Joshua Elsdon is currently a PhD candidate at Imperial College London, studying in the field of handheld robotics and augmented reality. He's been a keen tinkerer all his life, starting with audio engineering and high-voltage circuits as a teenager which has developed into a passion for robotics.

Like it?

Head to Joshua's YouTube channel for demos of his camera-based location system and very tiny robots following lines, performing synchronised patterns and generally whizzing about: **http://bit.ly/JEmicrorobots**

Further reading

To keep up to date with Joshua Elsdon's micro robots project and the release of version 6 of the kit for under £100, head to **http://bit.ly/HdayMicroRobots**

Micro robots

A pragmatic approach to teaching robotics has led to a project to build robots smaller than pocket change

Can you give us an overview of the micro robots projects? What's the idea behind your micro robots?
The micro robots project was formed when discussing how the Imperial Robotics Society could develop a course for teaching higher-level multi-robot behaviour. We have a very successful course introducing the basics of robotics on a small robot platform, roughly the size of an A5 sheet of paper, but robots of this size quickly become a problem if you want to control a load of them at once. The area you have to cordon off becomes prohibitive; also, generally you can only have one set that the class must share.

We decided that this course would not need access to the low-level hardware, as that would have been covered in the previous course, so we can use the full power of miniaturisation to reduce cost and size. We hope that in using very small robots to teach robotic behaviour

> "We use the robots for fun programming exercises"

classes, we can have multiple systems available for testing and have to use less space for the arenas. Additionally, the low cost of highly integrated electronics that could be assembled automatically could lower the burden on volunteer instructors. Naturally, this seed for the project has given rise to a multi-year development effort for me and my hobby partner Dr Thomas Branch.

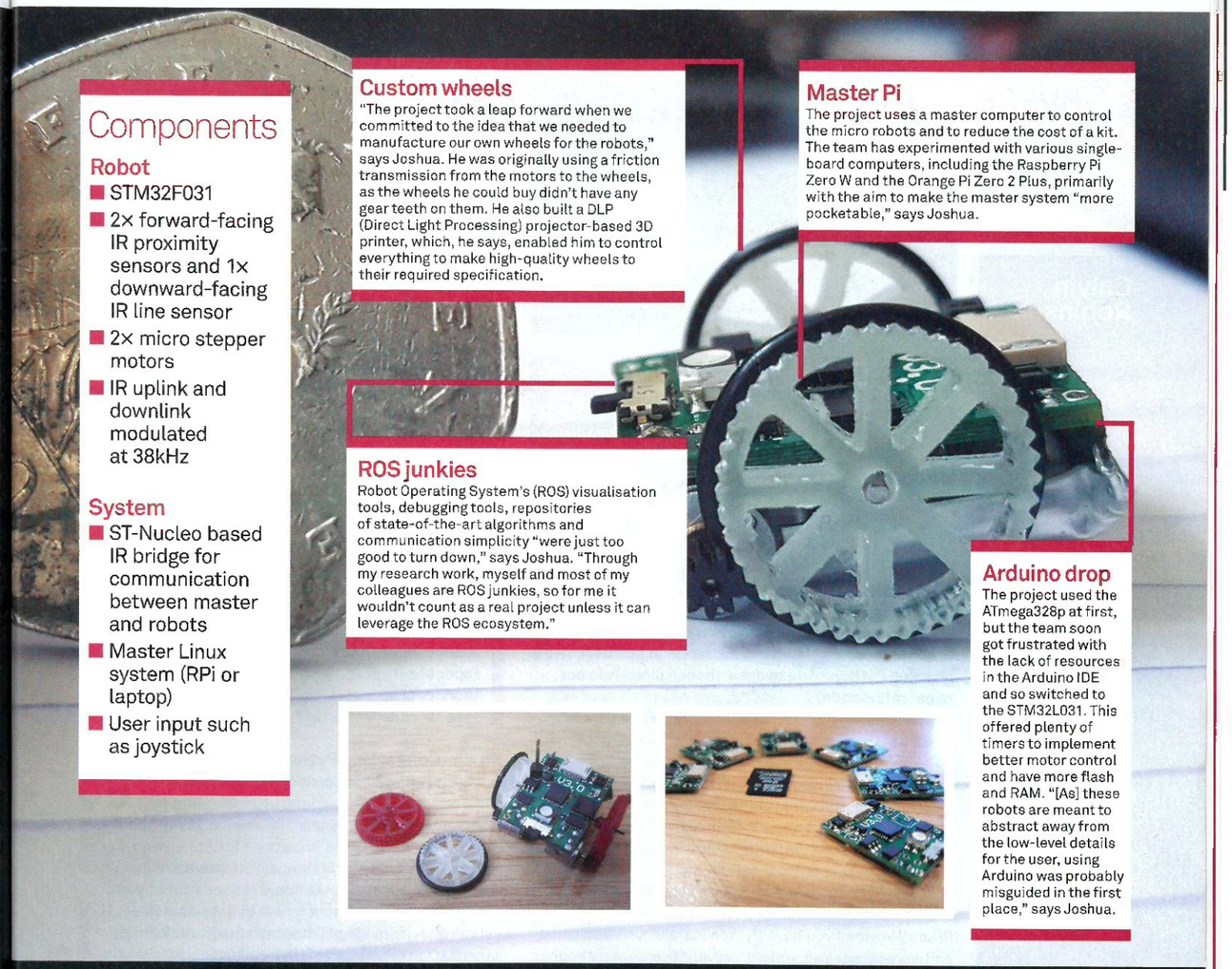
You've recently mentioned using a camera, QR and OpenCV for tracking the robots – can you explain how this works?
For most robotic experiments, knowing the location of individual robots is a fundamental piece of information. The issue is that the sensors on board the robots are not sophisticated enough to discover their location from the environment. So a typical solution is to have an overhead camera keep track of where the robots are to provide input to the navigation algorithms. With a fixed camera this can be achieved reasonably simply as the system's coordinates can be based relative to the camera and the size the robots will appear in the image can be hard-coded. Though due to the fun I have had whipping the robots out at opportune moments, I wanted the system to be possible to deploy completely ad hoc. Therefore, we have implemented a system that uses a QR code like marker in the scene as a coordinate reference that provides the computer vision system with a sense of scale and orientation. The camera does not need to be orthogonal to the surface, and we can even use the location of the camera as input to the system.

