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Enabling the use of a collaborative table for simulation in operations

Aleksandra Poziomkowska, Irvine Nyandowe, Elias Ribeiro da Silva, Anita Friis Sommer

Abstract

Benefits of Industry 4.0 are often enabled by combining and connecting several different technologies. In this study, we explore Industry 4.0 within manufacturing design, where a combined tool is being developed, termed a collaborative table (co-table). The Co-table combines digital twin technology and virtual simulation with a physical, tangible user-interface for easier testing of pre-designed layouts before implementation. However, due to the newness of this approach, challenges related both to technical and managerial aspects are faced to introduce new technologies in daily basis operations. Thus, this study explores the technical feasibility of introducing this technology in the operations environment, the main benefits and challenges faced during the implementation, as well as investigate the impact the technology has for co-creation and innovation within the teams.

Keywords: Simulation, Digital twin, Collaborative table, Technology adoption, Smart factory, Innovation

1. Introduction

The fourth industrial revolution has had a major impact on operations within manufacturing companies all over the world. New technologies enabling the implementation of industry 4.0 continue to be developed at an exponential rate and the adoption of Industry 4.0 technologies has been shown to have an influence on the competitiveness and operational efficiency of companies. The introduction of industry 4.0 principles and enabling technologies in manufacturing design contributes to both the market view and the operational perspective within companies. While the market view contributions allow companies to present new digital-based solutions to their customers, operational benefits include improved processing times, reduced set-up times and production costs (Morrar and Arman, 2017; Dalenogare et al., 2018). However, many companies still face challenges in identifying and implementing the right industry 4.0 technologies to improve their organizational and operational efficiency in factories and production lines (Kumar and Siddharthan, 2013). This study focuses on industry 4.0 in manufacturing design, more specifically it looks into how simulation and digital twins impact the development of new manufacturing designs such as production set-ups and factory layouts.

1.1. Simulation and digitization within industry 4.0

Digitization is amongst the major leading points discussed within the industry 4.0 topic. Kagermann (2015) defines digitization as the networking of people and things and the convergence of the real and virtual worlds that are enabled by information and communication technology. Manufacturing companies are implementing digitization at various levels within their organizations to help improve innovation in production. Simulation is also an area that has seen much growth with the continued popularity of the fourth industrial revolution for creating improvements in the quality of decision making in a fast and efficient way (Vaidya et al., 2018). Simulation has been shown to reduce development cycles and costs as well as increasing the quality of products and enabling the management of knowledge (Rodič, 2017). According to Uriarte et al. (2018), simulation presents a way of testing various scenarios without physically setting up different use cases that would be time-consuming as well as costly. This is particularly important when designing new factory layouts and production lines. This facilitates fact-based decision making within manufacturing companies leading to the implementation of optimal solutions.

Research calls for further studies on the impact of new digitization capabilities within Industry 4.0 on manufacturing design (Husar et al., 2019).

In our study, simulation is used to model a new factory layout in an interactive manner and determine the best locations for...
the factory machines. Simultaneously, the simulation allows users to navigate within the factory layout using various point of views. Metrics such as power usage, number of parts created, and machine efficiency are used to measure the performance of the simulated layout.

1.2. Collaborative table as a tangible user interface to 3D simulations

While simulation provides virtual actualizations of physical systems, it does not provide a human-centric interaction interface between the physical and virtual environments (Tao et al., 2019; Malkawi and Srinivasan, 2005). Various innovations have in the past been able to provide interfaces that enable human interaction with virtual simulations. A recent development called Collaboration Table (Co-table) (Grube et al., 2019) is a module that allows interaction between the virtual world of manufacturing simulation and humans using 3D physical objects. In this instance, the Co-table acts as an interface between humans and the simulated virtual environment which represents actual machines and processes in a manufacturing factory simulation. This enables an interface between humans and the simulated virtual environment. It is a novel application that has been shown to aid in the presentation of layout simulations and other 3D environments. However, due to its novelty, there is a need for further study and experimentation in order to identify further value and potential of the Co-table for manufacturing companies. This study explores the following research question: “What value does Co-table contribute towards collaboration and decision making within teams in manufacturing companies?”.

To address this question, this study assesses the use of the Co-table to determine its value for manufacturing companies, in particular how teams collaborate, innovate and make fact-based decisions. Furthermore, this paper addresses how companies can best implement the Co-table to realize the benefits gained from this technology.

