Smartwatch Integration in Digital Supply Chains

Ioan-Matei Sarivan, Casper Schou, Ole Madsen, Brian Vejrum Wæhrens

Smartwatch Integration in Digital Supply Chains*

Ioan-Matei Sarivan[1 [0000−0002−1469−9639]], Casper Schou[1 [0000−0001−7831−311X]], Ole Madsen[1 [0000−0003−2133−2541]], and Brian Vejrum Wæhrens[1 [0000−0001−6140−5587]]

Department of Materials and Production, Aalborg University, Fibigerstræde 16, 9220 Aalborg, Denmark
ioanms@mp.aau.dk
https://www.mp.aau.dk/

Abstract. As the maturity of digital integrated supply chains grows, the amount of operations which are tracked or which are directly controlled by a computerised system has seen a rapid increase with the emergence of the Industry 4.0 paradigm. This is notably desired in high-cost countries where having an overview on the supply chain is crucial in ensuring the delivery dependability for the customer. However, the manual tasks are overlooked to a certain extent. Most digitalisation initiatives have the worker interact manually with the manufacturing execution systems (MES) using terminals placed around the shop floor. Two scenarios in which the worker has to interact with a MES are given in this paper and a digital solution is proposed to solve the implied shortcomings concerning the interface between production planning and shop-floor production. A solution comes under the form of an open-source, freely available smartwatch app designed to be used by the workers for fast and easy interaction with the MES and enterprise resource planning system while at the same time serving as a task deployment method. The solution proposal is aligned with extant initiatives of obtaining end-to-end supply chain digitalisation while enabling the worker's fast responsiveness upon task deployment.

Keywords: Digital supply chain · Smartwatch · Smart manufacturing systems · Task deployment

1 Introduction

An end-to-end digitalized supply chain offers the ability to oversee the flow of data and materials, and the use of distributed resources in a centralised manner. The technical realisation of a digital supply chain is made through the successful integration of its business and technical systems (e.g. Enterprise Resource Planning System, Manufacturing Execution System etc.) [1]. However, the amount of captured details when attempting a systematic digitalisation can either be

* Supported by MADE (Manufacturing Academy of Denmark)

overwhelming or insufficient [2]. As a consequence, it becomes a question of granularity, in how much detail a process can be broken down concerning if an activity can be completely, partially or not at all digitalized [3].

This paper presents a granular approach towards digitalisation of supply chains by targeting manual operations carried out by blue-collar workers. It is aligned with the efforts of combating factors that are hindering the implementation of digital technologies within small-medium enterprises (SME) like management awareness and required skill intensity [4]. A technical artefact is proposed, meant for small medium enterprises to experiment with the use of smartwatch devices in their attempt of optimising manual task deployment and coordination. The artefact is an open source, proof of concept on how wearable devices can be used as a digital integration tool in an industrial manufacturing environment.

The paper is structured as follows: the conducted literature study within the context of manufacturing supply chain digitalisation in high cost environments is presented in section 2 which serves as motivation for the development of the artefact. Moreover, the perspective of two use-cases from industry are given, where digitalisation of manual labour is relevant. The third section presents related work regarding support of manual labour using smartwatches. The proposed digital solution is presented in section 4. The paper is concluded with a discussion on how the presented artefact can fit in the digitalisation initiatives taken in high-cost environments, while placing it in relation with already existing similar technologies.

2 Motivation for using smartwatches in industry

To motivate the development of the artefact presented in section 4, a literature study was conducted regarding the perspective of supply chain digitalisation in high-cost environments. A study backed up by empirical data gathered from industry in these environments (e.g. Sweden) point out that the main challenge of the northern industry is to compete with companies from low-cost countries (e.g. Eastern Europe, Asia) on product cost [5]. Therefore, manufacturing companies which stay located in high-cost environments should choose to invest in the maturity of their digital supply chain in order for them to gain an edge on the quality, delivery dependability, flexibility, innovation, cost efficiency and sustainability dimensions of their business [5].

However, investing in the digital maturity of the supply chain also needs to make it possible for the existing methods to be combined with the new methods in clever ways to unlock performance [6]. Nygaard et al. [6] state this target can be achieved by frequent experimentation with new technologies in order to prevent taking costly and overwhelming decisions. It is further stated that there is a need for more efforts into the operational design of IoT based solutions.

Following the literature study in the context of high-cost environments, a strong motivation was found for supply chain digitalisation backed up by national plans in most of Europe [7]. Moreover, discussions with two industrial partners

have further strengthened the motivation of looking into how the traditional human labour can benefit from digitalisation. The discussions were in line with the companies' initiative of developing their methods of adopting and utilising new enabling technologies that assist the workers in performing their daily tasks [8]. Two use-cases are hereby given:

2.1 Case 1

Automotive manufacturer in Germany: while assembling electronic components, the worker must confirm the successful assembly of the item within the MES by using a touchscreen interface available in various locations around the factory floor. The worker expressed the desire for a system which is highly portable, for it to be carried inside the body of the car when necessary and that it facilitates the interaction needed with the MES in order to complete the task.

