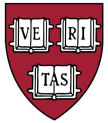
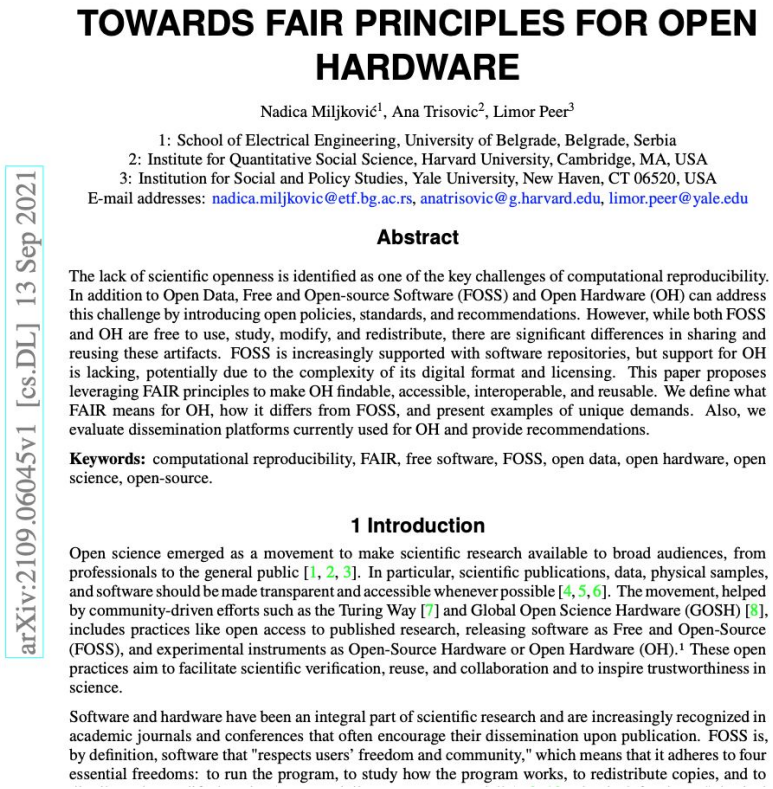


Toward FAIR principles for Open Hardware

Gathering for Open Science Hardware (GOSH)
December 7, 2021

Ana Trisovic, Harvard University

- Joint work between Nadica Miljković, Limor Peer, and myself
- https://arxiv.org/pdf/2109.06045.pdf



TOWARDS FAIR PRINCIPLES FOR OPEN HARDWARE

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Abstract

The lack of scientific openness is identified as one of the key challenges of computational reproducibility. In addition to Open Data, Free and Open-source Software (FOSS) and Open Hardware (OH) can address this challenge by introducing open policies, standards, and recommendations. However, while both FOSS and OH are free to use, study, modify, and redistribute, there are significant differences in sharing and reusing these artifacts. FOSS is increasingly supported with software repositories, but support for OH is lacking, potentially due to the complexity of its digital format and licensing. This paper proposes leveraging FAIR principles to make OH findable, accessible, interoperable, and reusable. We define what FAIR means for OH, how it differs from FOSS, and present examples of unique demands. Also, we evaluate dissemination platforms currently used for OH and provide recommendations.

Keywords: computational reproducibility, FAIR, free software, FOSS, open data, open hardware, open science, open-source.

1 Introduction

Open science emerged as a movement to make scientific research available to broad audiences, from professionals to the general public [1, 2, 3]. In particular, scientific publications, data, physical samples, and software should be made transparent and accessible whenever possible [4, 5, 6]. The movement, helped by community-driven efforts such as the Turing Way [7] and Global Open Science Hardware (GOSH) [8], includes practices like open access to published research, releasing software as Free and Open-Source (FOSS), and experimental instruments as Open-Source Hardware or Open Hardware (OH).[1] These open practices aim to facilitate scientific verification, reuse, and collaboration and to inspire trustworthiness in science.

Software and hardware have been an integral part of scientific research and are increasingly recognized in academic journals and conferences that often encourage their dissemination upon publication. FOSS is, by definition, software that "respects users' freedom and community," which means that it adheres to four essential freedoms: to run the program, to study how the program works, to redistribute copies, and to

Why open science?

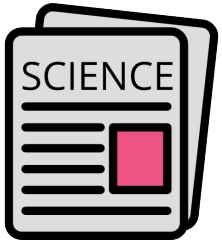
- Provide accessible publications, data, software, methods and physical samples to the general public
- It inspires trustworthiness in science and enables research verification, reuse and transparency
- It reduces social inequality by enabling anyone to access scientific knowledge

Open-Source Hardware (OSH)

"physical artifact, either electrical or mechanical, whose design information is available to, and usable by, the public in a way that allows anyone to make, modify, distribute, and use" it.

