Online Monitoring and Control FDM Devices: Study

Rebeka Tauberová(✉), Peter Lazorík, Lucia Knapčíková, and Jozef Husár

Faculty of Manufacturing Technologies with a Seat in Presov, Department of Industrial Engineering and Informatics, Technical University of Košice, Bayerova 1, 08001 Prešov, Slovakia

{rebeka.tauberova,peter.lazorik,lucia.knapcikova,jozef.husar}@tuke.sk

Abstract. Digitization is the key word of the term Industrial Revolution of fourth generation. Digitization in industrial enterprises makes it possible to examine various influences on production processes without the necessary entry into real production. Thanks to technologies, that are part of the digitization of manufacturing enterprises such as, augmented reality, virtual reality, additive manufacturing, digital twin, and artificial intelligence, we can monitor selected parameters without interfering with the production process. The funds spent, ensuring the transformation of a traditional enterprise into a digital enterprise, ultimately save production costs. The concept of digitization within industrial enterprises has taken on much greater dimension and importance in connection with events such as COVID 19, which has affected everyday life all over the Earth. At that moment, many companies realized, what a great advantage digitalization of the entire production is. The pressure of events and economic influences led to the accelerated adoption of digitization and intelligent automation. Introduction of digital technologies ultimately makes it possible to use resources, which are entering the production process, more efficiently and intensively. The advantage of digitization of production is increasing material productivity, and the optimization of input production costs. The implementation of artificial intelligence tools in production enables remote control of production in additive manufacturing. Advancing digitalization is big change in many fields such as aviation, medicine, engineering, and automotive industry. Main and necessary pillar are the employees with their skills, knowledge, and years of experiences. Additive manufacturing is field with great potential for the future. There is a big space for new innovations, process improvement and also for quality monitoring. This study is reporting about the online monitoring and control for Fused Deposition Model devices.

Keywords: Additive manufacturing · Fused Deposition Modeling · Online monitoring · Octoprint

D. Perakovic and L. Knapcikova (Eds.): FABULOUS 2023, LNICST 542, pp. 135–146, 2024.
https://doi.org/10.1007/978-3-031-50051-0_10

1 Introduction

The basic elements of additive manufacturing were commercially developed and researched since the end of 1980s. Additive manufacturing (AM) is a process of creation physical objects from 3D models layering and application of material. It is advanced manufacturing technology, which is creating 3D objects from based on drawings created in CAD system. Technology of additive manufacturing is well known and widespread throughout the engineering industry. But also, in specific areas such as custom – made products, also in a medical purposes and automotive industry as well. 3D printing can be defined as the opposite of traditional manufacturing such as turning or milling. Advantage od additive manufacturing is not only that it is cheaper and more accessible, but also AM is more environmentally friendly. Compared to traditional production additive manufacturing produce at least almost no material waste, which represents a more sustainable way of technology, which saves and reduces the amount of material entering the production process. Advantage of AM is the possibility to connect the 3D printer with the external devices such as virtual glasses, sensors or with programmable logic controller. In general, there are several methods of additive manufacturing on the market. Most often used methods are FDM (Fused Deposition Modeling), DMD (Direct Metal Deposition), SLS (Selective Laser Sintering), IJM (Inject Modeling) and SLA (Stereo Lithography).

This study is focused primarily on the FDM method in 3D printing and online monitoring and control of specific device. Huge benefit in additive manufacturing is the possibility to control the particular 3D printer remotely. It is possible through the Octoprint, which is free open-source applications, that allows a remote-control 3D printer remotely. Octoprint can be connected to the smartphone, which can control the start of the printing anytime. Before successful remote control, 3D printer must be connected through (USB) Universal Serial Bus with the single board computer Raspberry Pi on which Octoprint is running. Single board computer (Raspberry Pi) has to be connected to the network, where Octoprint is running as a supplementary application. For remote control of 3D printer, it is necessary to be connected on a local network, where the IP address is assigned. If the IP address is not public Octoprint has to be linked with the cloud platform through the authentication data. Cloud application will allow us to connect remotely with the Octoprint, anywhere with the available internet connection. If the mentioned steps are followed correctly, it is possible to communicate with the 3D printer. Most frequently used cloud applications are for instance Karmen and Octoprint Everywhere.

