TECHNOLOGY FEATURE

AUTOMATED SCIENCE ON A SHOESTRING

Do-it-yourself projects give researchers the equipment they need at bargain prices. But making your own technology requires commitment and time, and it is rarely easy.

B. G. WONG *ET AL.*/*NAT. BIOTECHNOL.*

A DIY automated system for culturing bacteria or yeast, eVOLVER, can cost just US$5,000 to build.

BY MIKE MAY

A system of reagent bottles and naked circuit boards tethered to a laptop lies silent. But at a command, the arrangement whirs into life. Microfluidic pumps transfer culture media from 2-litre bottles into vials filled with bacteria. Other pumps remove waste from the cultures. Beneath each vial, a magnet attached to a computer fan mixes the culture with a stir bar, while other devices control the temperature and optically record the density of the cultures. Meet eVOLVER, an automated system for culturing bacteria or yeast.

Caleb Bashor, a bioengineer at Rice University in Houston, Texas, didn't buy this complex experimental set-up; he and his colleagues built it themselves. "No commercially available system does quite what eVOLVER does," says Bashor, who studies how environmental conditions and DNA combine to control bacterial behaviour. Such studies depend on someone being there to precisely control the environmental conditions in which bacteria grow, and to repeat the process as frequently, and reproducibly, as possible. Enter eVOLVER, which can control up to 16 cultures at a time. "By automating multiple parallel experiments in a single run, the time you save basically scales with your throughput," Bashor says. With a full set of vials, eVOLVER can run 16 bacterial growth experiments in the time it would take to do a single one by hand.

There are at least two benefits to the do-it-yourself approach. One is flexibility: scientists can build just what they need to automate their particular lab processes, instead of buying an off-the-shelf configuration. More obvious is the economic advantage: Bashor estimates that comparable equipment would cost US$100,000 or more, but a scientist can build an eVOLVER for $5,000–10,000, depending on the desired throughput, controls and sensors. The system is described in the literature[1], and detailed instructions are available from Bashor on request. As a result, he says dozens of eVOLVERs have been built. ▶

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But DIY hardware development is inevitably iterative. "You build a scheme for hardware and electronics," Bashor says, "and then realize it wasn't quite right, and then the next iteration might still not be quite right." Prospective DIY'ers should expect to devote some effort to the design. "You have to balance how much time you want to invest," Bashor says.

THE PERFECT STORM

Science has long embraced a DIY ethos. But thanks to the ready availability of open-source software, electronics, 3D printers and online forums, DIY is having a moment. "The mechanical manufacturing side is far more accessible than before," says Bashor. Tutorials and online resources abound for 3D printing[2], for instance, including several classes on the educational website Coursera.

The same is true of the electronics. Instead of building complicated circuits from scratch on a 'breadboard', scientists can turn to open-source tools, such as the widely used Arduino programmable circuit board, to design, build and code the controls needed.

But DIY is, well, DIY. Even with all those resources greasing the wheels, it's still up to the scientist to do the work. "You need to be willing to dig in and try to learn it yourself," says Eric Greenwald, an imaging specialist at the University of California, San Diego, who has made some of the hardware in his lab himself. And, like the rest of science, DIY projects are experiments.

Take Brian Chow's handcrafted plate reader, for instance. Like Bashor, Chow wanted to build something that didn't exist — a low-cost plate reader for teaching labs. A bioengineer at the University of Pennsylvania, Philadelphia, Chow assembled a development team comprised mostly of undergraduates to take on the task.

A microplate reader automatically moves a multi-well plate relative to a spectroscopic sensor, to detect reactions by measuring fluorescence, for example. The challenge was building a reliable and low-cost stage for moving the samples, and integrating that with low-cost optoelectronics. Once the researchers found the right parts and put them together, they used open-source automation software, written in-house in the programming language Python, to make the system work. "Philosophically, I believe in supporting the open-source-hardware community," Chow says.

But that's a commitment that requires a significant investment of time and energy. Chow's project needed 3D printed parts, custom circuit boards and laser-cut components[3], not to mention bespoke Python scripts and an inventory of some 121 parts.

The resulting reader, which can accommodate 96-well plates, cost about $3,500 — half the price or less of even a used commercial device. But the system is also as much as 1,000 times less sensitive, Chow admits. Still, it's good enough for many cellular and protein-based applications, including measuring fluorescence from proteins and even the time course of some molecular processes.

AUTOMATING IMAGING

Those intimidated by building instruments from scratch can take a middle-ground approach and modify existing hardware. Greenwald, for instance, tweaked the OT-One, a robotic pipetting system made by Opentrons in New York City, to automate reagent addition and sample imaging in cell-signalling studies.