Researchers

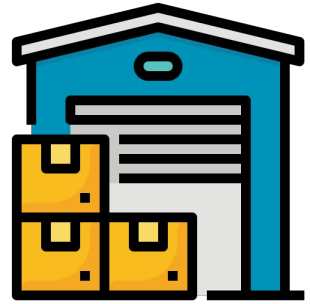
Research paper



Journal

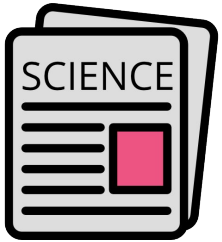
Researchers

Research
data, code
& hardware

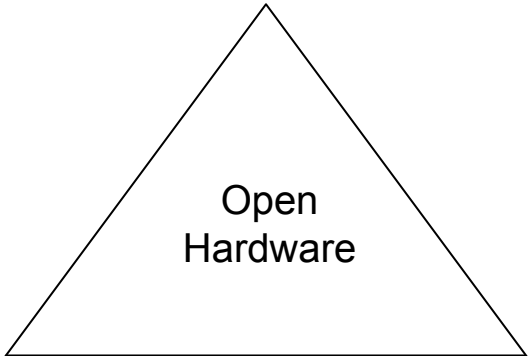


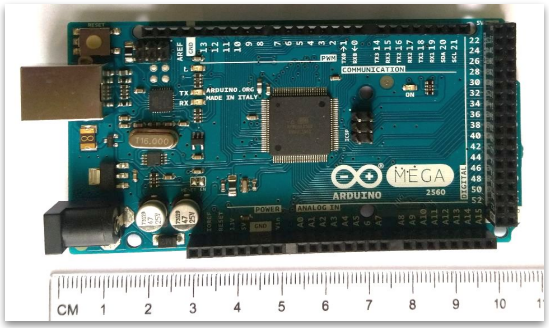
Data repository

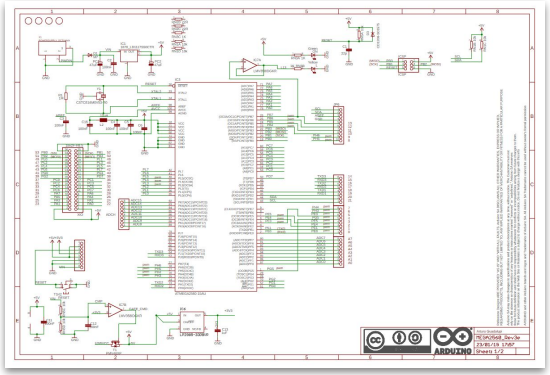
Research
paper



Journal

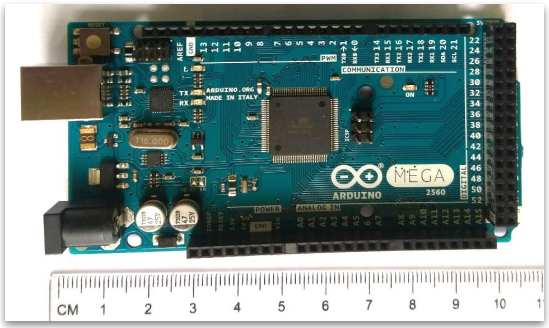

Open
Hardware

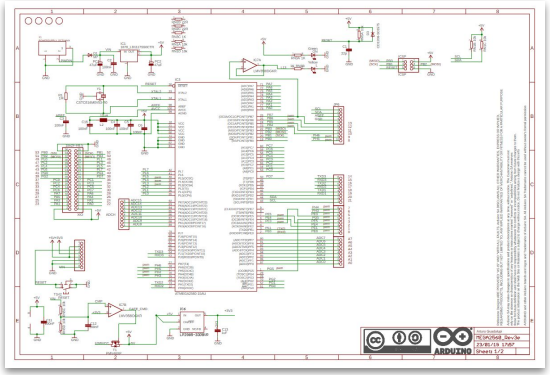

MEGA
ARDUINO
2560
COMMUNICATION
POWER
ANALOG IN
CM 1 2 3 4 5 6 7 8 9 10

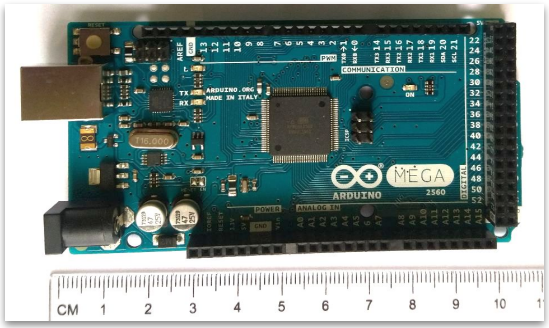


Open
Hardware

Open
Physical Design
(schematics, bills of
materials, printed
circuit boards
(PCB), other)



