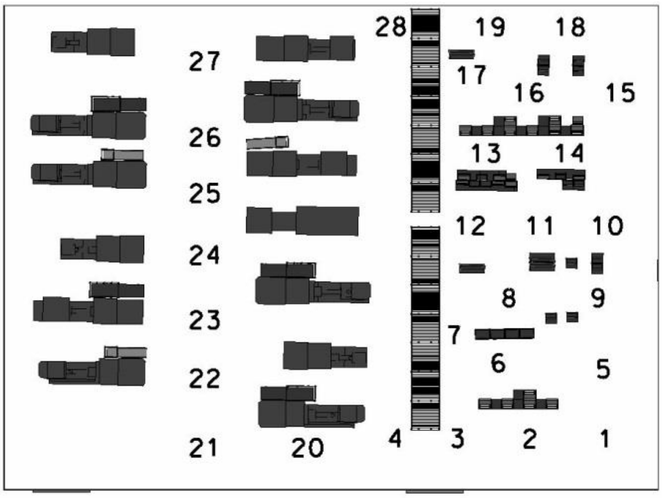

Fig. 3. Map of scanner's positions

Becoming familiar with the object and creating a map of scanner's position should be done prior to commencing the scanning process. Such practice allows to avoid so-called "dead areas" – fields that were not reached by the scanner and, as a result, geometric data were not registered. Figure 3 presents the map of scanner's position developed for the scanned object. Additionally, layout of referential items (shields and bullets) fundamental in the process of connecting scans in a point cloud should be designed.

3.2. Point cloud processing

Another stage of the process is to connect individual scans in one point cloud. FARO SCENE software supports this procedure in quick and precise manner due to automatic shield and reference bullet recognition. Figure 4 displays three point clouds from single standpoints, whereas figure 5 shows a complete point cloud build from 28 individual scans.

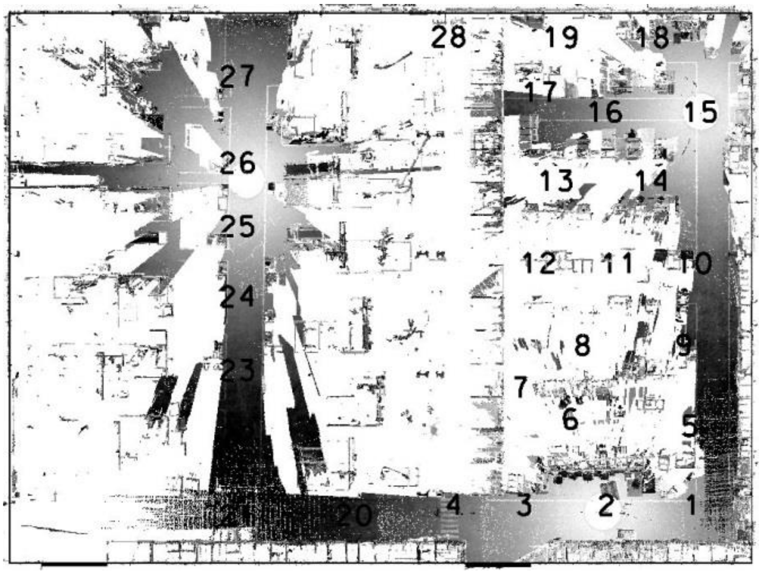

Fig. 4. The point clouds from single standpoints

Fig. 5. Complete point cloud

Processed data are subsequently exported to a format supported by the environment in which the 3D model is going to be created. In case of discussed project it was a POD format. There exists also a possibility to share a point cloud via SCENE Webshare which enables to screen it through Internet browser.

There is also a possibility to create a virtual walk around the facility by means of panoramic pictures (TruView). Frequently, it supports the modeling process because makes is easier to recognize objects that would be hard to identify on the basis of point cloud itself. Moreover, TruView allows to perform measurements of scanned objects or to decipher coordinates of selected points.

3.3. 3D models creating

The creation of 3D models of a production hall and its equipment is the final preparation stage. Bentley Descartes application was used to construct the 3D models as it is adapted to cooperate with point clouds. Modeling consisted in creating outlines of appropriate cross-sections which, subsequently, were extracted into area within accurate length – arising from the point cloud. Figure 6 presents transition from an illustrative part of a point cloud to the 3D model of a work station.