2.2 Case 2

Metal structures manufacturer in Denmark: work force coordination of the human welders happens off-line without having the status of the weldments being tracked within the MES system. The MES system is only used to a limited extent by specialised workers within the factory. The management expressed the desire of having all the workers in the factory interact with the MES system, but without high training investments. Their main expectation is to facilitate task deployment and fast reaction regarding events triggered by various machines around the factory that need immediate attention, e.g. a milling machine needs a tool change to continue the programmed task.

3 State of the art: smartwatches in industry

The usage of wearable technologies in the manufacturing industry for digital integration is documented in literature to a limited extent in terms of having an artefact specifically designed for integration of human labour in a digital supply chain. The use of smartwatches is however encouraged as it makes the interaction with the digital platforms easier when compared with traditional methods [9]. E.g., to use a bar-code scanner, the worker needs to stop what they are doing, lift the scanner, perform the scanning action, put the scanner back and continue whatever they were doing [9]. The interaction is made easier likely because of the available data input and output methods supported by the touchscreen.

Several examples from literature were selected by the authors to illustrate existing efforts in having smartwatches present in industrial environments. These however are specifically focused on exploiting the available sensors on the smartwatch to perform activity recognition in healthcare and sports applications [10], having energy efficiency as main research motivation. The available sensors on a smartwatch are exploited in a manufacturing application too, where artificial intelligence is used to classify the task performed by the worker as successful

or unsuccessful based on audio and accelerometer data gathered by the sensors available on the smartwatch [11].

Solutions targeted to industrial manufacturing revolving around digital integration using smartwatches are available commercially, being provided by various start-up companies, in the spirit of Industry 4.0. Such a company exists in Germany and offers a proprietary smartwatch which is advertised as being able to be integrated in the MES of the customer company [12].

Following the state of the art analysis that use of smartwatches in industrial manufacturing environments, a research gap has been identified in what concerns the use of these devices in supply chain digitalisation attempts by providing the blue-collar worker a wearable and direct interface for the MES, which is also freely available in an open-source form.

4 Task deployment using smartwatches

Even though, several solutions are already commercially available, the artefact presented in this section aligns with the initiative of providing small medium companies the possibility of experimenting with smartwatch like technologies before deciding on a large scale implementation, as supported by Nygaard et al. [6]. A prototype was developed under the form of an open source WearOS application [13]. The application can run on any smartwatch device that has WearOS as an operating system, thus taking advantage of the widely spread familiarity with the Android system which runs on smartphones. Therefore, little to no training is required for the user to get acquainted with the functionalities of the application once it is installed on the smartwatch. While in use, the app can receive tasks for the worker to perform automatically, from the MES.

When an event tracked by the MES occurs, e.g. a CNC machine needs to be unloaded, the task is sent to all the connected smartwatches which have the necessary roles (assigned in the MES) to fulfil the task. A task can have one of the following statuses:

- PENDING: the task is pending acquirement by an available worker
- ACQUIRED: the task was acquired by worker with smartwatch ID "x" and it is in progress
- COMPLETED: the task was completed by worker with smartwatch ID "x"

The process happens in real time upon user's interaction with the system using the graphical user interface (GUI) available on the smartwatch's screen, which can be observed in Figure 1 and 2.

Once a new task is created by an event triggered in the MES, the task is sent to all the connected smartwatches of the workers who can perform the task, under several predefined criteria. The task is added to a stack through which the worker can navigate using the "PREV" and "NEXT" navigation buttons available on the app's GUI (Figure 1). Depending on the priority of the task, it is displayed with a yellow background (NORMAL) or red background (URGENT). When a new task is received, a chime is played and haptic signal is performed in order

Fig. 1. Photo of the task coordinator app while showing an "urgent" task generated by "Robot2" with the description "Task Execution Error". The second task our of two tasks available in queue for the user is displayed. The "prev" and "next" buttons allows the user to navigate through the tasks queue

to alert the worker depending on the task's priority. The tasks are displayed in a first in - first out pattern, but urgent tasks take priority over a normal task by being displayed on screen as soon as it arrives. A task can be acquired by an available worker who has the necessary roles by tapping the "ACQUIRE TASK" button. Once acquired, the task disappears from all the other smartwatches connected to the MES. Upon completion of the task, the user must tap "TASK COMPLETE", as observed in Figure 2. This will update the status of the task on the MES's side. The origin of the task and the description of the task are also displayed on the GUI, where the origin of the task is represented by an IoT device that requires the worker's attention or by manual tasks that is queued in the manufacturing execution system.

