OPEN RESEARCH CASE STUDY

University of Reading

Building Open Lab Hardware to Tackle Antimicrobial Resistance

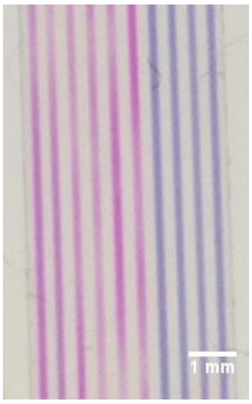
Microbiological imaging can be lengthy and labour-intensive without expensive lab-automation. Using Open Source hardware and software, Dr Al Edwards' Biomedical Technology Lab designed a robot to take high-resolution images of experiments capturing changes in colour and fluorescence due to bacterial growth. This affordable solution has increased the Lab's capability to image and screen samples with higher throughput, accuracy, and more kinetic data. The system is fully customisable to suit any imaging experiment and costs only £600 to build from Open Source resources.

Open Source 3D printing and a Raspberry Pi computer have allowed our lab to build an affordable imaging robot which can take high-quality images at regular intervals. This allows our researchers to image bacterial growth for antimicrobial resistance screening at a much faster rate and without constant hands-on time in the lab, all for only £600.

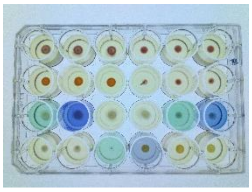
Our **Biomedical Technology Lab** builds simple low-cost solutions for current and future healthcare problems. These include point-of-care bioassay devices to test for antimicrobial resistance and help tackle antibiotic overuse. Traditional microbiology methods are slow, so we developed a smaller and faster version using microcapillary films where visual cues, such as colour changes, could detect bacterial growth. Because these films cannot be imaged by commercially available readers, we built our own imaging system using the frame of a 3D printer as the base. Our aim was to create a solution that was accessible for other researchers wanting to implement similar systems, and adaptable to a wide range of imaging requirements.

The assembled imaging robot. © 2020 Sophie Jegouic. Licensed under **CC BY 4.0**

We named our invention POLIR, for Raspberry Pi camera Open-Source Laboratory Imaging Robot. We approached the design by hacking existing Open Source designs and components: a Raspberry Pi computer and camera for control and imaging; a 3D-printed RepRap 3D printer frame as the architecture; OctoPi software to remotely control and monitor the system; and Repetier software to interpret the G-code (computer code used to instruct machine tools). The G-code written to control the camera, the designs, and links to the software and hardware are freely available in GitLab[1] under an Open Source MIT License.



An image of the colour change in a microcapillary indicating bacterial growth



An image taken by the robot of bacterial motility

A key challenge we encountered was acquiring the necessary knowledge, given our lack of experience in coding and building laboratory hardware. By interacting with the online Open Source hardware and software community, we were able to improve our design. The support from the Open Source community is brilliant: we made use of online tutorials on how to write code in Python to operate the Raspberry Pi camera, and videos explaining how to wire up the 3D printer motors to the microcontroller, something we would not have been able to do by ourselves. An additional benefit of using open hardware has been the exposure of our work to different audiences: this has included a feature on the **Hackaday website**, reaching an audience of engineers and engineering enthusiasts, a blog post on the **Raspberry Pi website**, and a University of Reading **press release**.

Using the robot in our lab, we have decreased the amount of time spent in-lab for researchers, while increasing the quality and quantity of kinetic data recorded. Our hope is that other laboratories can implement versions of this open hardware solution to reduce the amount of time spent imaging in the lab by researchers, enabling them to continue other research, and reducing the need for out-of-hours work.

To encourage further innovation, we published our research in an Open Access journal[2], with supporting data accessible in the University's Research Data Archive[3], and our designs, code and software freely available in GitLab[1]. Since building this robot, we have discussed simple open hardware fixes to lab problems with other researchers at the University of Reading and beyond, whether it be time-lapse imaging, LED lighting setups or use of 3D printed materials for outreach projects. We have also met with other researchers at the School of Chemistry, Food and Pharmacy Coding Club to share our expertise and learn new skills.

This work also led to a commercialisation project funded under Innovate UK's ICURe programme. ICURe enables members of a research group to explore the commercial potential of their research. In January-March 2020 Dr Sarah Needs visited laboratory equipment trade shows and clinical diagnostic research labs in the UK, US and Canada to learn about the market and understand labs' high-throughput needs. Using the insights gained we are now exploring ways to make POLIR available in kit form for people to build themselves and as a fully assembled product. Our aim is to make this powerful new lab tool accessible to as many researchers as possible.

Open at a glance

- Open Source customisable laboratory imaging hardware, easily built using an Open Source 3D printer, Raspberry Pi computer, camera and microcontroller for only £600
- Flexible for experiments of any format, controlled remotely using Open Source software and able to collect data every 3 minutes for any time period
- Design, software, code and instructions freely available for researchers to use and customise

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References and further information

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2. Needs S. H. et al. (2019). Exploiting open source 3D printer architecture for laboratory robotics to automate high-throughput time-lapse imaging for analytical microbiology. *PLOS ONE* 14(11): e0224878. https://doi.org/10.1371/journal.pone.0224878
3. Needs, S. and Edwards, A. (2019). Dataset associated with the article 'Exploiting Open Source 3D printer architecture for laboratory robotics to automate high-throughput time-lapse imaging for analytical microbiology'. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.220

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