2 Fused Deposition Modeling Method

The FDM (Fused Deposition Modeling) method is the most widespread among the others mentioned, mainly due to its simple operation and relatively low price. Before printing starts it is necessary to create or download 3D model in STL format. STL format must be converted to the GCODE language, which can communicate with the specific printer. Then the created file is connected via Universal Serial Bus (USB) to the 3D printer. Basic principle of FDM method starts with the advancement of thermoplastic filament from large spool. Filaments is captured by the extruder gear and pushed down towards the hot end. Subsequently the nozzle is heated to melt the filament and moved in the x,y and z directions according to a pre-determined design. Due to the rapid hardening of the material, the model is created immediately after the filament is extruded from the nozzle by layering the material. If we want to achieve the desired fiber connection effect, it is necessary to control the printing parameters, such as the printing temperature and the material application speed. The printing temperature is often closely related to the selected filament. If the mentioned procedure is followed, it is possible to achieve the required quality of product printing. Following figure shows FDM 3D printer. (Fig. 1).

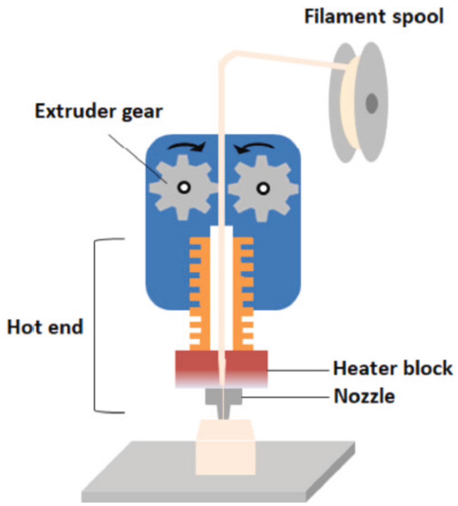

Fig. 1. Fused Deposition Modeling 3D Printer

Specific printer which is connected to the Octoprint is Creality CR-30. This 3D printer uses technology FDM for printing. Specific property of Creality CR-30 is infinity Z axis printing zone, which allows users to print unlimited. Another advantage of this printer is built in rolling conveyor belt. This type of printer is suitable to be placed on conveyor belt in production as it is shown in the next Fig. 2.

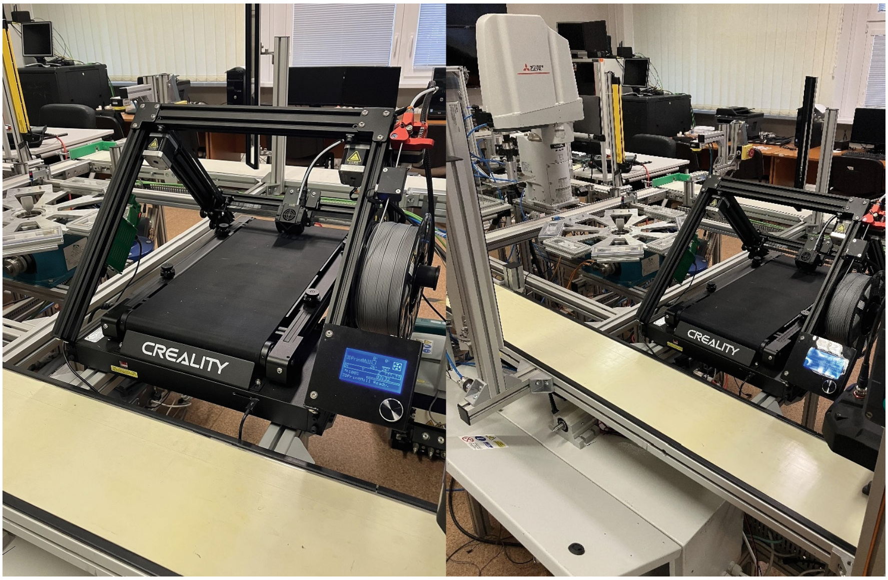

Fig. 2. Creality CR-30 placed on conveyor belt

Following Table 1. Represent the basic parameters of 3D printer Creality CR-30.