The remainder of this paper is organized as follows. Section 2 outlines the state of art in simulation, and technically introduces the co-table. Section 3 describes the research approach and introduces the methodology for the case study. Case results and further discussions are presented in Section 4 while concluding remarks, implications and future work are outlined in Section 5.

2. State of the art

2.1. Simulation

Simulation is the reproduction of a real system with its dynamic processes in a model aiming to reach transferable findings for the real world. It facilitates planning, implementing, and operating complex technical systems, which is being used by many organizations (Malkawi and Srinivasan, 2005). The trend in simulation development has shifted from purely analytical and optimization-oriented models to integrating simulation models into decision support tools to be used concurrently. With the new requirements for simulation model design, simulation has developed to a standard tool in an engineer’s portfolio, used to solve a range of engineering but also design problems. According to Sanin and coworkers industrial designers and decision-makers base most of their decisions on the knowledge gained from previous situations and less on knowledge-based industrial design and manufacturing techniques. Furthermore, they identify some limitations to the knowledge-based approach such as long times, high costs, domain specificity and a disregard for previous knowledge (Shafiq et al., 2015). Laudante (2017) identifies digital manufacturing as the integration of industry 4.0 technologies such as 3D printing, internet of things, big data and simulation. Additionally, the study states that simulation provides virtualization and 3D visualizations that produce data that is crucial to designing new production lines.

The simulation tool which is used in this case is the object-oriented program called Tecnomatix Plant Simulation by Siemens. It is a discrete event-based simulation tool, which allows, among others, the modeling and analyses assembly processes, transport systems with their transport controls, workers with multiple qualification profiles or storage logic and production processes (Bangsow, 2010). Furthermore, visualizing the complete model in the Plant Simulation 3D environment allows a 3D presentation of the system behavior. The 3D environment designed in Plant Simulation can be seen in Fig. 1.

2.2. Co-table

The collaboration table (Co-table) is a newly developed product that uses two additional Technologies: Tecnomatix Plant Simulation software from Siemens and a plug-in from Edddision Technology. The Co-table is a physical tool that consists of a digital part and connects it with the physical counterpart: graspable objects.

It bridges the virtual elements, such as machinery, conveyor, or workers, with physical elements represented by 3D printed or constructed figures, mirrored in Tecnomatix Plant simulation (Malkawi and Srinivasan, 2005). This bridging aims to develop interaction between 3D simulation and non-technical users to view and interact with the virtual simulation through physical objects, reducing the complexity of dealing with simulation software.

This Co-table hides the complexity of simulation and provides a place for owners and managers to interact with the layout and make strategic decisions. This tool allows non-experts to test the manufacturing layout, redesign it and get the statistic reports of the new set-up.

3. Case study

To critically evaluate the Co-table contribution towards collaboration and decision making, a case study is conducted at a large, global manufacturing company in the industry of fast-moving consumer goods. The Co-table is applied to a manufacturing design project to demonstrate the value related to planning and designing the layout. In this case, it is for a novel Additive Manufacturing (AM) factory area. In order to assess the technical feasibility of the Co-table, the study started with an initial data collection process in which interviews with 2 managers and 5 stakeholders involved in the project were carried out. Using the initial 2D layout designs for the AM factory and the collected machine data, a simulation was constructed in Siemens Tecnomatix Plant Simulation.
A Co-table instance was created based on the factory layout simulation. Miniature graspable 3D objects resembling the actual machines were then created, either from building bricks or 3D printed objects. These were placed on the Co-table to correspond to positions of the initial AM factory layout and served as the representation of the machines added to the simulation. The resulting artefact formed the basis of this study. Versions of this artefact were presented to the stakeholders within the company including the AM factory project participants.