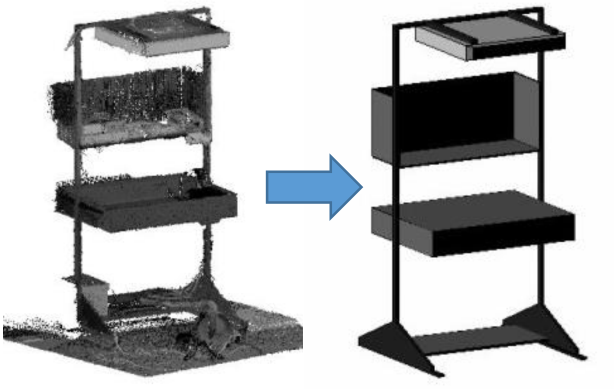

Fig. 6. Transition from point cloud to 3D model

Models of a hall and its equipment prepared in such manner were subsequently exported to FBX format which makes it possible to use them in virtual reality environment after converting to active object in Unity 3D.

4. POSSIBILITIES OF USING A MODEL AND VIRTUAL REALITY

A hall and its equipment created by using a method described above may be adopted in production layout designing, in designing new production spaces and reorganization of existing ones. Software available on market allow for conducting a series of analysis and simulations such as: material flow analysis, planning of work station arrangement, determining distribution of the routes of transportation means and regulating the efficiency of production lines. In case of less advanced analysis a model created in any program that allows for its display and editing (AutoCAD, Inventor, Bentley Descartes) is considered to be helpful. Figure 7 shows an illustrative change of workplaces arrangement performed in Bentley Descartes program. In case of need for creating a visualization, virtual reality is a great solution that allows for carrying out a virtual walk around created production hall, implementing changes in workstation positioning and searching for new solutions. Figure 8 presents what the hall looks like in virtual reality.

Staff training which should be as close to real working conditions as possible and, at the same time, should minimize the cost and reduce danger of carrying them out. Considering those factors, VR environment seems to be the ideal solution, therefore it has been gaining considerable popularity in recent years. Initially, virtual reality was used mainly in military training yet it promptly started to be implemented in fields of ergonomics, safety and in cases where trainings conducted in real conditions could pose a threat for health and safety of humans. Examples of such circumstances are observed in virtual operations, works in nuclear power plants (in order to reduce ionizing radiation) and mines where working environment is extremely threatening. Taking into consideration that 40% of accidents involve young workers, trainings allowing for high competence level prior to commencing work seem to be a considerably promising solution (Grabowski, 2012).