Table 1. Parameters Creality CR-30

Product Parameters Creality CR-30	
Print tech: FDM	Nozzle Qty: 1
Print Size: 200 * 170 * ∞ mm	Hot Bed Temperature: $\leq$ 00 °C
Product Size: 535* 656 * 410 mm	Nozzle Temperature: $\leq$240 °C
Package Size: 685 * 565 * 302 mm	Layer Height: 0,1 mm-0,4 mm
Product Net Weight: 16,5 kg	Maximum Power Consumption: 350W
Package Gross Weight: 20,5 kg	Power Requirement: AC 100–200/200–240, DC 24V
Slicing Software: Crealitybelt	Supported Materials: PLA/TPU/PETG
Printing Precision: $\pm$ 0,1 mm	Filament Diameter: 1,75 mm
Nozzle Diameter: 0,4 mm	

2.1 OctoPrint and Software

Octoprint can be connected to the smartphone, which can control the start of the printing anytime. Before successful remote control, 3D printer must be connected through (USB) Universal Serial Bus with the single board computer Raspberry Pi on which Octoprint is running. Single board computer (Raspberry Pi) has to be connected to the network, where Octoprint is running as a supplementary application. For remote control of 3D printer, it is necessary to be connected on a local network, where the IP address is assigned. If the IP address is not public Octoprint has to be linked with the cloud platform through the authentication data. Cloud application will allow us to connect remotely with the Octoprint, anywhere with the available internet connection. If the mentioned steps are followed correctly, it is possible to communicate with the 3D printer. Most frequently used cloud applications are for instance Karmen and Octoprint Everywhere. Following block diagram on the Fig. 3 represents software and hardware system.

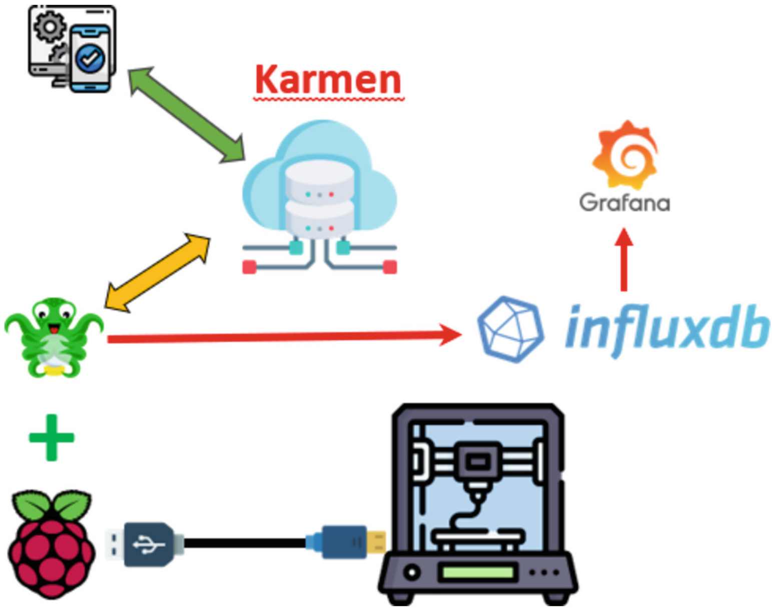

Fig. 3. Block Diagram

Before working with the Octoprint it is necessary to configure initial state, for instance it is mandatory to configure access (username and password), model of printer (creality cr-30), additional printer profile (print volume, print bed, print volume, axes, nozzle diameter, number of extruder and default extrusion length). (See Fig. 4).