The perquisites of implementing this open source artefact for digital integration purposes are the availability of a MES and a sufficient number of WearOS smartwatches. The code for both the server and the client is available at https://github.com/MateiSarivan/Industrial-SmartWatch

5 Discussion and conclusion

The presented technical artefact is meant to provide manufacturing enterprises with a tool to experiment with in the attempt of achieving end-to-end supply chain digitalisation. The focus is on the deployment and management of manual tasks. Such it is expected to overcome the usual obstacles that are in the way of implementing new technologies [4]. This comes as an auxiliary system which is meant to be implemented inside the MES platform and used by the shop floor workers for fast responsiveness upon task deployment. By being designed around an element with a high degree of familiarity of a smartwatch, no training

Fig. 2. Photo of the task coordinator app running on two smartwatches. The smartwatch on the right hand side displays a "normal" task. The smartwatch on the left hand side displays an "acquired" task which is currently being performed by the worker.

investment is expected to be made by the companies for using the device. The artefact competes with current solutions commercially available, by having an open source design which anyone can use as-is or further develop to fit individual use-cases, without having to engage into long-term commitments with an external know-how supplier [6].

The prototype as it is in the current state, aligns with the use-cases presented in section 2. The wearable nature of the device allows the worker to have it "at hand" in places where a traditional digital interface is impossible to be placed, like the body of the car. The software design allows for fast worker response upon task deployment as required in the second use-case. Further development of the artefact can take into account more complex interactions with the digital platforms available in the manufacturing environment, such as data collection using the equipped sensors [11].

Testing of the artefact was only performed in a controlled environment in the laboratory of the affiliated university, as access to real production environment Was limited at the time. Given the functionalities of the prototype like the ability to send tasks immediately to the factory personnel as they emerge and the "at-hand" interface of the app, an infrastructure is established to address the use cases and the identified research gap which motivated the development.

5.1 Acknowledgements

The authors would like to thank MADE FAST Association for providing financial support, and the MADE FAST associated companies for providing relevant information from the manufacturing industry. MADE FAST is financed by the member companies, the Innovation Fund Denmark under the Danish government, private funds and Universities.

References

1. Groover, M. P.: Automation, Production Systems, and Computer-Integrated Manufacturing. 4th edn. Pearson, England (2016)
2. Forrester, J.W.: Industrial Dynamics. The M.I.T. Press and John Wiley & Sons Inc. New York, London (1961)
3. Fleischmann A., Oppl S., Schmidt W., Stary C.: Contextual Process Digitalization. Springer Open, Cham (2020)
4. Bell T.: Supply Chain Integration Systems by Small Engineering to Order Companies: The Challenge of Implementation. Journal of Manufacturing Technology Management **21**(1), 50–62 (2009)
5. Sansone, C., Hilletofth P., Eriksson, D.: Evaluation of critical operations capabilities for competitive manufacturing in a high-cost environment. Journal of Global Operations and Strategic Sourcing
6. Nygaard, J., Colli, M., Wæhrens, B.V.: A self-assessment framework for supporting continuous improvement through IoT integration. In: 1st International Conference on Industry 4.0 and Smart Manufacturing (ISM 2019), Procedia Manufacturing, pp. 344–350. Elsevier, Italy (2019)**13**(3), pp. 229–250 (2020)
7. Colli, M., Cavalieri, S., Cimini, C., Madsen O., Wæhrens, B.V.: Digital Transformation Strategies for Achieving Operational Excellence: a Cross-Country Evaluation. In: Proceedings of the 53rd Hawaii International Conference on System Sciences (HICSS), pp. 4581–4590. University of Hawaii, Hawaii (2020)
8. Saabye, H., Kristensen, T.B., Wæhrens, B.V.: Real-Time Data Utilization Barriers to Improving Production Performance: An In-depth Case Study Linking Lean Management and Industry 4.0 from a Learning Organization Perspective. Sustainability **12**(21) (2020)
9. Lindell, C.: Wearables on the manufacturing floor. Food Engineering **90**, pp. 52–55 (2018).
10. Garcia-Ceja E., Galván-Tejada, C.E., Brena, R.: Multi-view Stacking for Activity Recognition with Sound and Accelerometer Data. Information Fusion **40**, pp. 45–56 (2018)
11. Sarivan, I.-M., Greiner, J.N., Álvarez, D.D., Euteneuer, F., Reichenbach, M., Madsen, O., Bøgh S.: Enabling Real-Time Quality Inspection in Smart Manufacturing Through Wearable Smart Devices and Deep Learning. In: 30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2021), Procedia Manufacturing, pp. 373–380. Elsevier, Greece (2021)
12. WorkerBase SmartWatch, WorkerBase GmbH, https://workerbase.com/connected-worker-platform. Last accessed 15 Jul 2021
13. Introduction to Wear OS, Google, https://developer.android.com/training/wearables Last accessed 14 Jul 2021