The participants were able to interact with the simulation and change machine positions as well as navigate the plant floor of the simulated AM factory all through the Co-table. Additionally, the participants had the possibility to check the statistical results of each interaction. The feedback provided by the participants was used to improve the artefact in the next iteration of the Co-table simulation instance. The participant feedback was recorded after each artefact presentation. The participants were observed while they interacted with the Co-table and notes were taken. In addition to the observation studies, 5 semi-structured interviews and 2 unstructured interviews were conducted with the participants. The semi-structured interviews included some predetermined questions to obtain similar data from the participants. These guide questions were based on some of the themes we were investigating regarding the Co-Table. The open-ended question structure offered the flexibility that allowed spontaneous issues to be explored fully. Unstructured interviews allowed us to ask broad and open questions that enabled the participants’ thoughts and concerns to be investigated in greater depth. In both interview strategies, subsequent questions were determined by the interviewee’s responses. Additionally, a video presentation of the Co-table and layout simulation was prepared. This presentation was circulated on the company social network and the resulting feedback contributes to the data triangulation and enriches the data analysis. The interaction between the virtual environment and the digital elements using the Co-table can be seen in Fig. 2.

After each stakeholder interaction, the interviews were redesigned for the next presentation to incorporate insights gained from the previous observations and interview responses. The interview responses, participant observation and presentation feedback were used as the primary data for this study. Additionally, the data obtained from the project documentation and minutes of meetings between stakeholders and the Co-table software designers are also used in this study.

4. Results and discussion

The undertaken interviews and observation studies indicated potential value towards collaboration and decision making in using the Co-table among both the managers as well as simulation experts. At the management level, the main goal was to understand how emergent technology brings value by decreasing complexity for team collaboration and speeding up the creation and testing of alternative scenarios.

Fig. 3 illustrates the qualitative analysis based on data structuring and coded interviews (Hall and Khan, 2003). The representative data is extracted from the interviews both with managers as well as simulation experts. This data translates to the first-order concepts which are phrasal descriptors to categories and are retaining informant terms. Second-order themes are gained from our research questions as well as findings on Co-table from (Grube et al., 2019). The last step represents merged themes resulting in aggregate dimensions.

From the data analysis, we find that the Co-table contributes to manufacturing design in 4 key areas: communication, decision making, engagement, and co-creation. First, the communication aspect is impacted by the use of Co-Table as the participants are able to not only explain but physically demonstrate their ideas. The simulation experts are able to communicate their layout design in a simpler way, whereas the managers and non-experts are able to contribute to the layout design process. This could lead to the promotion of the Co-table as a communication tool that facilitates the transfer of tacit knowledge within project teams. A comment obtained from feedback on video presentation also corresponds to our findings on communication:
Table 1

<table>
<thead>
<tr>
<th>Challenges/Frustrations</th>
<th>Implications</th>
<th>Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenges while setting up the co-table</td>
<td>Lack of sufficient knowledge inside the company</td>
<td>Accelerating the learning curve by workshops and training</td>
</tr>
<tr>
<td>Long-time spend on set up</td>
<td>Lack of familiarity with the tool</td>
<td>More interaction with the Co-table</td>
</tr>
<tr>
<td>Frustration with many trials and errors</td>
<td>Impatience of participants and too high expectations</td>
<td>Acceptance of the learning process and internal change management</td>
</tr>
<tr>
<td>Two screens to interact with (the Co-table projection and the display with Plant Simulation)</td>
<td>Confusion about which screen is the main one to focus and rely on</td>
<td>Making it clear which is the main reference</td>
</tr>
</tbody>
</table>

“This would definitely help to simplify the exhibition, as the public has a clearer idea of line movements in production.”

The second area where the Co-Table has been found to positively impact manufacturing design is decision making. The Co-table enables managers faster decisions through direct engagement with the simulation environment. This means that before any decision is reached, the operational implications are revealed and considered through the co-table. This impacts how decision-making is done in manufacturing design within projects as real-time statistical validation becomes part of the process. This is also supported by the comment extracted from the feedback on the video presentation:

“Great to see a demo of Digital Engagement and an enabler for more fact-based decisions”

Engagement is the third area the Co-Table contributes to. The simplified complexity of simulation invites non-experts to interact and engage in the layout design process. Access to simulation is traditionally limited to those with simulation skills. The Co-table allows those without simulation skills to be more involved in the process. This engagement amongst involved stakeholders ensures that the layout simulation process is more inclusive and transparent. The fourth theme where the Co-Table brings value is Co-Creation. The analysis showed that the Co-Table can facilitate group discussion and increases the ease of conveying a message due to the graspable objects. This implies that throughout the process, both simulation experts and non-experts can co-create the factory layout.

While for the participants it was easy to navigate in the 3D simulation environment using Co-table, the prototype set-up itself brought several challenges. The implications and suggestions to alleviate the current limitations are demonstrated in Table 1.

