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# Production Systems Lab (F220)

## Lab demonstration as follow-up of the webinars

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School of Engineering, Polytechnic of Porto, Portugal

June, 8th, 2022

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## = Previous Webinar =

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# Open Design, Open Process and Open Production


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Many examples of Open approach are available today, from software (probably the most common) to hardware, from science and technology to business and manufacturing. Open approach is considered an approach towards fast-growing community-based that is settled in a platform, to develop a specific subject.

Due to relevant role of Manufacturing, during this webinar, Open Design, Open Process and Open Production perspectives will be presented as a Neo-Industrialization and its potential relation with Industry 4.0.

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= Ongoing Project related to Open Design in Production Systems Lab =

# Cyber-Physical Systems using Open Design: an approach towards an Open Science Lab for Manufacturing

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AGENDA

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1. Introduction
2. Proposal of a Cyber-Physical System (CPS) architecture supported by Open Design (OD)
3. Implementation of Open Science Lab for Manufacturing (OSLab4Man)
4. Conclusions

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Framework

There is a broad consensus that Cyber-Physical System (CPS) is a critical element in Industry 4.0 (1). One of the major challenges with CPS is the integration of physical equipment processes and computational processes (2). Industry 4.0 requires Smart Factories and to achieve this state of evolution it is required to infrastructure support as Smart hardware and software (3).

Due to the increase of the engineering problems complexity, it is required a greater need to have research teams and work with multiple physical and computational systems (4). Dynamic and integrated manufacturing systems are necessary to predict, react and align within complex and turbulent surroundings, and to support an evolutionary system Intelligent CPSs (1) are mandatory.

1. Putnik GD, Ferreira L, Lopes N, Putnik Z. What is a Cyber-Physical System: Definitions and models spectrum. FME Trans. 2019;47(4):663–74.
2. Lee EA. Cyber physical systems: Design challenges. Proc - 11th IEEE Symp Object/Component/Service-Oriented Real-Time Distrib Comput ISORC 2008. 2008;363–9.
3. Wang S, Wan J, Li D, Zhang C. Implementing Smart Factory of Industrie 4.0: An Outlook. Int J Distrib Sens Networks. 2016;2016.
4. Xu L Da, Xu EL, Li L. Industry 4.0: State of the art and future trends. Int J Prod Res. 2018;56(8):2941–62.

Challenge

Many research and technology organizations (RTOs), such as universities, applied universities and research entities, are financially supported by state subsidies and public contracts and, due to the turbulent environment, there is a trend of shrinking budgets (5). RTOs that study in the CPS field are developing many architectural infrastructures and it is essential for the concept proof to verify and validate these infrastructures with testbeds in research laboratories for industrial environment and, consequently, industrialization. Research laboratories may represent heavy investment (6), and, in CPS research, hardware and software infrastructures and services could mean an onerous financial challenge.

To overcome research challenges Open Science (OS) is gaining importance among research communities. According to (7), OS is “a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and new collaborative tools”.

5. Coccia M. Metabolism of Public Research Organizations: How Do Laboratories Consume State Subsidies? Public Organ Rev. 2019;19(4):473–91.
6. Pearce JM. Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. Elsevier Inc.; 2013. 1–271 p.
7. European Commission. EU Open Innovation, Open Science, Open to the World [Internet]. European Commission. 2016. 108 p. Available from: http://europa.eu/rapid/press-release_SPEECH-15-5243_en.htm

# 1. Introduction

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## Challenge

The trendy concept of open approach (8) is a core principle in OS and multiple variations and ramifications are address and comprises within OS.