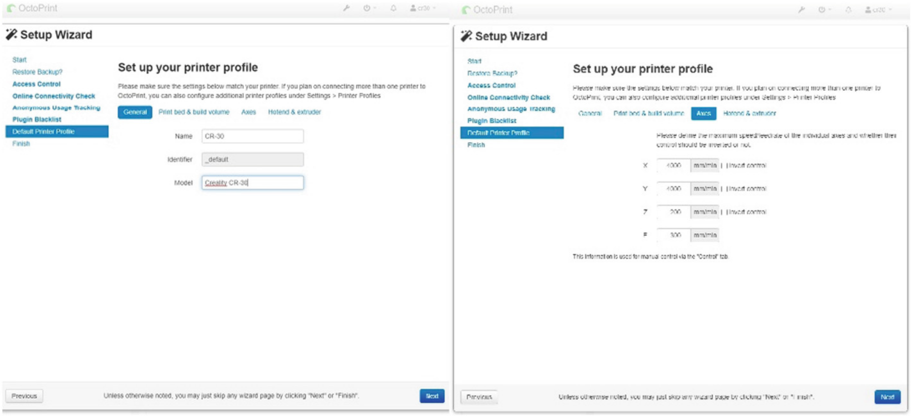

Fig. 4. Configuration of Octoprint

After completing the configuration, it is possible to go to the initial page intended for the user interface. In the user interface is possible to remote control the printer, start printing, control the printing temperature or to monitor the printing process. (Fig. 5).

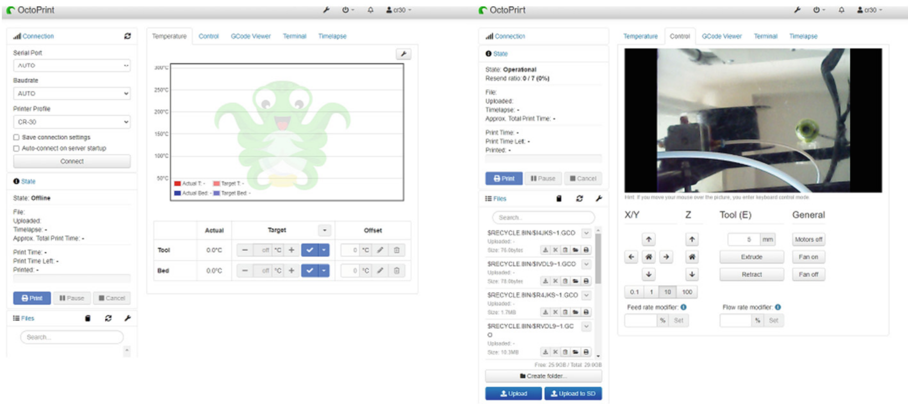

Fig. 5. User interface of Octoprint

3 Research and Discussion

Research part of submitted study is dedicated to configured part of the Octoprint. Configured Octoprint enables to control 3D printer Creality CR-30, which is situated in laboratory, remotely. Octoprint is running on single board computer Raspberry Pi, which can be placed directly on 3D printer. Amendment between the basic shape of Octoprint and configured shape of Octoprint is in external additional modules. During the configuration were used six external modules to achieve the desired shape of Octoprint:

- Karmen Connector
- Octoprint-Influx DB
- Custom CSS
- Print Scheduler
- Dashboard
- PrettyGCode

Karmen Connector is cloud applications, from which is possible to communicate with the specific 3D printer remotely. Karmen Connector can be connected to the smart phone, which allows notifications to be sent and inform user about the printing process.

Octoprint-Influx DB is time series database, where the data for instance temperature are sent from the Octoprint. Collected data are sent only as a numbers to the selected database file, where they are subsequently stored. The octoprint itself does not store the specific data about the printing process, that is the reason why the database Influx DB is necessary.

Following Fig. 6 offers a view on Octoprint, which is running on Raspberry PI.

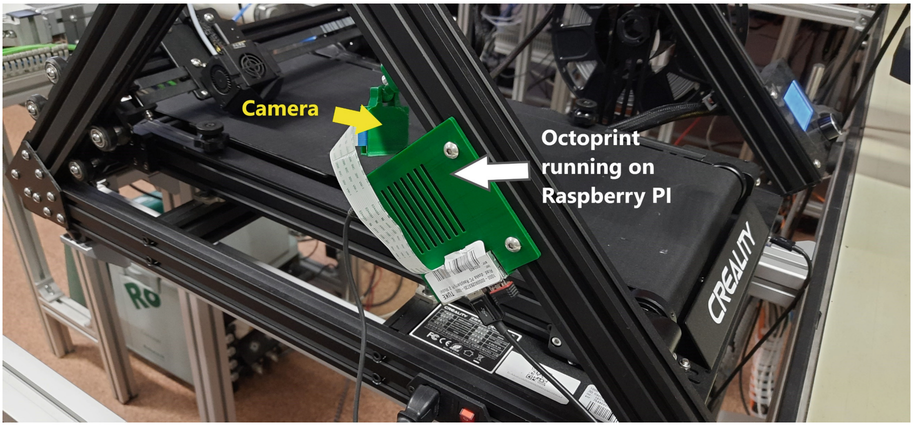

Fig. 6. Octoprint running on Raspberry PI

Custom CSS is additional external module used for customizing the basic user interface. Selected requirements are modified through the CSS programming language. For our needs, the base color of the user interface was changed from white to purple. Because the purple color represents our faculty of Manufacturing Technologies (Fig. 7).

