Supported by
ICELAND LIECHTENSTEIN NORWAY eea grants

Invited paper

AUGMENTED REALITY IN THE DIGITAL FACTORY

Emmanuel FRANCALANZA[1], Jonathan BORG[1], Philip FARRUGIA[1], Lawrence FARRUGIA[1]

Abstract The digital factory concept covers a broad range of applications across the factory life cycle. From the conceptual planning and design of manufacturing systems to the service and maintenance of factories. The aim of the digital factory is to support manufacturing stakeholders in their activities and improve performance in terms of quality, time and cost. In pursuing this aim, this research has undertaken activities in developing digital factory tools, employing augmented reality technology. This research paper therefore presents the state of the art in augmented reality in the digital factory. This paper then presents how this research has contributed towards developing a factory planning application that leverages augmented reality technology to solve real life manufacturing problems.

KEYWORDS: Digital Manufacturing, Factory Planning, Decision Support

1. INTRODUCTION

Manufacturing is a broad subject and encompases many activities and operations from product conceptual design to manufacturing system maintenance and everything in between [1]. A factory can be defined as the location were manufacturing and industrial operations take place. Factories can include several interconnected production areas, manufacturing systems and automated production cells. In fact as defined by Westkamper, factories are complex and long life products which have to be adapted to the needs of markets, production and technologies [2]. Based on the concept of the digital factory design developed by Westkämper [3] the factory life-cycle consists of several planning activities which precede the ramp-up, factory operation and manufacturing execution phases, and eventually maintenance and reorganisation or disposal of the factory.

As can be imagined, several stakeholders are involved and responsible for developing the factory on many levels (layout, production system, cell, machine) [4], and these stakeholders carry out the factory planning activity with the goal of producing a specific product or a range of products.

As defined in the German standard VDI 5200-1 [5], factory planning can be seen as a design-process of a factory from the first idea to the start of production that is systematic, goal-oriented, structured in successive phases and supported by methods and tools. Hence similarly to the design of a product, the planning of a factory can be considered as a decision intensive activity. These decision making activities occur throughout the factory life cycle and include site and network planning, material handling and equipment design, process planning or factory operation [2].

The reality is that decision makers in the manufacturing industry frequently face the problem of assessing a wide range of alternative options, and selecting one based on a set of conflicting criteria [6]. These manufacturing stakeholders have to therefore be supported in order to take the right decisions and be guided in their activities. An approach to support and guide the manufacturing stakeholders is to utilise ICT tools developed for the Digital Factory. In fact an important requirement of the Digital Factory is to provide stakeholders with information and knowledge support during decision making activities.

2. THE DIGITAL FACTORY

The digital factory [3] has been proposed in order to support the implementation of smart factories through the use of virtual environments and representations that supplement the real manufacturing systems across the factory life cycle. As defined in VDI 4499 [7], the aim of the digital factory is the holistic planning, evaluation and ongoing improvement of all the main structures, processes and resources of the real factory in conjunction with the product.

---

[1] CERU, Department of Industrial and Manufacturing Engineering, University of Malta, Malta

Augmented Reality (AR) technology can therefore be considered as forming part of the digital factory applications that can be used in supporting the decision making activity in several factory life stages.

3. AUGMENTED REALITY IN THE DIGITAL FACTORY

As explained by Novak-Marcincin et al. [8], Augmented Reality (AR) applications can support several areas of manufacturing, including AR aided robot control, AR aided testing and assembly and AR aided transport and storage. AR applications can also be employed to support the planning process on the shop floor [9]. These superimpose computer-generated information onto the real environment rather than replacing it as in the case of Virtual Reality (VR).

The visualisation has to be context dependent and congruent with the real environment. With the visual combination of virtual planning results and real manufacturing surroundings, users can view different possibilities of equipment positioning and validate the generated data. AR also displays the used colours, surfaces and propositions of the different objects correctly to grant a high rate of recognition by the user. Measuring distances or positions of machinery is also possible [9].

AR can be either done either by using a Head-Mounted Display (HMD) in Video-See-Through, or else by using a vision based tracking system to recognise the virtual objects in the real surrounding. Each virtual object is linked to a different tracker and, by shifting it, the virtual element will be moved around in the scene [9]. AR systems can also be used with an interactive table-based planning by superimposing 3D objects onto an existing paper-plan.

4. AUGMENTED REALITY IN FACTORY PLANNING

Before a manufacturing layout can be installed in a factory, layout designers must be confident that they have generated the best possible layout that supports the manufacturing process, optimises space and production, and guarantees a high maintainability and profitability [5]. Therefore, the planning result should be evaluated in view of the requirements of the manufacturing layout so that it can be validated.