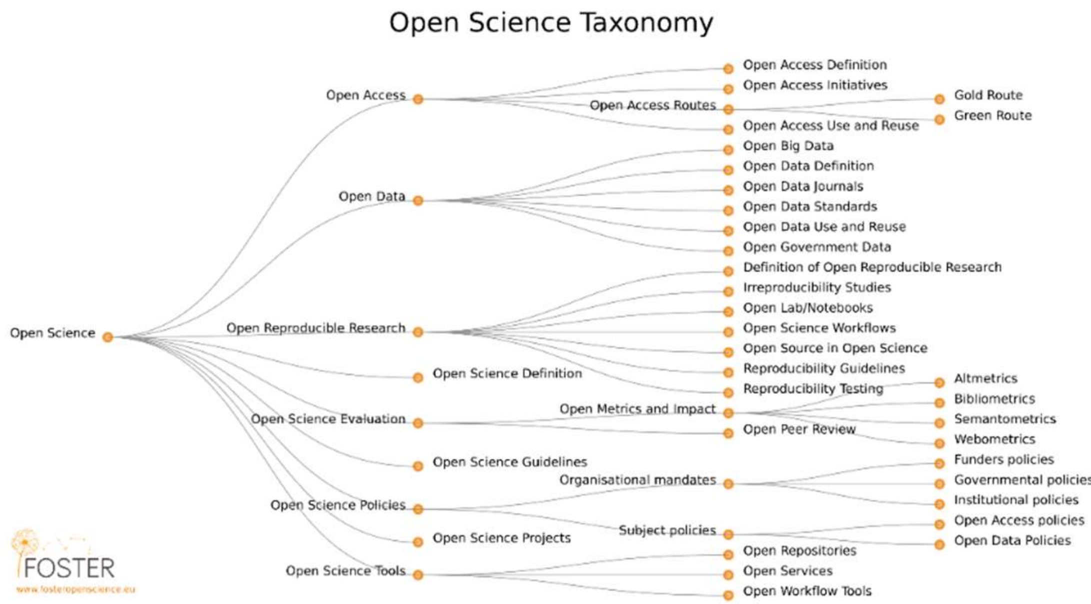


Figure 1 - Open Science Taxonomy (9).


8. Castro H, Putnik G, Castro A, Dal Bosco Fontana R. Open design initiatives: An evaluation of CAD Open Source Software. In: Procedia CIRP. 2019. p. 1116–9.
9. Pontika N, Knoth P, Cancellieri M, Pearce S. Fostering open science to research using a taxonomy and an elearning portal. ACM Int Conf Proceeding Ser. 2015;21-22-Octo.

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## Challenge

To significantly reduce the high investment in laboratories there is a need to resort to Open Lab (6) by RTOs, in which Open Design (OD) concept must be adopted. Following the open approach, such as OS, OD addresses software and hardware design development based on open source, freely and digital available, and supported by communities of members with common interests. Supported in digital repositories or platforms, OD is considered to be community-based generative process with fast-growing (10). According to (11), many communities are oriented to develop research projects adopting reproducibility and replicability (R&R) practices and could be considered as OD a design method for R&R practices.


6. Pearce JM. Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. Elsevier Inc.; 2013. 1–271 p.

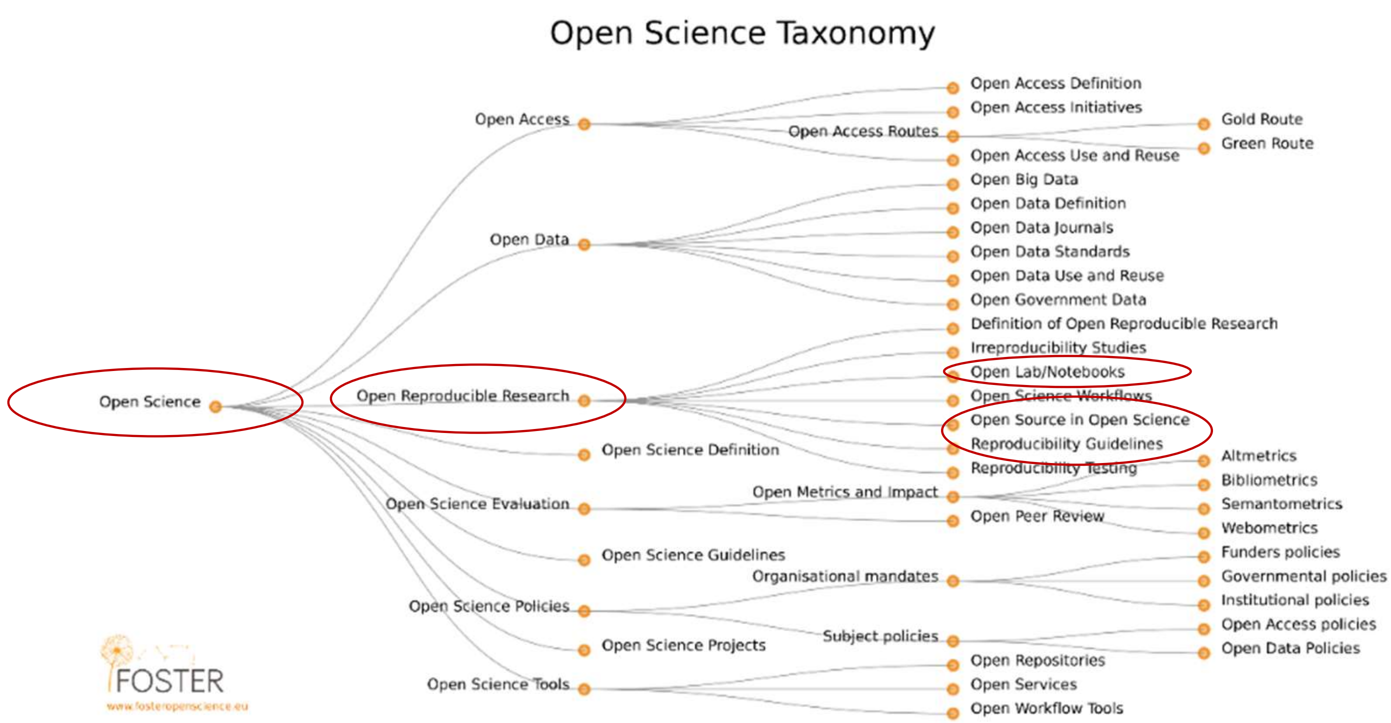
10. Castro H, Putnik G, Castro A, Dal Bosco Fontana R. Could open design learn from wikipedia? In: Procedia CIRP. 2019.