Print Scheduler simplifies printing process because it enables to plan the printing forward ahead of time. This module is offering great help in situations, when it is not possible to be physically all day in laboratory, or when the factory has a commission, which has to be done in specific deadline as soon as possible.

Dashboard is module, which is used to configure the user interface of Octoprint. Basically, Dashboard enables to add commands, which user wants to have. For instance, if user wants to have a button on the user interface for temperature coming from an external sensor, it is necessary to click it in the dashboard.

PrettyGCode is visualization module, which displays colored lines to give you some idea, what the printer is doing and animates progress during the printing.

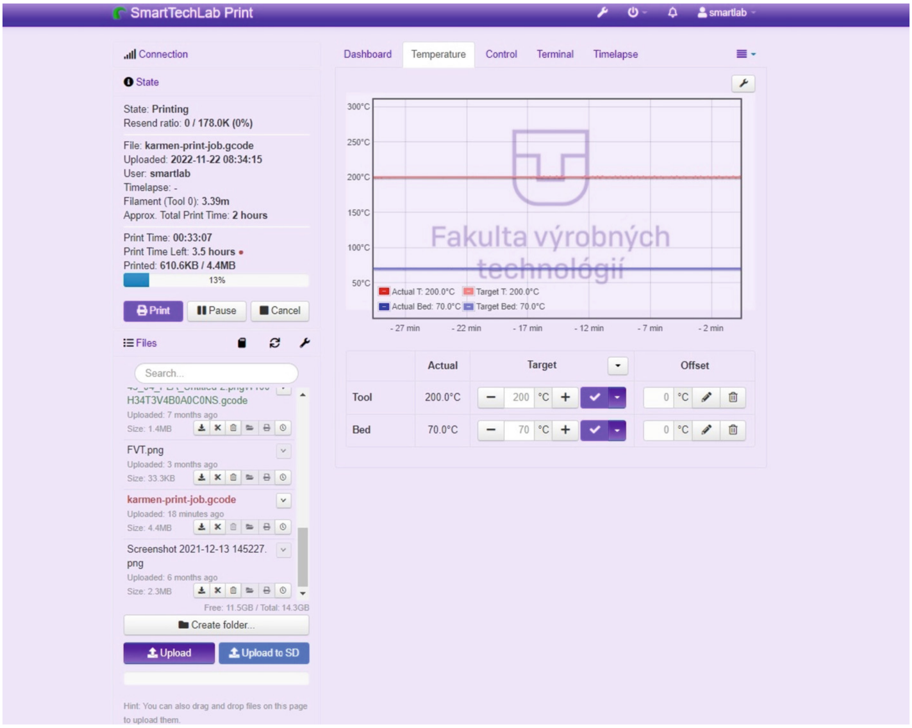

Fig. 7. Configured Octoprint

For this study was Octoprint configured and adapted according to the selected requirements. Additional configurations were made via using external modules listed above. The configured Octoprint was given a name SmartTechLab Print because 3D printer Creality CR-30, which can be controlled remotely by Octoprint, is situated in laboratory, which is called SmartTechLab. (See Fig. 6, Fig. 7, and Fig. 8). It is also possible to add more 3D printers, which can be connected remotely. For instance, this possibility is great for big laboratories, where employees have ten or more 3D printers. In order for remote control to be possible, the entire procedure explained above must be repeated for each printer separately. In large laboratories this possibility to remote control 3D printers is big advantage for employees, because they don't need to go the laboratory to simply turn on the 3D printer.

