Sustainable Engineering through Open Hardware and Digital Fabrication

Ingeniería Sostenible a través del Hardware Libre y Fabricación Digital

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ABSTRACT: This article deals on how open hardware combined with digital fabrication fosters sustainable engineering.

RESUMEN: El presente artículo trata de como el hardware libre combinado con la fabricación digital aporta a la ingeniería sostenible.

1. Introduction

Open hardware refers to the collaborative development of physical devices, such as 3D printers, that are designed and shared openly among users. This movement is characterized by a growing number of projects supported by infrastructure like makerspaces and fablabs, which facilitate innovation and fabrication []. The Arduino microcontroller has played a significant role in this ecosystem, serving as a critical component in many open source projects, including the Rep-rap 3D printer. Overall, open hardware fosters community collaboration and accelerates technological advancement in digital fabrication.

Open hardware and sustainable engineering are interconnected concepts that promote accessibility and innovation in technology development. The movement towards open fabrication, particularly in the realm of microfabrication, encourages collaborative efforts among research communities to develop cost-effective scientific equipment. Low-cost resin 3-D printing, specifically mask-based stereolithography (MSLA), exemplifies this trend by providing affordable solutions for rapid prototyping of microdevices, which can significantly enhance sustainable aquaculture practices []. This approach not only reduces costs but also fosters wider participation in technological advancements aimed at supporting genetic resource management.
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2. Sustainable Engineering

Massive Open Online Courses (MOOC) have been used to bring access to education in topics related to sustainable engineering i.e. drinking water systems [Bustamante, 2022]. Here, we can highlight the openness of MOOCs and the availability to a massive quantity of interested people. The openness can be interpreted in two senses not mutually exclusive. One sense is open access to the content of the course. The other sense is the use of open license in the course, in order to be provided by another provider (i.e. government, ministry, foundation, municipality or educational institution among others).

3. Open Hardware

Open hardware is also known as open-source hardware (OSH) or libre hardware. Depending on the context, related terms sometimes are used by other authors such as open source electronics, open source consumer electronics products, open source design, open-source sensors, open source actuators open source laboratory equipment, open source medical devices, open-source devices and/or open-source equipment. I prefer open hardware for its simplicity and generality.

2.1. Open Hardware Licenses

As with open-source software (OSS), there are licenses accompanying each open hardware design. Or at least, there should be an attached license. This is not always the case because some open designs do not mention the applicable license. **Table 1** shows a list of open hardware licenses and their release year.

Table 1 Open Hardware Licenses

Short Name	Long Name	Based on	Year
TAPR OHL v1.0	Tucson Amateur Packet Radio Open Hardware License v1.0	GNU GPL	2007
CERN OHL v1.0	CERN Open Harware License v1.0	N/A	2011
SHL v0.50	Solderpad Hardware License v0.50	Apache License 2.0 N/A	Estimated 2012
SHL v0.51	Solderpad Hardware License v0.51	SHL v0.50	2012
CERN OHL v1.2	CERN Open Harware License v1.2	CERN OHL v1.0	2013
SHL v2.0	Solderpad Hardware License v2.0	SHL v0.51	2018
CERN OHL v2.0	CERN Open Harware License v2.0	CERN OHL v1.2	2020

SHL v2.1	Solderpad Hardware License v2.1	SHL v2.0	2020

Figure 1 Sustainable engineering and Digital Fabrication

4. Digital Fabrication

Digital fabrication is also known as digital manufacturing. It is related to 3D printing, additive manufacturing or advanced manufacturing [Saldarriaga]. Design for Manufacturing and Assembly (DfMA) is a design methodology that focuses on simplicity of the design to make the manufacturing as simple and as fast as possible. DfMA should consider digital fabrication and related terms that can contribute to its ideals [Roxas].

5. Conclusions

Sustainable engineering, in the sense of engineering practice and engineering education, can be attained using open hardware and digital fabrication methods.

6. Declaration of competing interest

I declare that I have no significant competing interests including financial or non-financial, professional, or personal interests interfering with the full and objective presentation of the work described in this manuscript.

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9. Author contributions

PENDING

10. Data availability statement

Further data is available on request by email to the corresponding author.

References

[1] M. Bustamante-León et al., “The Personalized and Inclusive MOOC: Using Learning Characteristics and Quality Principles in Instructional Design”, *Sustainability*, vol. 14, no. 22, pp. 15121, 2022, doi: 10.3390/su142215121

[2] A. Saldarriaga, E. I. Gutierrez-Velasquez and H. A. Colorado, “Soft Hand Exoskeletons for Rehabilitation: Approaches to Design, Manufacturing Methods, and Future Prospects”, *Robotics*, vol. 13, no 3, pp. 50, 2024, doi: 10.3390/robotics13030050

[3] C. L. C. Roxas et al., “Design for Manufacturing and Assembly (DfMA) and Design for Deconstruction (DfD) in the Construction Industry: Challenges, Trends and Developments”, *Buildings*, vol. 13, no. 5, pp. 1164, 2023, doi: 10.3390/buildings13051164