While at the management level the perceived usefulness of the co-table is high, the simulation experts did not see the added value of Co-Table into their simulation. This might be due to the fact that the Co-table implementation requires the 3D implementation of the simulations, additional preparation of the physical objects as well as the integration of another software resulting in increased development times. This difference in perceived usefulness remains on the fact that simulation experts have already been exposed to the digital environment whereas the non-experts are often excluded from the technical environments during the layout design process.

One of the major topics brought up was the mismatch between the time spent on the setting up the Co-table and the final benefits received during the presentation. It was argued that this can be caused by the steep learning process of new technology and the nature of this being an early prototype. Reducing the hours spend on the preparation could be solved by providing the employees responsible for Co-table additional training on the Co-table (eddiion plugin) and practice while getting familiar with the new tool.

Hall and Khan. 2003 argue that the skill level of workers is one of the determinants of technology diffusion within a firm. The same study suggests that technology adoption can be slow if the technology requires complex-new skills and these new skills are costly or time-consuming to acquire (Luthra and Mangla, 2018). This is a common challenge within organizations where there are continuous technological changes. However, the set-up time and software integration, are unique challenges. This could be due to the independent updates of software involved in the Co-table simulation set-up. In order to improve this aspect, there is a need for closer collaboration between stakeholders involved.

From Table 1, we can conclude that for the best Co-table user experience, people have to acknowledge the need for training and sufficient practice to better understand the capabilities of the technology. A study suggests that “habit positively moderates the effect of perceived usefulness on cognitive attitude and affect” (Huang, 2017). Additionally, contemporary information system research suggests that the technology acceptance model is driven mainly by habit rather than by conscious judgment (Aarts and Dijkstra, 2000). Therefore in the initial phase of the Co-table adoption, there is a need for constant interaction with the Co-table among the employees rather than only focusing on understanding the value. This could be done but incorporating the Co-Table into the company’s daily workflows and promoting its use in daily presentations.

Furthermore, according to Meredith (1987) larger firms have a disadvantage in the implementation of new technology. This is due to the narrower perspective they have in the form of departments. Smaller firms have a broader perspective due to closer engagement with between all members of the firm. They further argue that top management is more involved in the implementation and can motivate and drive successful new technology implementation. In our case, while there was a team directly working with the Co-table, there is still a need for people working exclusively with the new technology.

According to Luthra and Mangla (2018), successful implementation of a new technology oftentimes requires complex new skills as well as time and resource investment. Therefore the adoption process can be slow, which is evident in our study. The speed of Co-table adoption should accelerate as more people become familiar and comfortable using and interacting with it. As such, there is a need for further studies, investigating how Co-tables - and similar tangible user interfaces to simulation - add value to manufacturing design.

5. Conclusion

This paper explores the impact of a tangible user interface to simulation (Co-table) on collaboration and co-creation in manufacturing design. The findings indicate a positive impact on four main factors: Communication, Decision Making, Engagement and Co-Creation. Furthermore, results show the interactive solution can facilitate that both management, customers as well as other stakeholders engage more actively in the decision process. This co-table prototype reduces the limitations previously restricting 3D and simulation software to be operated only by qualified techni-
cians. This potentially enables broader, immersive and more inclusive manufacturing design.

While the Co-table has shown positive contributions, some limitations were also identified. Firstly, in order to maximize the value capture, further studies need to be undertaken to investigate the required knowledge and skills level of the participants for the best user experience and value capturing. Secondly, work still needs to be done in order to provide a seamless software experience. Further investigations should be carried out in order to discover ways in which the Co-table set-up time can be shortened. While this study has contributed to understanding the initial benefits of using the Co-table, two main limitations are seen: (i) The case is conducted within one company. This can bias the sample making it unfeasible to generalize the results (ii) Another limitation is the Co-table integration with only one simulation software. There could be better integration achieved with other simulation programs.

Next steps aim to analyze and test whether the benefits and limitation for the Co-table adoption also apply to different industrial fields and the how different sectors can better capture the value from the Co-table use, allowing the development of an adoption framework that is cross-sectoral and can be used within different industries. Besides, to address one of the limitations, integration with different 3D modeling or simulation platforms could be carried out.

Declaration of Competing Interest

None.

References
