Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, Vol 3, No 1, 2021, Article ID 506

Digital assistance for mobile 3D-printing of medical supplies

M. Vogt[*], K. Janzen, A. Voßhenrich, J. Lakämper and R. Lau

Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT, Hamburg, Germany
[*] *Corresponding author, email: maximilian.vogt@iapt.fraunhofer.de*

Abstract: In order to enable fast medical response in times of pandemics or other humanitarian crises, decentralized manufacturing networks based on additive manufacturing technologies are suitable for the demand-driven production of protective equipment and medical supplies. The use of mobile manufacturing units is intended to increase the resilience of isolated and overwhelmed hospitals in developing countries. In this paper, a digital assistance system for enabling untrained staff to handle the mobile manufacturing unit as well as operate and maintain 3D printers on site will be discussed.

I. Introduction

While the Corona pandemic appears to be nearing its end in most developed countries, the current first-time vaccination rate in Africa is still below 3% (June 2021) [1]. Here and in other developing countries, further new epicenters of the pandemic are more than likely [2]. Therefore, and also with a view to future pandemics, mobile and self-sufficient production units are becoming increasingly important. The supply chains of goods and services have become increasingly complex due to globalization and thus more vulnerable to disruptions. Individual failures within a supply chain can lead to the interruption or breakdown of the entire value chain [3]. Therefore, it will become increasingly important in the future to create fast and short-term ways of bridging, which can only be ensured by decentralized production. Additive manufacturing (AM) processes can contribute to increasing the resilience of such complex value creation systems [4]. AM is already a common technology in medicine, but the processes for producing medical supplies differ significantly from the highly complex clinical workflow of patient-specific devices [5]. Moreover, the technology is not yet so ubiquitous that every hospital has access to AM machines.

Scientists at Fraunhofer IAPT have therefore developed a mobile production unit that enables decentralized production using AM for medical supplies. The focus here was particularly on user-machine interaction, as this is one of the most important and yet most frequently neglected aspects of decentralized manufacturing. Especially in crisis situations, on-site training of personnel is often not possible and manual work steps must be designed in such a way that they can also be performed by untrained persons.

II. Material and methods

In the project “MobiMed”, a twenty-foot freight container was converted in a mobile additive production unit which, thanks to CSC (Container Safety Convention) certification, can be shipped worldwide and thus taken to crisis areas to provide short-term supply of medical equipment and bridge disrupted supply chains quickly. For this purpose, the container is equipped with workbenches, air-conditioning and AM systems that allow it to be used in almost any environment. In addition, a data management system with an accompanying augmented reality application was developed in order to enable untrained personnel to use the MobiMed. The goal of the software development was to enable the operation of 3D printers without any prior knowledge in case of emergency.

II.I Integration of AM processes in MobiMed

In MobiMed two AM process chains with the most promising productivity estimations were integrated [4]. A fused filament fabrication (FFF) printer is utilized to print headbands for face shields using PLA filaments. After the print job of 16 parts, support structures must be removed and the headbands have to be assembled with a transparent shield to finalize the protective gear. Stereolithography (SLA) is used to fabricate swabs from medical resin (Formlabs Surgical Guide Resin). The printed parts are washed out with isopropanol (IPA) and cured in a curing oven. Afterwards the stacks of 204 swabs are taken apart, packed individually and sterilized. Fig. 1 shows the AM process chains of these two parts.

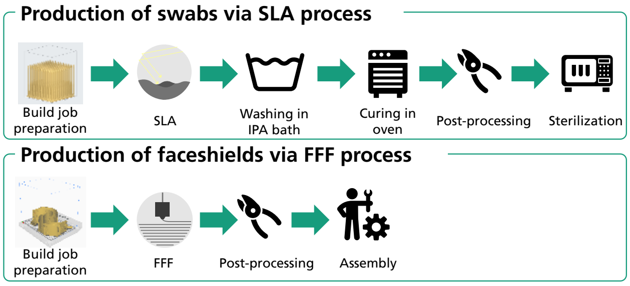

Figure 1: Schematic representation of the two process chains implemented in the mobile manufacturing unit MobiMed.

DOI: 10.18416/AMMM.2021.2109506

For the last steps, a separate room is included in the container with a packaging station and sterilization autoclave.

II.II Digitization of the process chains

To enable data and machine preparation, a software system with cloud connection was developed. For the decentral retrieval of prepared build jobs of new parts, the container is equipped with a mobile router. The system consists of a workflow management module and a digital assistance application. The workflow management module provides a structured display of all activities and acts as a hub for notifications regarding pending maintenance processes and the availability of consumables. An integrated ordering system ensures traceability of the critical medical products and provides data collection as well as data visualization. Via this interface, e.g. hospitals in the area of deployment can request new products.