11. Yen A, Flowers B, Luo W, Nagesh N, Tueller P, Kastner R, et al. A UCSD view on replication and reproducibility for CPS & IoT. CPS-IoTBench 2021 - Proc 2021 Benchmarking Cyber-Physical Syst Internet Things. 2021;20–5.

# 1. Introduction

Challenge Proposal

This work proposes an approach of an Open Science Lab for Manufacturing (OSLab4Man) addressing a R&R and, for this reason, open source and low-cost CPS supported by OD.



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The proposed CPS architecture aims to be social, scalable, replicable, and with remote and open access to the infrastructures, capable to be considerate an exponential technology and leading to true ubiquitous system.

Within this architecture OD repositorium of digital products are available, in which the OSLab4Man is also available, to customize and replicate these products.

It is emphasized that all the resources and services included in the system, whether at a physical or computational/digital level, meet the open-source and/or low-cost premise (12) and addresses *Cloud Manufacturing* (13), the *Industrial Internet of Things* (IIoT 4.0) (14) and the *Smart Factory* (15).

12. Vieira G, Barbosa J, Leitao P, Sakurada L. Low-cost industrial controller based on the raspberry pi platform. Proc IEEE Int Conf Ind Technol. 2020;2020-Febru:292–7.
13. Xu X. From cloud computing to cloud manufacturing. Robot Comput Integr Manuf [Internet]. 2012 Feb [cited 2011 Sep 12];28(1):75–86. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0736584511000949
14. Boyes H, Hallaq B, Cunningham J, Watson T. The industrial internet of things (IIoT): An analysis framework. Comput Ind. 2018;101(March):1–12.
15. Chen B, Wan J, Shu L, Li P, Mukherjee M, Yin B. Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges. IEEE Access. 2017;6:6505–19.