You also mention using the Raspberry Pi 3; how does that fit into project?
Originally we were thinking of this as a business case for providing educational kits, which are very price sensitive. Using the Raspberry Pi jumped out as a method of supplying the complete computational system with no setup for the user. We were aiming for the cost price of a robotic system with six robots and master computer to be roughly £100. Though because we are still doing lots of development on the project, we primarily use a full desktop system, for convenience.

Have any interesting projects have come out of the micro robots project and the training you've been running at Imperial?
Currently the robots are not used in teaching at Imperial, though in the future we hope to change that. I am using them in my private tutoring sessions with two 13-year-old boys. We use the robots for fun programming exercises, and we use a larger version of the robots for teaching SMD soldering techniques. The primary guiding project is to implement robotic football, though I always try and let the students have input on where the project goes, so we will have to wait and see what we actually implement.

Can you tell us about the robot HAT you're working on?
We had a couple of spare pins on the programming connector for the robot, so we decided to break out an I²C interface for expansion boards. As a proof of concept, we are partially through implementing a TOF (time of flight) laser scanner on the front of the robot. Due to the precise nature of the stepper motors we use for the drive motors, we should be able to collect a 360-degree laser scan of the environment from a robot. This can be used for SLAM (simultaneous location and mapping) which, if we can pull it off, would be by far the smallest robots to complete this task.

You mention that v6 is ready for manufacture? Is there a kit coming out soon?
Yes V6.0 is more or less ready to go; it implements an accelerometer for our new idea, running the robots on walls. We have demonstrated the fact that the robots can drive on a ferromagnetic surface mounted to a wall; the accelerometer will provide all robots with a reliable absolute orientation relative to gravity. As far as kits, it seems unlikely that there would be a kit any time soon – everything you need to know is open source; only the batteries are a pain to get. We are likely to make a larger batch this year for a demonstration of the system, and perhaps that would lead to some opportunity where the robots can be supplied publicly.



Components

Robot
- STM32F031
- 2× forward-facing IR proximity sensors and 1× downward-facing IR line sensor
- 2× micro stepper motors
- IR uplink and downlink modulated at 38kHz

System
- ST-Nucleo based IR bridge for communication between master and robots
- Master Linux system (RPi or laptop)
- User input such as joystick

Custom wheels

"The project took a leap forward when we committed to the idea that we needed to manufacture our own wheels for the robots," says Joshua. He was originally using a friction transmission from the motors to the wheels, as the wheels he could buy didn't have any gear teeth on them. He also built a DLP (Direct Light Processing) projector-based 3D printer, which, he says, enabled him to control everything to make high-quality wheels to their required specification.

Master Pi

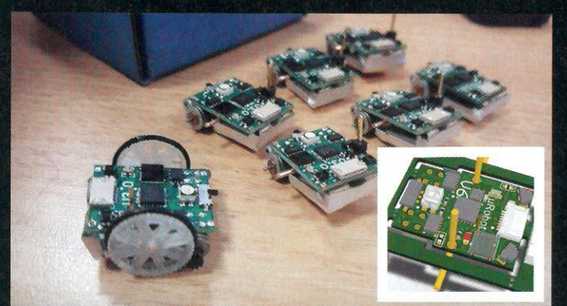
The project uses a master computer to control the micro robots and to reduce the cost of a kit. The team has experimented with various single-board computers, including the Raspberry Pi Zero W and the Orange Pi Zero 2 Plus, primarily with the aim to make the master system "more pocketable," says Joshua.

ROS junkies

Robot Operating System's (ROS) visualisation tools, debugging tools, repositories of state-of-the-art algorithms and communication simplicity "were just too good to turn down," says Joshua. "Through my research work, myself and most of my colleagues are ROS junkies, so for me it wouldn't count as a real project unless it can leverage the ROS ecosystem."

Arduino drop

The project used the ATmega328p at first, but the team soon got frustrated with the lack of resources in the Arduino IDE and so switched to the STM32L031. This offered plenty of timers to implement better motor control and have more flash and RAM. "[As] these robots are meant to abstract away from the low-level details for the user, using Arduino was probably misguided in the first place," says Joshua.



Above Version 6.0 of the micro robot kit is almost ready to go (rendered, above) and includes an accelerator for running the robots on walls: "We have demonstrated the fact that the robots can drive on a ferromagnetic surface mounted to a wall," Joshua tells us. "The accelerometer will provide all robots with a reliable absolute orientation relative to gravity."

Above A recent trip to a large robotics conference saw the micro robots well received, but did highlight a few problems: "The lesson learned [...] was that any demo of the project should be portable and quick to set up," says Joshua. For future trips he intends to integrate his calibrated system with controlled lighting and a mount for the camera into a single-board computer