With the global population steadily rising, optimising agricultural productivity and land use to grow enough food is an ever more pressing issue. Raising crops is a precision industry, and one in which farmers are constantly under pressure to produce more from their acreage in order to meet the demand for food, at a cost that will keep their main customers – the supermarkets – competitive. Minimising the use of pesticides and fertilisers is critical to maintaining profits, as well as to preventing soil degradation, while labour to sow and harvest crops is in increasingly short supply. Seasonal labour shortages can be eased by drafting in casual workers from other states or countries, but the bigger trend is towards the increased mechanisation and industrialisation of farming.

Directed Machines is a small but important player in the growing agri-robots sector, developing and marketing Land Care Robots (LCRs) for a wide range of vertical markets. Raspberry Pi is a crucial part of the company’s successful designs.

| Raspberry Pi solution | Raspberry Pi 4  
|-----------------------|-------------------
|                       | RP2040            |
| Size of business      | Small to medium  
| Industry              | Agri-robots       |

Directed Machines: Raspberry Pi powers customisable robots for precision agricultural tasks

Raising crops is a precision industry, and long-term trends in farming are towards increased mechanisation. Directed Machines’ Land Care Robot, built around Raspberry Pi 4 and RP2040, is a cost-effective way to free up scarce human capital.

Robots could have multiple uses across the growing season – preparing the ground, applying fertiliser and pesticides, sowing seeds, removing weeds, transporting seedlings from place to place ready for planting out, and harvesting the crops. Each of these tasks would need to be performed accurately to justify the robot’s outlay and for it to be a true replacement for hard-to-find seasonal manpower. The right to repair is a big issue in the agricultural industry, so there were important considerations regarding the maintenance and servicing of complex machinery.

The challenge

After a successful 21-year career in software development, George Chrysanthakopoulos was keen to capitalise on his thorough knowledge of robotics: he was the technical lead of a large, secret, consumer robotics initiative at Microsoft before moving to VMware, where he became a fellow. For his own, post-industry, project he began designing solar-powered robots to help deal with the annual snowfall. Discussions with neighbouring small-scale farmers quickly convinced George there were myriad possible uses for robots in agriculture, and there was a healthy market for low-cost mechanised assistants that could help solve some of their pesticide and plant management issues. Profit margins on small farms are especially tight and farmers would need to be able to perform multiple tasks with their robot and to repair it on-site, meaning readily available parts and fairly simple but robust hardware were imperative. Nonetheless, there seemed to be a market for relatively low-cost, heavy-duty, solar-electric, autonomous machines.
The solution

Chrysanthakopoulos set about developing a modular robot that could be used for a variety of agricultural tasks. Prototypes of the first Directed Machines-branded product, a laser-guided autonomous weeding robot, had field trials in early 2018 and were followed by the more powerful Raspberry Pi-based Land Care Robot – the base unit for Directed Machines’ modular offering.

As well as Raspberry Pi 4, the Land Care Robot uses a board with Raspberry Pi’s flagship microcontroller RP2040, together with an Adafruit IMU, as a sensor co-processor to support autonomous navigation. A second RP2040 microcontroller board acts as a low-current electronics co-processor, monitoring and regulating solar charging.

“The cost/benefit ratio of using the Raspberry Pi ecosystem is second to none”

Why Raspberry Pi?

The Land Care Robot was built around Raspberry Pi for cost reasons, as well as the reliability and availability of hardware. The company reasoned that with a huge installed base and active community, the chances of bugs being found in Raspberry Pi units were minimal. This, of course, is critical when it comes to machinery that may be remotely located and would therefore need to be updated or replaced by customers. "If you can do it on a Raspberry Pi, there are huge advantages to doing [so],” says Dan Abramson, Directed Machines co-founder and COO. "You've sold millions and millions of units, the chances of bugs popping up are really, really low.” He also mentions the "richness of the ecosystem around the Raspberry Pi" and its relatively low energy requirements. "So if you can do it on a Pi, there are compelling reasons to do it on a Pi."

Abramson adds: "Raspberry Pi is a very beautiful match for our first principles, algorithmic architecture philosophy. Instead of throwing brute-force computing power at solving engineering problems, we leverage the structure inside those problems to reduce the computational requirements related to those problems... Raspberry Pi is a beautiful tool, a beautiful partner to execute the calculations that we need to execute.”

"The cost/benefit ratio of using the Pi ecosystem,” says Abramson, "is second to none."
The results

Directed Machines has been selling across North America in constrained fashion for the past two years, meaning plenty of advance research to ensure Land Care Robots are a suitable fit for each client’s needs. Development was entirely in-house and took just two years including mechanical development, electrical development, and all the software development. For the past two years, Directed Machines has been selling into market and deploying the Land Care Robot platform “in all sorts of different interesting use cases and verticals,” says Abramson. “It’s an autonomous robot, and you can attach different implements to our robot to allow it to perform different tasks. You might attach a mower deck to our robot to allow it to mow grass. You might attach a snowplough to our robot to allow it [to plough snow], you might attach a cart to our robot to allow it to pull whatever it is you want to be pulled in.

“Customers include golf courses, solar farms, rural properties, and nurseries that have to tow potted plants in very heavy volume. The LCR can be deployed in a wide range of terrain settings, from very, very flat properties that we need to perform tasks on, to one we have in Southern California that overlooks the Pacific Ocean, where the terrain is 55 degree slopes.”

As well as handling very challenging terrains, the Land Care Robots are fully autonomous and capable of completing multiple tasks without user intervention. “We keep adding features to what we do all the time, and we continue to improve the robustness of our engineering and to experiment with new sensors. We are doing that more and more, using sensors that we find in Raspberry Pi’s ecosystem.”

Britt Fletcher is the owner of Mutiny Bay Blues in Washington, an organic blueberry farm run along sustainable principles, and a Directed Machines investor. Directed Machines approached Fletcher two years ago, keen to use Mutiny Bay as a test site for its robotic solar-powered machine. “The Land Care Robot’s ability to mow acres of a very structured row environment, as well as many of our open areas, while not using gas and also freeing up a farmworker to handle more difficult tasks, made coming on board an easy decision,” he says. Working in a high-stakes structured environment can be a particular challenge, but LCR updates to improve accuracy in response to feedback means Mutiny Bay now has a machine that Fletcher trusts to work unsupervised: “The cost is about three quarters of what it had been and, more importantly, frees up increasingly scarce human capital.”

In 2021, Blueweave Consulting estimated the smart agricultural market to be worth approximately $11.5 billion, and predicts this to nearly double to $24.3 billion by 2028, citing demand for precision agriculture as a key driver. Daren Richins runs an entrepreneurial farm business in Utah. He believes the direction agriculture is headed is “fairly obvious”, with labour shortages and increased capital expense taking a big toll on farmers. “I think the answer to these challenges lies within robotics and technology. As I’ve had the opportunity to work with my Land Care Robot, I’ve been able to peer into a not-so-distant reality that relies quite heavily on this type of technology to satisfy the challenges we face today in agriculture. Directed Machines has been an excellent partner in taking this bull by the horns.”