Open Source Imaging Initiative

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Motivation

Magnetic resonance imaging (MRI) is the most powerful diagnostic imaging modality available. The major drawbacks are cost and complexity, limiting its use mainly to industrialized countries and larger hospitals making MRI a scarce commodity around the world [1]. The aim of the open source imaging initiative is to address this issue by developing an affordable MR scanner which is easy to site, operate, maintain and repair and make its technical documentation available according to the standards of open source hardware. Combining innovation and open source allows major reduction of investment and operational costs with the ideal: From the community to the community.

Innovation

State of the art clinical MRI scanners operate at magnetic field strength of B_0=1.5T and 3.0T. These "high" magnetic fields are achieved using superconductors together with a liquid helium cooling system to reach cryogenic temperatures. This makes the magnet by far the most expensive hardware component. Multiple studies showed that there are several clinical applications where the diagnostic value gathered from low field MRI (B_0=0.2T) is equivalent to high field systems ($B_0 \geq 1.0$T) [3-7]. Low field permanent magnets in Halbach arrangements are a viable alternative avoiding superconductors and liquid helium, and can even be designed such that gradients in the magnetic field can be used for spatial encoding, removing the need for high power gradient amplifiers [2]. In addition low field systems are safer for patients and workers than their high field counterparts. Additionally, lower static magnetic fields reduce hazards of injury from ferromagnetic objects such as medical equipment or medical implants. Thus scanner siting in unconventional locations where access to the area is not limited to few specially trained operates may-well require low field scanners. The lower SNR of low field scanners is partially offset by reduced SAR, favorable changes in some relaxation parameters, reduced susceptibility shifts and thus the ability to use low imaging bandwidths. Finally permanent magnets eliminate any risk of a quench and the need for large current sources. Halbach magnets are much smaller in size allowing

for a “mobile” application while $B_0 \approx 0$ outside the magnet makes the need for an extra scanner room obsolete.

The pursuit of a robust, inexpensive RF electronics console benefits from recent developments in digital signal synthesis and reception. For example software defined radio (SDR) potentially allow significant reductions in price and complexity, as well as ease of replacement, in the entire transmit and receive chain [8]. Our estimated total price for such an MR system using permanent magnets is below $20000. Such a price makes it a viable alternative to computed tomography, x-ray and ultrasound imaging for dedicated clinical applications. Open Source Imaging is not limited to MR systems using permanent magnets alone. On the contrary we want to foster collaboration, education, knowledge transfer and customized development without restrictions on technological specifications.

Open Source

The Open Source Imaging initiative follows the values of open source hardware. We want to grant complete access to the technical documentation (circuit diagrams, part lists, PCB layouts, CAD designs etc.). Developments will be licensed under the CERN OHL license. While the Open Source Imaging initiative is not-for-profit, the licensing strategy supports commercial use, which is intended in order to support distribution of the technology at a later stage (Fig.1). The technological complexity of MRI and the fact that development in MRI is predominantly carried out by the research community justifies an open source approach. The advantages of open source development are:

1. No more black boxes; Transparency for research, education and innovation.
2. Fast and cost effective maintenance
3. Technology transfer to regions where trained staff are a scarcity
4. Customized development; Reduction of complexity by simple push button systems (e.g. knee scans with hard coded imaging protocols). Design influences of local environments (e.g. rural hospital with unstable power supply).
5. Encouraging scientific values: collaboration, reproducibility and citations. At the same time open source hardware benefits from good documentation by means of scientific publications.

The website OpenSourceImaging.org functions as the communication platform with an overview of running projects and links to external developer/documentation sites. So far we included our developments on a multipurpose 3-axis measurement system (~$3000) (Fig.2). Halbach magnet designs and an RF power amplifier (~$1000) will be incorporated next (Fig.2). We will furthermore add past and future open source soft- and hardware projects from the MR community. Outsourcing development to the community, will eventually allow for long-term affordable prizes. The open source hardware movement is gaining momentum and will most likely follow the footsteps of open source software.

Conclusion

Regardless public or private healthcare system, MR costs determine healthcare outcomes. There is a high demand for affordable MR technology around the world to improve patient diagnosis and treatment. We, the MR research community are able to meet this demand. By means of collaboration we can lay

the ground for affordable, high quality medical devices. Please visit www.opensourceimaging.org, contribute, and help us making this vision reality.