## 2. Proposal of a Cyber-Physical System (CPS) architecture supported by Open Design (OD)

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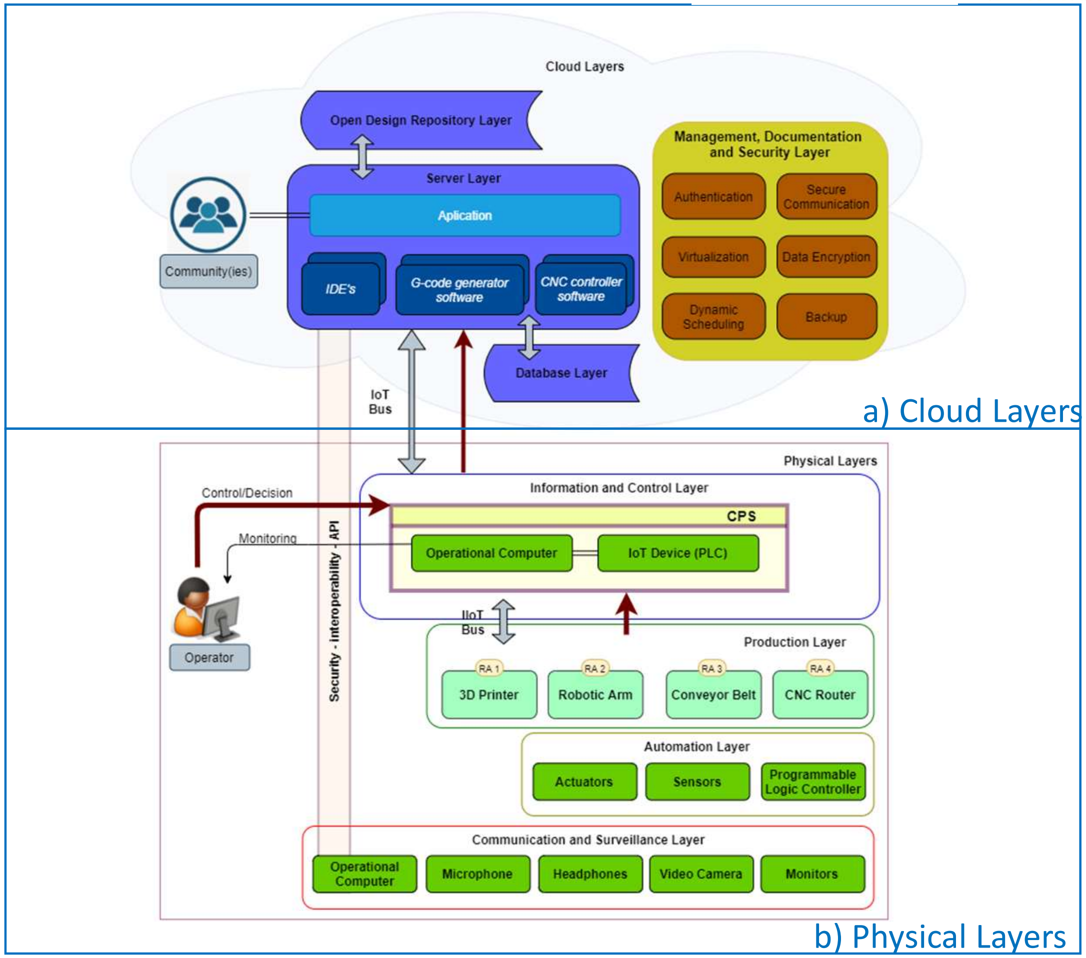


Figure 2 - Architecture of the proposed CPS supported by OD.