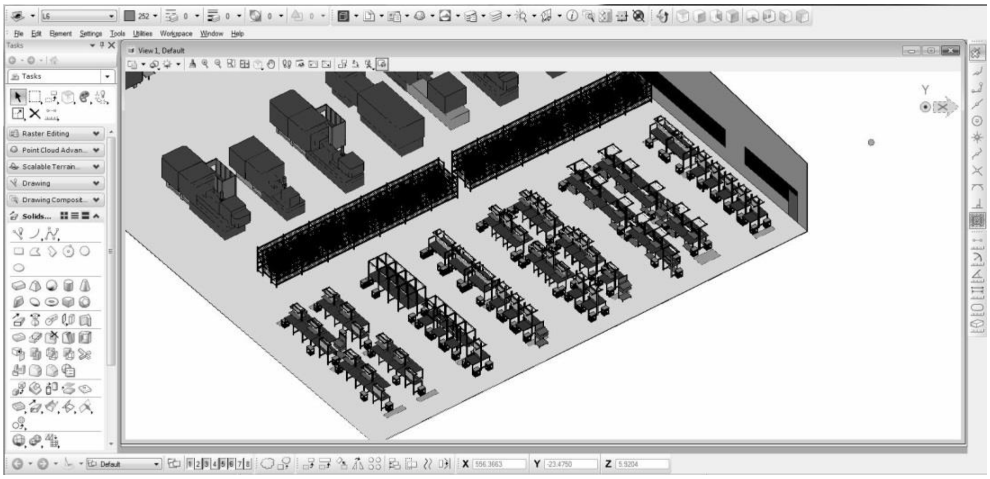

Fig. 7. Change of work station arrangement performed in Bentley Descartes

Creating a digital twin which constitutes a digital copy of a real production system and is created in order to optimize it. The concept of a digital twin is based on 3 pillars: real, digital and virtual world. The first one is created by a real factory, where the project is implemented in digital environment and there, thanks to sensors collecting and analyzing data from real-time production processes, allows for a variety of operations, namely: shortening and improving production process, locating inefficient processes, reducing the time of launching new products. The digital part is represented via digital models and may be evaluated by means of computer simulation. It involves planning and virtual staff trainings. The last component binds together the real-time production system with a virtual model of production system which is called digital twin (Skokan, 2019).

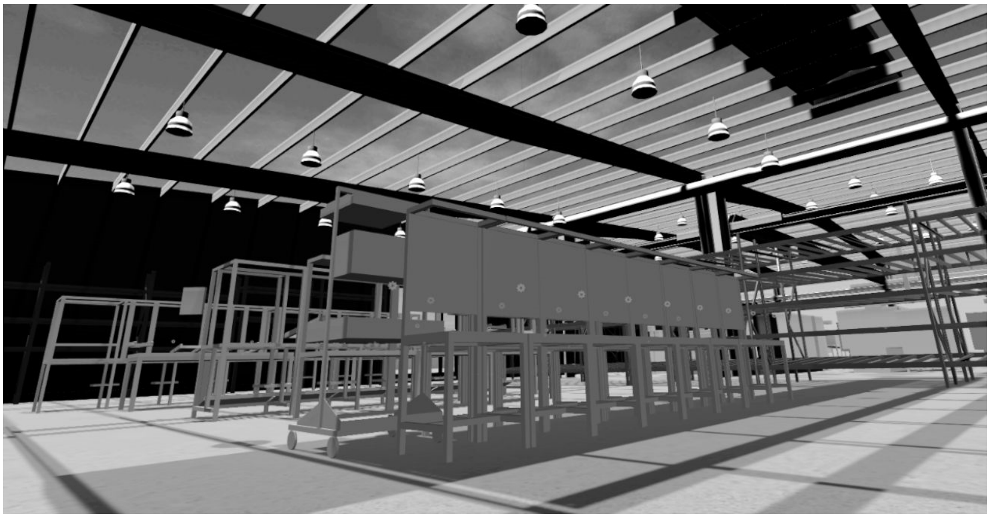

Fig. 8. Model based on point cloud

Quick validation of newly designed solutions in terms of ergonomics, it is next usage of this technology. It consists in connecting virtual and augmented reality by means of CERAA application which has a unit adopting augmented reality to conduct analysis of worker's ergonomic positions. A user within virtual hall may perform his or hers work and the chosen positions can be compared with a mannequin and acceptable range of motion screened via CERAA application. The advantage of such solution is eliminating the need for establishing a real workspace in order to test it in terms of ergonomics. Additionally, models created with the usage of parametric measurements can be altered quickly and revised with respect to suitable anthropometric measurements of workers. A wider scope of discussion regarding proposed conception, together with presenting functionalities and restrictions of a system, will be a matter of a separate publication.

5. CONCLUSIONS

A quest for intensification of the process of obtaining information regarding the reality is reflected in the development of laser scanning technology as it allows for precise, non-invasive and quick registration of digital data about the examined object. Diverse types of scanners coupled up with devices supporting the scanning process provide means for highly precise scanning of objects with various surfaces and sizes.

An intense development of laser scanning led to implementing this technology in various sectors of industry. A point cloud, which is the result of 3D scanning, provides a diverse set of information about the object and gives the opportunity to obtain any view, capture and cross-section established on formerly registered data is a huge asset of the 3D scanning. 3D models based on point cloud can be used in management, stocktaking, planning and analysis. They may also serve as the basis for being used in virtual reality environment which gains considerable amount of implementations. Some of them being: production layout designing, staff trainings, creating digital twins, validating workstations ergonomics without the need to have them in physical form.

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