As part of an initiative to develope digital factory tools to support the factory planning activity, this research [10], has contributed the AR factory planning approach framework illustrated in Figure 1.

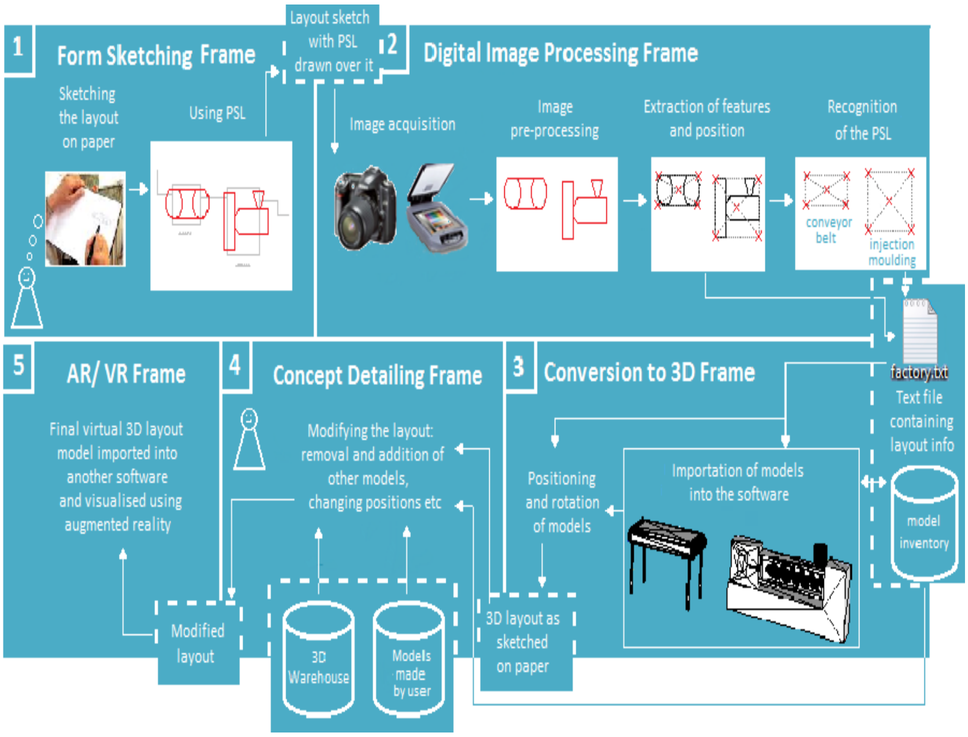

Figure 1 - AR factory planning approach framework

This approach is made up from a number of frames that support the factory planner to derive an AR model from an intial sketch. This work builds on the work initially presented by Farrugia et al. in [11]. The approach begins with the factory planner sketching the layout of the factory on a paper. The factory planner utilises a prescribed sketching language (PSL) to define different machines and their position in the layout. The PSL is made up of a library of different symbols, each representing a particular machine, such as a CNC machine or Lathe.

The next step in the approach is to capture the image using a digital interface such as a digital camera, mobile phone or image scanner. The digital image is then processed using image recognition software to extract the symbols and their relative positioning. The symbols are recognised, coverted to meaningful information and save into a text file containing the layout info. In the next frame this information is converted into a 3D model. The machine information is related to three dimensional machine models in a model inventory. These models are called up and positioned in the correct orientation and location within a 3D space.

When all the machines have been located and placed in the 3D scene, the factory plan 3D model is made available to the user. In the fourth frame the user then has the possibility of adding further detail or modifying the 3D factory layout. The final frame then allows the user to visualise the completed 3D model in AR. An example of such a 3D factory layout plan is shown in Figure 2.

Figure 2 - AR objects onto paper-plans

Different stakeholders, such as machine operators, company management and process engineers, can leverage the power of AR to visualize the factory plan. This can help the factory planner to make better decisions by modifying the layout according to the feedback received from all the stakeholders involved.

5. THE FUTURE OF AUGMENTED REALITY IN INDUSTRY 4.0

From a manufacturing perspective the development of technologies such as smart sensors [12], RFID [13], grid [14] and cloud [15] manufacturing, are pushing towards a fourth industrial evolution, or as defined by the German Federal Minister of Education and Research, Industry 4.0 [16]. With the advent of industry 4.0, otherwise referred to as cyber-physical production systems, the amount of information available to actors in the manufacturing industry is going to increase significantly.

In the smart factory [17] cyber-physical systems will be continuously collecting data from the shop floor that may be relevant to the factory planner who is reconfiguring a plant layout. This data from the real factory will be available together with data being generated by the Digital Factory tools in the virtual factory during the factory planning process. These combined activities generate a very large data set that is difficult to store, access and analyse. Therefore it can be concluded that the smart factory paradigm brings along the challenges associated with Big Data, especially in the decision making stages [18]. Data management and information retrieval will therefore become an essential element of the factory planning process.