## 2. Proposal of a Cyber-Physical System (CPS) architecture supported by Open Design (OD)



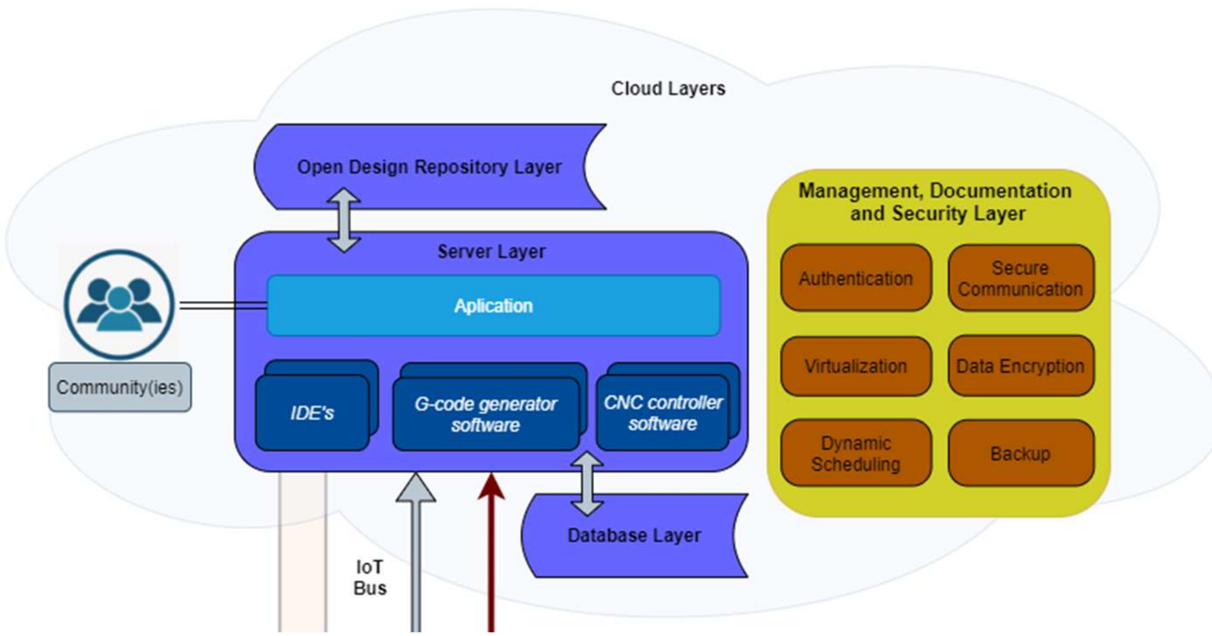


Figure 2 a) - Architecture of the proposed CPS supported by OD – Cloud Layers.

# 2. Proposal of a Cyber-Physical System (CPS) architecture supported by Open Design (OD)



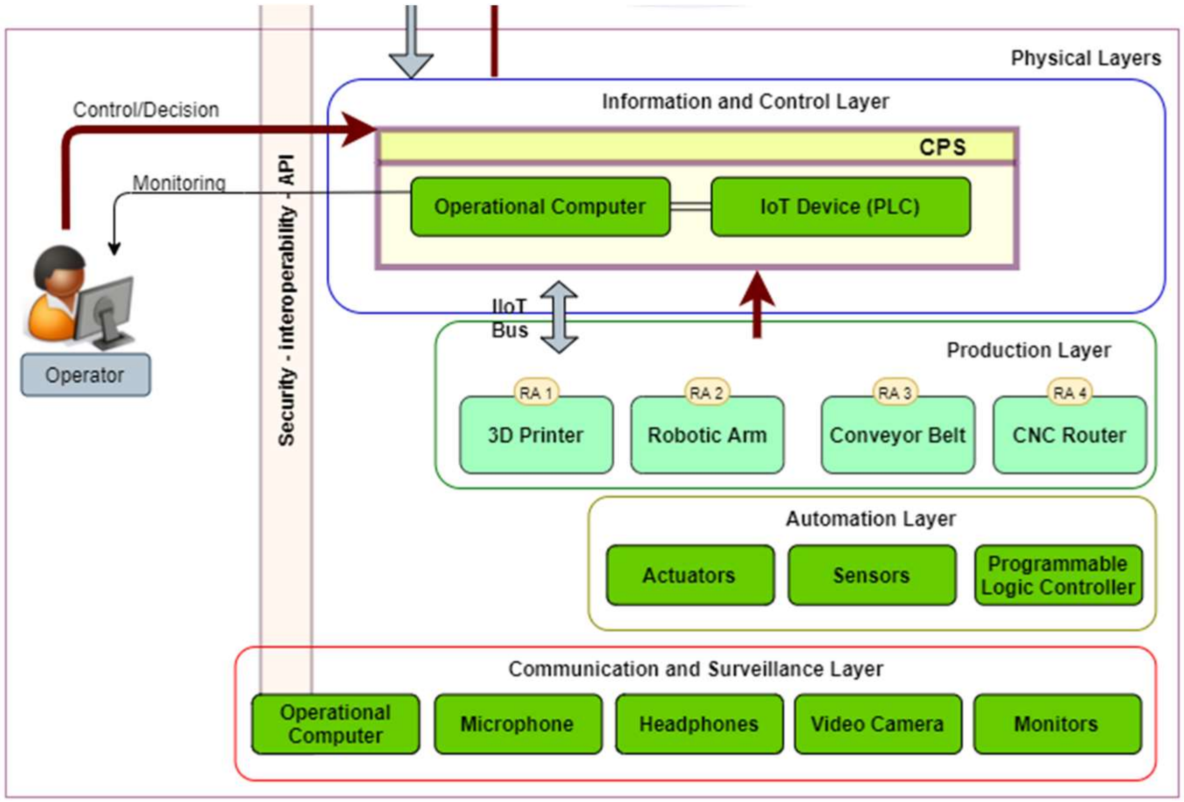


Figure 2 b) - Architecture of the proposed CPS supported by OD – Physical Layers.