The Opentrons robot, for which Greenwald paid $5,000, has an 8-channel pipette for adding reagents to each sample, and accommodates 24- or 96-well plates. Greenwald needed, essentially, to mount that robot above an inverted microscope to image the reactions the robot was creating. He built legs from the same material as the robot's frame and connected them to it. Then, he cut a hole in OT-One to allow it to access the microscope's stage, and connected the robot's legs to an air table for stability. "Most any scope would work," Greenwald says. "It just needs to be a somewhat automated scope, like a motorized stage and automatic filter-wheel changing."

Greenwald uses his hybrid system to track fluorescent biosensors to measure cell signaling in live cells[4]. Without it, he says, such experiments would have to be done manually: adding drugs or stimulants by hand, waiting, adding another drug, imaging and repeating. The robot makes that process at least eight times faster — as well as, less prone to errors and less likely to cause repetitive stress injury.

As it turns out, Greenwald found a ready partner in Opentrons. "We started as a DIY project," says Will Canine, co-founder of Opentrons. Chiu Chau, the company's other founder, built the first Opentrons robot in his garage and e-mailed the plans to a DIY-biology distribution list. The company keeps the hardware and software for its robots open source. "That makes for a very DIY-friendly platform — enabling people to customize our technology to fit their own needs," he adds.

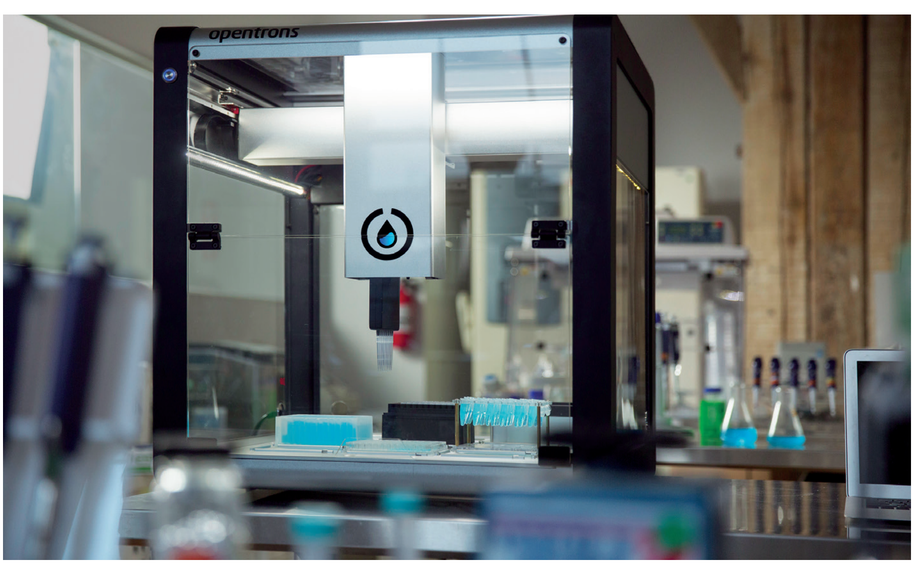
PHOTONIC COMMUNICATION

The need for custom automation isn't limited to life scientists. Mikael Mazur, a PhD student who works with engineer Jochen Schröder in the photonics laboratory at Chalmers University of Technology in Gothenburg, Sweden, is studying ways to boost the efficiency of data transmission in telecommunications applications. "If I can improve how much information can be passed over a given bandwidth, you can reduce the cost of a communications system or reduce the need for new systems," he says.

Mazur's experiments run around the clock, sometimes for two weeks. His set-up can include more than 20 devices — such as amplifiers, lasers, detectors — all of which he automated himself. By writing code with Python and using Arduino microcontrollers, he developed a system that easily accommodates new devices.

Initially, Mazur was sceptical about automating his set-up, but he works in a favourable environment for DIY hacking: Schröder helps to run lab-automation hackathons around the world for photonics projects written in Python. "These are sort of workshops where we show people what tools to use for lab automation," Schröder says. "It makes it easier for everyone to do great things."

In Mazur's case, he recalls wondering whether it was worth spending a week developing the system. Now, he says with a laugh, "I'm saving months!" ■



OPENTRONS

An Opentrons OT-One robot, like the one Eric Greenwald hacked to drive his cell-signalling studies.

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4. Greenwald, E. C., Wollman, R & Zhang, J. *FASEB J.* https://doi.org/10.1096/fasebj.2018.32.1_supplement.690.3 (2018).

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