References

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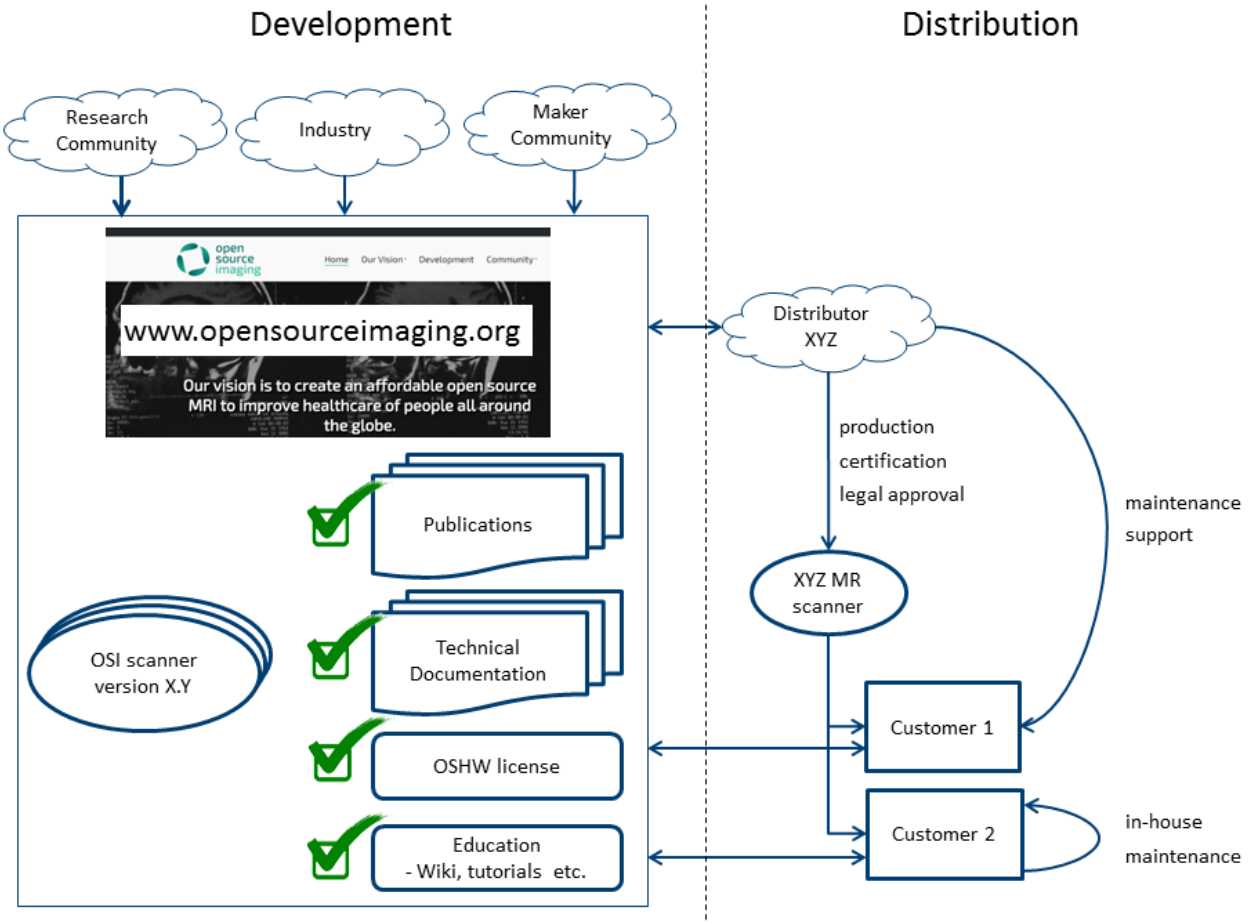
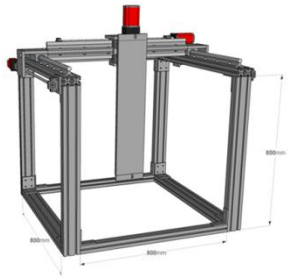
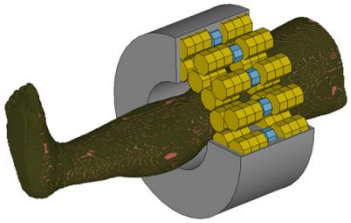


Figure 1 – Schematic of the open source imaging initiative. Development is performed by and for the community. www.opensourceimaging.org functions as a communication platform providing an overview of running projects, publications, links to technical documentation files and wikis of open source soft- and hardware projects around MRI.

Multipurpose Robot



Halbach Magnet Designs



RF power amplifier

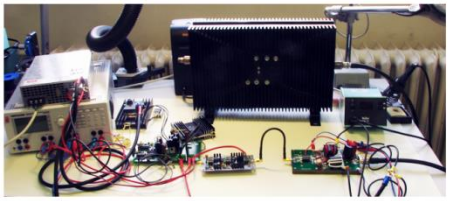


Figure 2 – Current developments that will be published on the website. (left) A 3-axis multipurpose robot with submillimeter accuracy (e.g. for static magnetic field or electromagnetic field mapping, 3D printing, CNC machinery). (middle) Halbach magnet and gradient designs for low field low cost MRI. (right) 1kW RF power amplifier 1.8-54MHz.