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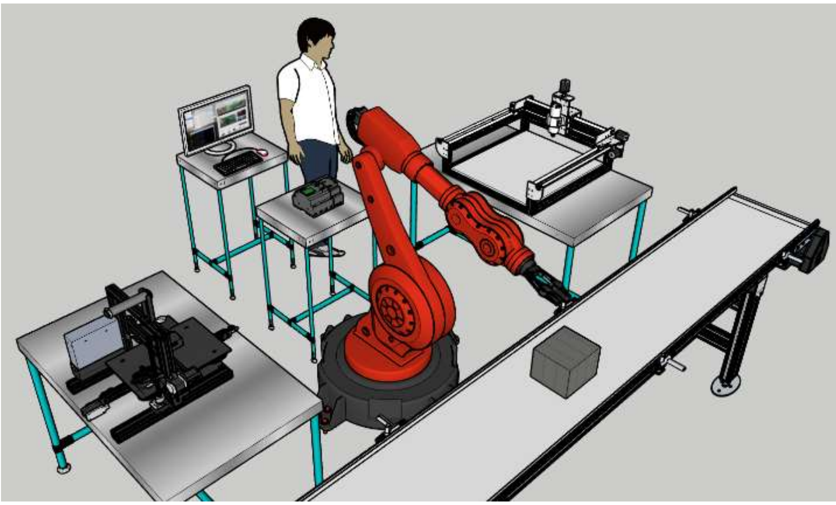
Production Layer



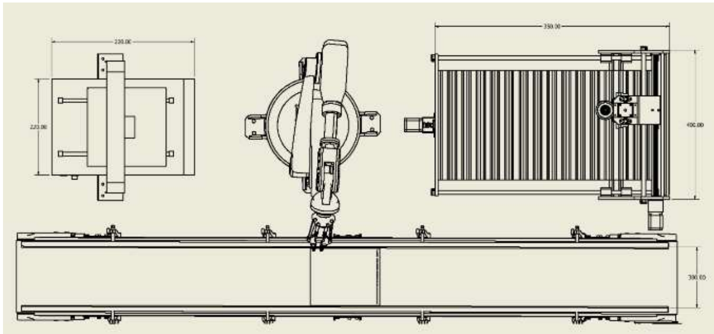


Figure 3 - Manufacturing System layout (3D, in left side, and 2D, in right side, models).