This said, factory planning stakeholders cannot continuously be presented with large amounts of available information to process. This is because human stakeholders are limited by their mental brain capacity in what is defined as the human brain’s working memory [19]. Only information which is of high relevance to the task and decisions currently being made needs to be presented to the stakeholders, otherwise there is the risk of information overload.

Therefore we can conclude that stakeholders in the factory planning process need to be provided with the right information at the right time, in a non-pervasive manner in order to take good decisions. This interesting challenge was behind the motivation of this research. In the next stages this research on the use of AR in the digital factory should therefore merge with other approaches undertaken to present information to manufacturing stakeholders. One such approach is to integrate AR applications with the JITIR approach presented by Constantinescu et al. in [20].

6. CONCLUSIONS

This paper has presented the state of the art in augmented reality in the digital factory and has also contributed towards developing an approach framework factory for a digital factory planning application that leverages augmented reality technology to solve real life manufacturing problems. This paper has also presented the challenges that factory planners will have to face in the near future with the advent of cyber-physical production systems, and highlighted how AR applications can be leveraged to tackle these challenges.

REFERENCES

1. C.I.R.P., Dictionary of Production Engineering; Vol III - Manufacturing Systems, Springer, 2004.
2. Westkämper, E., New paradigm in manufacturing engineering: Factory life cycle, Prod. Eng. 13 , pp. 143–146, 2006.
3. E. Westkämper, Digital Manufacturing In The Global Era, in: Digit. Enterp. Technol., 2007: pp. 3–14.
4. M. Schenk, S. Wirth, E. Müller, Factory Planning Manual, Springer, 2009.
5. Association of German Engineers (VDI):, VDI 5200-1:2011 Factory Planning - Planning Procedures, VDI-Verlag GmbH, Dusseldorf, 2011.
6. R. Venkata Rao, Introduction to Decision Making in the Manufacturing Environment, in: Decis. Mak. Manuf. Environ., Springer London, pp. 3–6., 2007.
7. Association of German Engineers (VDI), VDI 4499 Blatt 1 Digital factory - Fundamentals, (2008).
8. J. Novak-Marcincin, J. Barna, M. Janak, L. Novakova-Marcincinova, Augmented Reality Aided Manufacturing, Procedia Comput. Sci. 25, 2013.
9. W.S. F. Doil, Augmented Reality for manufacturing planning, Proc. Workshop Virtual Environ. EGVE3903, 71–76, 2003
10. S. Borg, Towards Sketch-based Virtual Prototyping of a Factory, University of Malta, 2011.
11. P. J. Farrugia, E.Francalanza, G.Attard, J.C. Borg, Factory Planning Through Paper-based Computer-Aided Sketching, 2010.
12. S. Vadde, S.V. Kamarthi, N.M. Berry, Smart sensors in a flow-line manufacturing system: an agent-based simulation, in: Int. Conf. Integr. Knowl. Intensive Multi-Agent Syst. 2005, pp. 635–640, 2005.
13. P.J. Zelbst, K.W. Green, V.E. Sower, P.M. Reyes, Impact of RFID on manufacturing effectiveness and efficiency, Int. J. Oper. Prod. Manag. 32, pp. 329–350 2012.
14. Constantinescu, Carmen, Grid engineering for networked and multi-scale manufacturing, in: 41st CIRP Conf. Manuf. Syst., Tokyo, pp. 111–114, 2008.
15. X. Xu, From cloud computing to cloud manufacturing, Robot. Comput.-Integr. Manuf. 28, pp. 75–86, 2012.
16. D.H. Lasi, P.D.P. Fettke, P.D.H.-G. Kemper, D.-I.T. Feld, D.-H.M. Hoffmann, Industry 4.0, Bus. Inf. Syst. Eng. 6 pp. 239–242, 2014.
17. D. Zuehlke, SmartFactory—Towards a factory-of-things, Annu. Rev. Control. 34, pp. 129–138, 2010.
18. J.M. Tien, Big Data: Unleashing information, J. Syst. Sci. Syst. Eng. 22, pp. 127–151, 2013.
19. A.D. Baddeley, Working memory, Clarendon Press ; Oxford University Press, Oxford [England]; New York, 1987.
20. C.L. Constantinescu, E. Francalanza, D. Matarazzo, O. Balkan, Information Support and Interactive Planning in the Digital Factory: Approach and Industry-driven Evaluation, Procedia CIRP. 25, pp. 269–275, (2014).