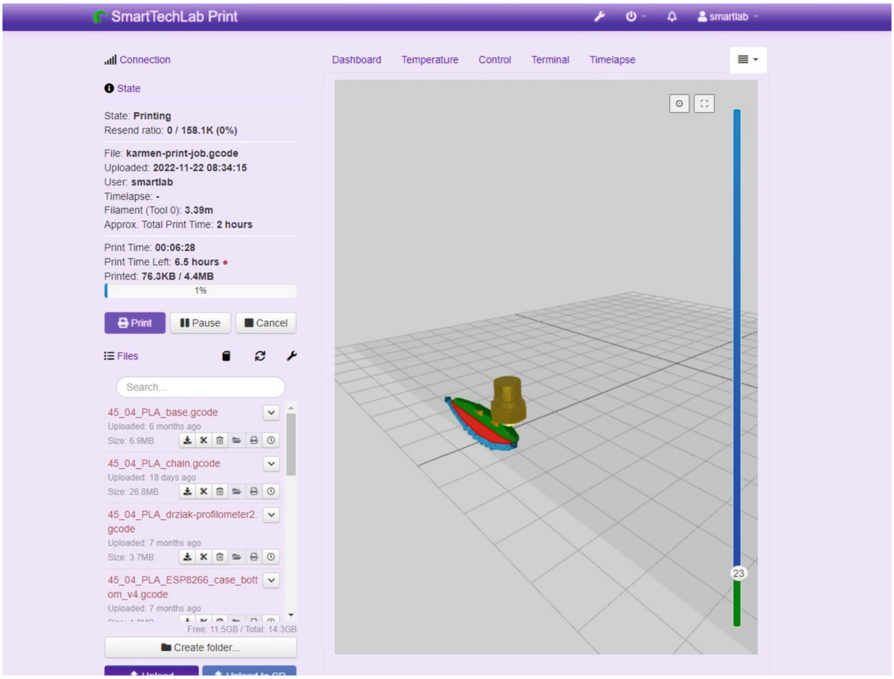

Fig. 8. 3D Visualization Octoprint

When the configuration of Octoprint is done, it is possible to start or pause or cancel the printing process. Octoprint dashboard displays information about printhead temperature, hot end temperature, total printing time. And it is also possible to control amount of filament needed for printing. On Fig. 7 is possible to see 3D visualization in Octoprint. This function of Octoprint dashboard is great for better imaginations of printed products. Following Fig. 9 displays bed temperature of printer Creality CR-30 and hotend temperature.

Displayed graph represents numerical data from printing process on 3D printer Creality CR-30. As we can see in the graph, the value of the measured temperature of hotend was 200,0 °C during the whole printing process and bed temperature was about 60,0 °C. Hotend temperature primary depends of type of filament, because every type of filament has different melting point. Presented graphs was download from visualization tool Grafana. (See Fig. 8).

Fig. 9. Bed and Hotend Temperature of 3D printer Creality CR-30

Collected data are sent from Octoprint to the database Influx DB, which is saving them only as numbers. Influx DB is type of database, which is built specially for handling metrics, events, or measurements, that are time-stamped. For the statistical expression of the collected data is used Grafana. Grafana is popular open-source time-series data visualization and alerting tool. It has a data source model, which is highly pluggable and supports multiple time series-based data sources like Prometheus, Influx DB or SQL databases like MySQL. Regardless of where the data is stored, it allows you to visualize data through graphs. There is also possibility to measure the temperature in the laboratory, where specific printer is placed, but in this case, it is necessary to have some external sensors, which are fixed and cooperate with the 3D printer.

4 Conclusion

In the submitted study, the monitoring of FDM device is ensured by the open-source application OctoPrint, through which is possible to remote control of specific 3D printer. With the help of the use of available modern technologies is possible to start printing process from any place with accessible internet connection. Additive manufacturing is rapidly developing progressive technology, that is hiding number of potential possibilities, which has a great enforcement in the future. The primary focus of this paper is to reduce physical interaction between machine and human through the remote control of specific devices in additive manufacturing. Reducing physical interaction between machine and human can save time and human labor, that can be replaced. The proposed system is already implemented and verified in the laboratory at Faculty of Manufacturing technologies with a seat in Prešov. Future studies will be focused on working with the filaments, which are an important part of whole additive manufacturing processes.

Acknowledgment. This work was supported by the projects VEGA 1/0268/22, KEGA 038TUKE-4/2022 granted by the Ministry of Education, Science, Research and Sport of the Slovak Republic.

