Case study: **Mobile on-farm digital technology for smallholder farmers**

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Abstract

For over 10 years the Australian Centre for Field Robotics (ACFR) at the University of Sydney has been developing novel mechatronic and software systems for the Australian agriculture industry. The aim is to support farmers with the research, development and commercialisation of digital tools that would help them increase yield and productivity and reduce input costs. In 2015 the ACFR received philanthropic funding to look at designing similar technology for smallholder farmers. The hypothesis is that with an appropriate education and training program coupled with low-cost on-farm mobile platforms and digital tools adapted from more precise technology, a system and methodology could be developed that delivers food and nutrition security and encourages next-generation growers to adopt digital agriculture techniques. These requirements led to the development of the Digital Farmhand. The Digital Farmhand comprises a small mobile platform that can be hand towed, remotely controlled, or set into autonomous mode. On the mobile platform exists a smartphone, sensors, and computing. Collectively the system can undertake precision seeding, spraying and weeding. Through the digital capability of monitoring and analysing individual plants the system has the potential to support better on-farm decision making, helping growers increase yield and productivity, reduce input costs, and maximise nutrition security. The Digital Farmhand has been trialled amongst small farm holders in Australia as well as in Indonesia and will be trialled next year in the Pacific Islands. The objective of these trials is to close in on the requirements that would meet the needs of those communities.

This talk is about the technology behind the project to build the Digital Farmhand – the piece of machinery in Figure 1. The aims of the project are (i) to see how to bring together as much off-the-shelf technology as possible, both digital and physical, to try and improve on-farm production and productivity; and (ii) to look at other aspects that could aid farmers in their day-to-day decision-making.

How it began

This Digital Farmhand project grew out of a project that is introducing similar technology in the horticulture industry in Australia. The platform in Figure 2, RIPPA, is solar electric; it operates for 24 hours; it has a number of different sensors underneath – multi-spectral sensors, hyperspectral sensors, laser units. It uses machine-learning algorithms to detect individual plants (e.g. Figure 3),

This paper has been prepared from a transcript and the slides and videos of the presentation.

Figure 1. Digital Farmhand – local smallholder farmer demo

Figure 2. RIPPA – Autonomous row-follower, checking on lettuce in Victoria.

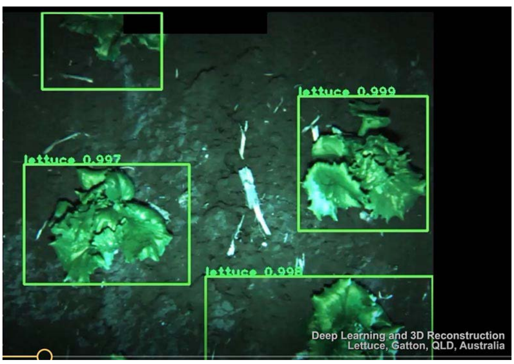

Figure 3. Deep learning on lettuce plants by RIPPA.

and the growth rates of those plants. We are getting better now at determining the health of the plant as well: whether it is water stressed, for instance. We can also make yield estimates per plant. The platform uses machine-learning algorithms, and it can apply a mechanical tine to remove weeds among the crop with absolutely no herbicide at all. That is one of the objectives in this project. There is a small 'fluid shooter' that can spray fluid onto each individual plant as the platform moves along. In this case it is applying water, but it could be fertiliser or herbicide or whatever the grower wanted to add. It also checks on the hydraulic conductivity with soil probes, as the unit moves along. In our next trial we plan to add foreign-object detection and foreign-object removal.

The platform exists because we have been funded by the horticulture industry to try and develop a system that can operate 24 hours, seven days a week and do precision on-farm mapping and also precision on-farm decision making and action in some form. This is catering for the 20–30% of Australia's growers, the big growers, who are looking for that 1–5% efficiency gain in their operations.

Catering for small growers

Two years ago we were given philanthropic funding to look at developing similar technology to support small growers. That meant focusing on three particular technologies.

The first is smartphones, but not in the way discussed so far today. We view smartphones as ubiquitous computers. They have temperature sensors, light sensors, humidity sensors, cameras on board, as well as gyroscopes, accelerometers and so on. So to us the smartphone is a beautiful computing platform with lots of sensors.

The second technology is 3D printing, which I believe is going to catch the agriculture 'wave' quite quickly, giving people the ability to manufacture any component, anywhere, to deal with a particular crop in any environment.

And the third technology is machine learning. Again our concept is unlike machine learning as only a way of dealing with data clustering. In our work, machine learning involves algorithms that give a machine the capability of making decisions in real time and, at a certain level, able to help and work with the farmer in some form.

One of the first things that we encountered as we started to talk to growers about repurposing these types of technology was their lack of digital knowledge. Therefore a key part of this program is to go into rural schools with these low-cost platforms and start to teach the kids how to use robotics, and how to code. Ideally we will show them how that applies within the food production cycle.