Production Layer

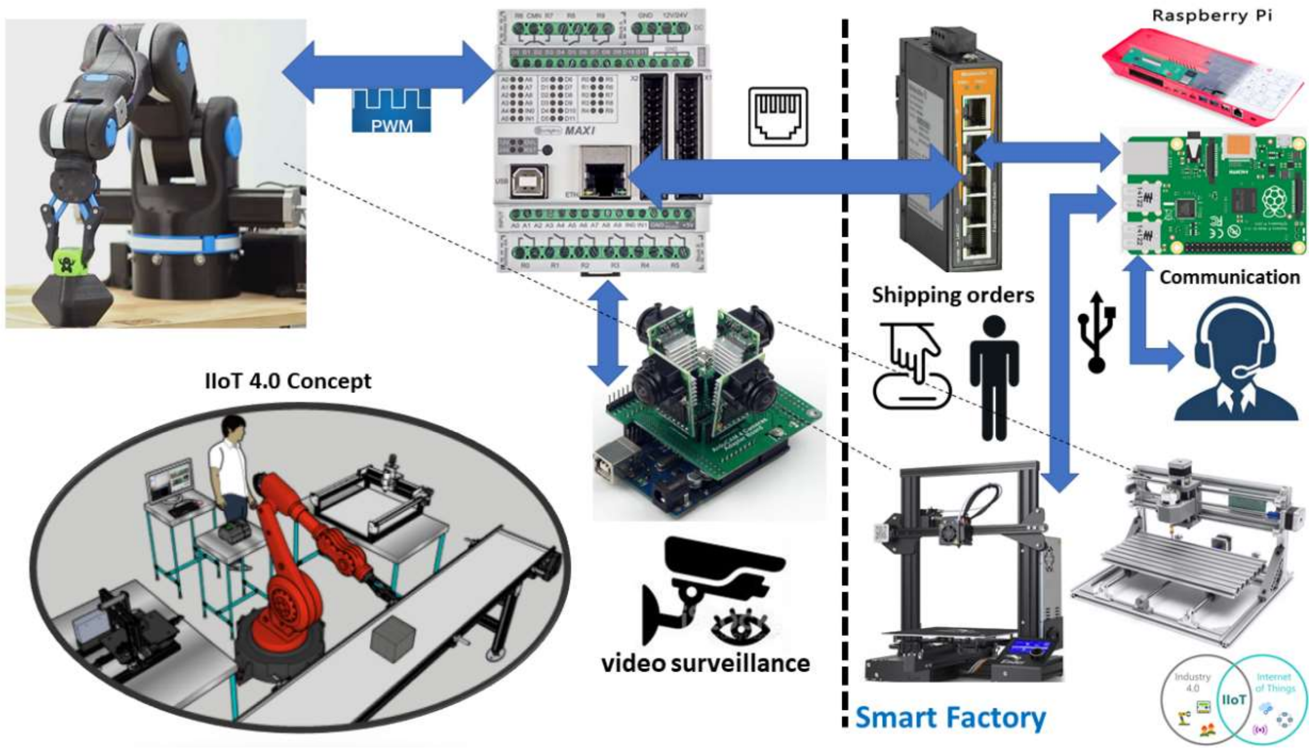



Figure 4 – Flow sheet of the OSLab4Man physical system.

# 3. Implementation of Open Science Lab for Manufacturing (OSLab4Man)

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## Production Layer

Table 1 – BOM of the OSLab4Man Physical System.

| Component | Component Model in OSLab4Man | Quantity | Some Alternative Open-Source and/or Low-Cost Component Model(s) |
|---|---|---|---|
| **Operational Computer** | Raspberry Pi 400 | 1 | • Raspberry Pi 4<br>• Raspberry Pi 5<br>• Raspberry Pi 3 Model B |
| **PLC** | Controllino | 1 | • PLC Arduino Ardbox & DALI<br>• OpenPLC |
| **3D Printer** | BeeveryCreative B2X300 | 1 | • RepRap<br>• Creality Ender 3<br>• Anet A8<br>• Original Prusa i3 MK3S |
| **Robotic Arm** | BCN3D MOVEO | 1 | • Dorna 2<br>• UFactory uArm<br>• Zortrax Robotic Arm |
| **CNC Router** | 3018. | 1 | • rBotCNC<br>• Carbide 3D Shapeoko 4<br>• Ooznest Workbee |
| **Conveyor Belt** | Customized from spare parts | 1 | -- |
| **Video Camera** | ArduCAM (OV9782) | 4 | • ESP32-CAM<br>• Waveshare OV9655<br>• SaintSmart Surveillance Arduino Camera |
| **Headphones with Microphone** | Tacens AH118 Headset | 1 | • 1Life Sound One Headset<br>• Ngs Ms103 |

## 3. Implementation of Open Science Lab for Manufacturing (OSLab4Man)



State-Of-The-Art

Robotic Arm

- ✓ Due to the trend of less public investment in R&D and the need of dissemination of knowledge among research communities, Open Science (OS) is a new approach to support collaboration and dissemination among researchers, based on digital tools.

- ✓ In the specific case of laboratories, the branch of Open Reproducible Research of OS forwards Open Lab as a key element to address the reproducibility and replicability (R&R) practices of research laboratories.

- ✓ Considering the importance for the research on manufacturing field of CPS and, consequently, implementation of a dedicated laboratory for this subject, this work proposes a CPS architecture based on Open Design (an *open-source* approach for hardware and software), and the implementation of the laboratory created as an *open-source* and truly *low-cost* solution, designated as Open Science Lab for Manufacturing (OSLab4Man).

- ✓ The CPS architecture is social (community-based), scalable, replicable, and with open access and remote control, aiming for a truly ubiquitous manufacturing system. All physical and computational/digital resources consider the *Cloud Manufacturing*, the *Industrial Internet of Things (IIoT 4.0)* and the *Smart Factory* and compress the *open-source* and/or *low-cost* premise for the implementation of the OSLab4Man.

Thank you for your attention!

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