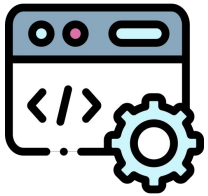


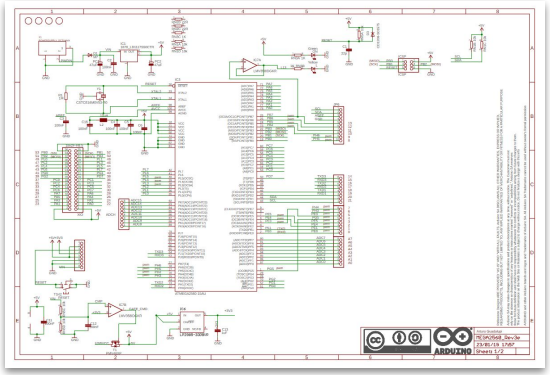


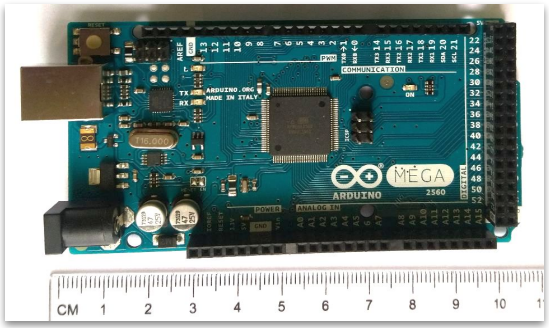
Open Hardware

Open Physical Design (schematics, bills of materials, printed circuit boards (PCB), other)

Open Software (interface (API), firmware, simulation and analysis code (HDL), other)







Open Hardware

Open Physical Design (schematics, bills of materials, printed circuit boards (PCB), other)

Open Software (interface (API), firmware, simulation and analysis code (HDL), other)

Open Documentation (on design, software, other)

Challenges of sharing OSH

- License for OSH design, software, data and documentation
  - Schematics with a graphical circuits can fall between analog design and software categories

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- Organizing, separating and interlinking resources
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- Metadata and documentation
  - No metadata standards for OSH

FAIR principles

- A set of guidelines to make research digital artifacts **Findable**, **Accessible**, **Interoperable** and **Reusable** by machine and by people
- Created for research data, but have been adopted for the dissemination of research software
- Have been widely cited, endorsed and adopted by a broad range of stakeholders

FAIR principles

Findable	
Accessible	
Interoperable	
Reusable	

Wilkinson, Mark D., et al. "The FAIR Guiding Principles for scientific data management and stewardship." *Scientific data* (2016)

FAIR principles

Findable	Describe data in metadata, assign DOI Metadata record is shared in data repository
Accessible	Accessible but not necessarily open Standard access protocol
Interoperable	File format open or proprietary Description of data elements
Reusable	License and usage rights Data provenance

Wilkinson, Mark D., et al. "The FAIR Guiding Principles for scientific data management and stewardship." *Scientific data* (2016)

Findable OSH

- Hardware is described with rich metadata
- Hardware is registered or indexed in a searchable resource through OSHWA or a registry
- Hardware is assigned a globally unique and persistent identifier through OSHWA or a trusted repository, such that each hardware component has a unique identifier

Accessible OSH

1. Hardware is open and retrievable by its identifier using a standardized communications protocol (the protocol is open, free, and universally implementable, and to allow for an authentication and authorization procedure, where necessary). All OSH files should be stored together on a repository infrastructure.
2. Metadata is accessible, even when the hardware is no longer available.

Interoperable OSH

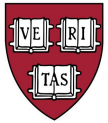
1. Hardware uses a formal, accessible, shared, and broadly applicable language for knowledge representation used in both academia and industry
2. Hardware uses vocabularies that follow FAIR principles
3. Hardware includes cross-references (to its software, data, documentation) and qualified references to other objects (e.g., software, data, documentation)

Reusable OSH

1. Hardware is richly described with a plurality of accurate and relevant attributes that reflects its complex structure (with clear and accessible usage licenses, to be applied on each of the components, detailed provenance on all components (bill of materials, assembly instructions and other), whilst meeting community standards).
2. Hardware includes qualified references to other hardware and available components

Conclusion

- Leveraging FAIR principles for the dissemination of OSH
- Discipline-specific standards are still underdeveloped
- FAIR for OSH would facilitate its recognition as a complete scientific output
- Limitations regarding its openness, working functionality, and computational reproducibility are expected, but can potentially be overcome with new research and development



Thank you!

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GitHub & Twitter: atrisovic