The other aspects of this project involve working with the Indigenous community, as well as developing-country needs.

Design and redesign

As roboticists we like to design, build, test, take it out, fail, come back, redesign and build again as quickly as possible – and go through that iteration process as much as we can. In our first iteration, all the 'smarts' were inside two tractor wheels with a cross-bar to stabilise the unit. Within 15 minutes you can piece this machine together, with a number of sensors underneath. We were interested in using the modular concept, to be able to put the device into the back of a van. That wouldn't be needed by a farmer, but could be useful to a cooperative or for going from farm to farm collecting data and information in various forms.

Figures 4 and 5 show the first iteration, the di-wheel: two powered wheel modules joined by an expandable central shaft (Figure 6). We took it from

Figure 4. First iteration of the Digital Farmhand: the di-wheel.

small farm to small farm around Australia, and tried it out to see what we could achieve (Figure 7). We also took it to some rural schools and were given phenomenally useful feedback from the students and the parents. To put a robot in front of these students, who have small paddocks and farms in their schools, and to be able to teach them how to code that robot within half a day to make it spray or map those paddocks, for example, is an interesting experience (Figure 8).

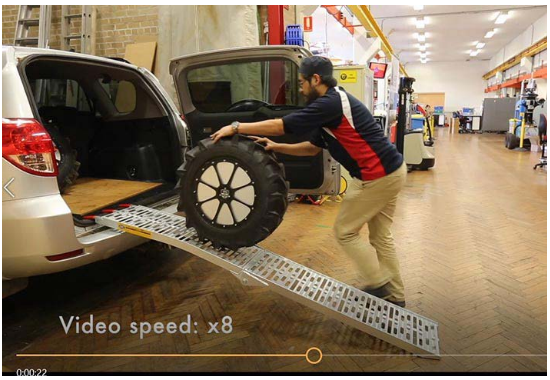

Figure 5. Being modular it is easy to transport in a station wagon.

Figure 6. Two people can quickly attach the expandable central shaft with its sensors.

Figure 7. Trial of the di-wheel adjusted to width to scan a row of vegetable crop.

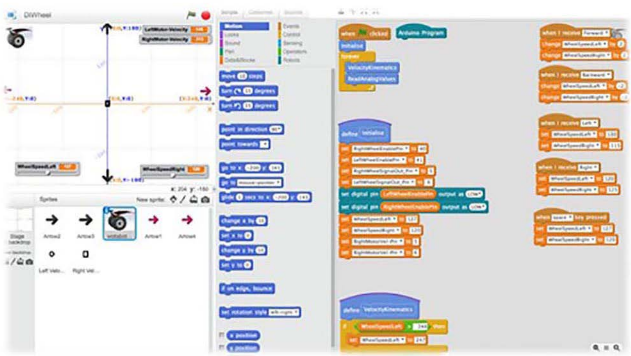

Figure 8. (*left and below)* Demonstrating to rural schools and teaching them coding

The bottom part of Figure 8 is a user interface that allows the student to come along and just push the di-wheel forward: go left, go right. The right-hand side of the diagram, those little blocks, are real-time functional blocks that keep changing according to what the student does. So the students learn how the system is coding itself in real time as they move the device, which gives them an immediate coding experience.

The third part of this project was a visit to a developing country. We went to Bandung in Indonesia, primarily because we knew people there, and we demonstrated the di-wheel to farmers on a series of different farms. We

Figure 9. Trial on a small farm in Indonesia, with selfie stick attached to hold a smartphone taking sharp photos.

installed a little selfie stick on the top – an off-the-shelf component with a smartphone on it with internal apps for programming. The selfie stick stabilises the smartphone and you get high quality pictures (Figure 9). We also visited electronic shops and manufacturing facilities, to understand the external ecosystem in relation to maintenance and availability. It seems that farmers in Indonesia are ageing, as they are in Australia, with few young people coming into farming and little labour available. People liked the di-wheel very much. The price would be a crucial factor, and might be beyond farmers' resources.

Improving through iteration

Not many changes were needed at the next iteration. We added a three-point tow hitch to the back of the device, which means you can attach a number of different tools. Figures 10 and 11 show how an added smartphone is now able to detect individual plants, segmenting out those plants, and by the end of the row producing a plot of number of plants, size of each and a crop yield estimate. We also hooked the smartphone to the spray tank, so it only sprays target plants at the right time, not everything.

The objective now is to determine if we can build a really low-cost platform, using as much 3D printing componentry as possible. We ran a demonstration this winter with the Greater Sydney Local Land Services. About 100 growers attended, and we started to talk to them about the various concepts. It was interesting that they saw this could give them the potential to grow niche crops that could then differentiate them from everyone else, especially if the learning algorithms were working well.