References

1. Zhang, X., Chu, J., Wei, S.: Design and simulation of remote monitoring system of 3D printer based on cloud platform. In: Institute of Electrical and Electronics Engineers (IEEE Xplore). 3rd International Conference on Automation, Electronics and Electrical Engineering (AUTEE), pp. 290–293 (2021)
2. Kakade, S., Mulay, A., Patil, S.: IoT-based real-time online monitoring system for open ware FDM printers. Mater. Today Proc. 363–367 (2022)
3. Naqvi, S.N.Z., Yfantidou, S.: Time Series Databases and InfluxDB. https://cs.ulb.ac.be/public/_media/teaching/influxdb_2017.pdf
4. Chakraborty, M., Kundan, A.P.: Grafana. In: Monitoring Cloud-Native Applications, pp. 187–240. Apress, Berkeley, CA (2021)
5. OctoPrint.: PrettyGCode. https://plugins.octoprint.org/plugins/prettygcode/
6. Creality.: Creality CR-30. https://www.creality.com/products/creality-cr-30-3d-printer
7. OctoPrint.: Download & Setup OctoPrint. https://octoprint.org/download/
8. Ngo, T.D., Kashani, A., Imbalzano, G., Nguyen, K.T., Hui, D.: Additive manufacturing (3D printing): a review of materials, methods, applications, and challenges. Elsevier. Compos. Part B Eng. **143**, 172–196 (2018)
9. Rieder, H., et al.: Online monitoring of additive manufacturing processes using ultrasound. In: Proceedings of the 11th European Conference on Non-destructive Testing, pp. 2194–2201 (2014)
10. Rankin, K.: Hack and: what's new in 3D printing, Part IV: OctoPrint. Linux J. **2015**(257), 5 (2015)

11. Millon, C., et al.: Development of laser ultrasonics inspection for online monitoring of additive manufacturing. Weld. World **62**(3), 653–661 (2018)
12. Bhushan, B., Caspers, M.: An overview of additive manufacturing (3D printing) for microfabrication. Microsyst. Technol. **23**(4), 1117–1124 (2017)
13. Mohamed, O.A., Masood, S.H., Bhowmik, J.L.: Optimization of fused deposition modeling process parameters: a review of current research and future prospects. Adv. Manufact. **3**(1), 42–53 (2015)
14. Lishchenko, N., Piteľ, J., Larshin, V.: Online monitoring of surface quality for diagnostic features in 3D printing. Machines **10**(7), 541 (2022)
15. Lishchenko, N., Lazorik, P., Demčák, J., Pitel', J., Židek, K.: Quality Control Monitoring in 3D Printing. In: Ivanov, V., Trojanowska, J., Pavlenko, I., Rauch, E., Peraković, D. (eds.) Advances in Design, Simulation and Manufacturing V. DSMIE 2022. Lecture Notes in Mechanical Engineering, pp. 31–40. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-06025-0_4
16. Chung, S., Srinivasan, P., Zhang, P., Bandari, S., Repka, M.A.: Development of ibuprofen tablet with polyethylene oxide using fused deposition modeling 3D-printing coupled with hot-melt extrusion. J. Drug Deliv. Sci. Technol. **76**, 103716 (2022)
17. Kristiawan, R.B., Imaduddin, F., Ariawan, D., Arifin, Z.: A review on the fused deposition modeling (FDM) 3D printing: filament processing, materials, and printing parameters. Open Eng. **11**(1), 639–649 (2021)
18. Richardson, M., Wallace, S.: Getting started with raspberry PI. O'Reilly Media, Inc. (2012)
19. Phang, S.K., Ahmad, N.B., Aravind, C.V., Chen, X.: Internet of Things based architecture for additive manufacturing interface. Int. J. Grid Util. Comput. **12**(5–6), 460–468 (2021)
20. Shandilya, H., Kuchta, M., Elkaseer, A., Müller, T., Scholz, S.G.: Additive manufacturing: comparative study of an IoT integrated approach and a conventional solution. In: Arai, K., Kapoor, S., Bhatia, R. (eds.) Proceedings of the Future Technologies Conference (FTC) 2020, Volume 2 FTC 2020. Advances in Intelligent Systems and Computing AISC, vol. 1289, pp. 976–986. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-63089-8_64