Digital assistance systems enable the specific support of humans in the work process by the punctual and software-based provision of information. Augmented reality (AR) is a suitable technological tool for this purpose. AR belongs to the immersive technologies, i.e. procedures that allow humans to immerse themselves in a virtual environment [6]. By means of AR, the user's visual perception can be enhanced by context-sensitive insertion of virtual elements. In this context, AR supported digital assistance systems offer a high potential for guidance and error reduction in AM [7]. In MobiMed, the AR digital assistance system supports the operator in performing maintenance processes and selecting the appropriate build job for production. Virtual 3D models of possible printjobs are projected to the operator. Further information, such as the required material or printing duration, is shown. Printing can be started directly from the application without the need to use a CAD program or interaction with the printer. This solution does not require an internet connection as long as no new build job is integrated. Fig. 2 shows the operation of the FFF printer in MobiMed using HoloLens AR glasses.

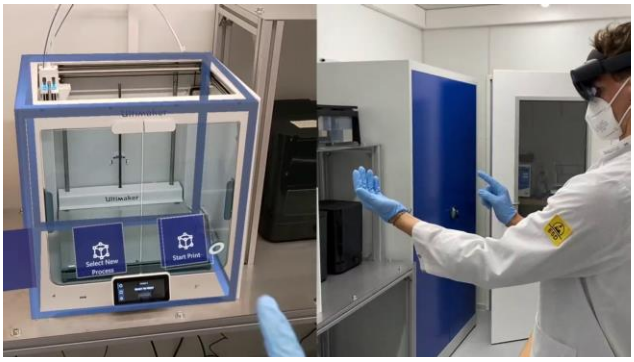

Figure 2: Left: First person view of the AR user interface with FFF printer control. Right: Operator using the AR glasses to control the FFF printer in MobiMed.

In a test environment, nine participants were provided with the AR system or the conventional manual of the FFF printer in order to perform a maintenance process and start a specific print job on the machine. The time of performance was stopped and they were asked to provide feedback afterwards.

III. Results and discussion

None of the nine individuals have worked with this AM machine before and the majority was new to AR glasses. All participants were able to perform the tasks successfully, both with the software and the manual. However, the survey revealed that all the participants think that AR has the potential to benefit AM, reasoning that it can be especially useful for untrained personnel and maintenance tasks. In a next step, the application should be tested with medical assistants, that have no experience in using 3D printers to perform all the necessary steps to print applicable medical supplies and monitor the MobiMed manufacturing unit.

IV. Conclusions

AM processes are considered a suitable technology for resilient production by providing flexibility in the event of emergency and failures in global supply chains. Two features in particular distinguish the newly developed mobile manufacturing unit MobiMed: Mobility and self-sufficiency. MobiMed was already successfully used to manufacture swabs and face shields via AM. By accompanying MobiMed with a digital assistance and workflow management system, untrained personnel shall be enabled to perform all necessary tasks to produce medical supplies and protective equipment in crisis situations. In the next step, the integration of a recycling system should be considered to enable the recovery of thermoplastic filament material. In addition, the use of a generator would enable temporary independence from an active power supply. This is the only way to achieve maximum self-sufficiency of the production unit, which is necessary to be able to operate quickly and flexibly on site.

Acknowledgments

Research funding: This work was supported by the Fraunhofer Internal Programs under Grant No. Anti-Corona 179-640001.

Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

References

[1] Johns Hopkins Coronavirus Resource Center, Understanding Vaccination Progress by Country, 2021. https://coronavirus.jhu.edu/vaccines/international (accessed 26 June 2021).

[2] E.F. Doungmo Goufo, Y. Khan, Q.A. Chaudhry, *HIV and shifting epicenters for COVID-19, an alert for some countries*, Chaos Solitons Fractals 139 (2020) 110030.

[3] W. Shih, *Is It Time to Rethink Globalized Supply Chains?*, 2020. https://sloanreview.mit.edu/article/is-it-time-to-rethink-globalized-supply-chains/ (accessed 15 June 2021).

[4] M. Salmi, J.S. Akmal, E. Pei, J. Wolff, A. Jaribion, S.H. Khajavi, *3D Printing in COVID-19: Productivity Estimation of the Most Promising Open Source Solutions in Emergency Situations*, Applied Sciences 10 (2020) 4004.

[5] I. Ludwig, A. Ernst, P. Gromzig, J. Wolff, *Clinical Workflow in Medical Additive Manufacturing*. Transactions on Additive Manufacturing Meets Medicine, Vol 1 (2019)

[6] P. Milgram, H. Takemura, A. Utsumi, F. Kishino, *Augmented reality: a class of displays on the reality-virtuality continuum*, in: Telemanipulator and Telepresence Technologies, Boston, MA, SPIE, 1995, pp. 282–292.

[7] M. Vogt, A. Rips, C. Emmelmann, *Augmented Reality in der additiven Produktion*, ZWF 115 (2020) 800–804.