Next steps: expanding understanding

With the next part of this project's funding we will go to the Pacific Islands, to three or four locations, to do a scoping study and a metric capture of how farmers would use this technology if they were to adopt it. What components would they want? For example, some farmers in Indonesia did not want the platform at all: they just grabbed the selfie stick with the smartphone and walked up and down the rows themselves, collecting data that was sufficient for their needs.

Figure 10. Improved imaging of lettuce plants, cf. Figure 3.

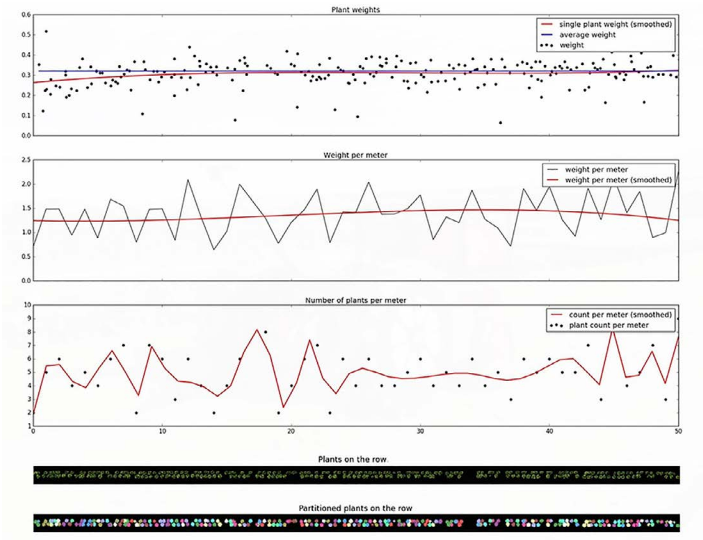

Figure 11. Yield estimates per plant from data collected along the row.

Education is another aspect of the work. In the past we have built Mars robots for the Mars Lab at Sydney's Powerhouse Museum, and had schools all over the country tapping in online to run their own Mars missions, and through that they learnt about robotics and coding. Next year we shall do a similar thing in reverse: building a few of these platforms, putting them into rural schools, and then having the student tap in to learn how to code the robotics. The teachers, rather than the kids, are the challenge here, because they need to fit these activities within the curriculum timeframe.

Smallholder farmers in Australia need training to use the platform: not just the user interface but also the physical system. We also need to learn what they want: do they need the motors, or would they just pull it along, or should it be remotely controlled or fully autonomous?

Considering the third iteration

What will the third iteration of this robot look like? Figure 12 summarises some aspects of the iteration. We are aware of the rise of the electric scooter across

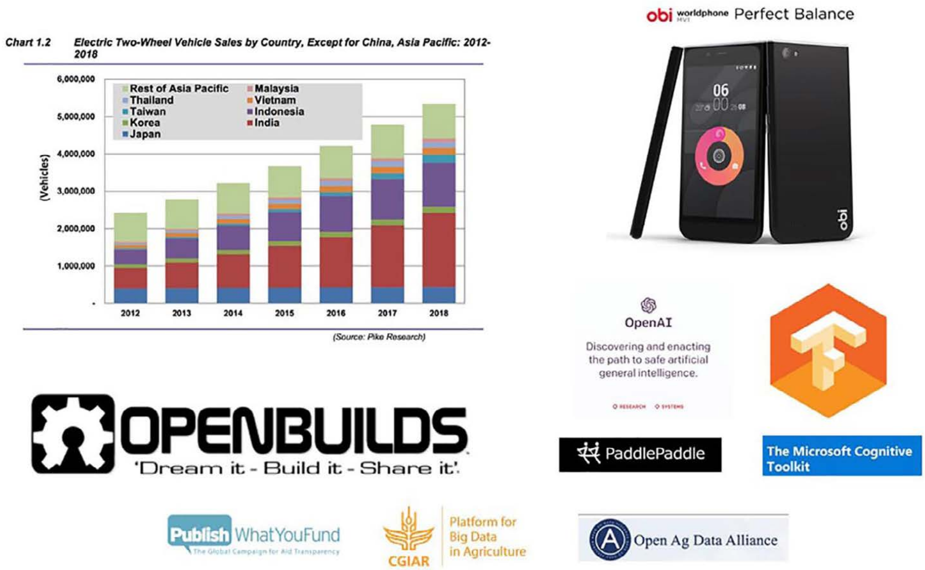

Figure 12. Digital Farmhand, third iteration. (*For chart at top left, see*: https://www.navigantresearch.com/wp-content/uploads/2012/04/ETVAP-12-Executive-Summary.pdf)

the Asia–Pacific region. If we can tap into that, and use the same battery power, motors and gear systems, then we also tap into the ecosystem that deals with their maintenance and availability. That supporting ecosystem is important. If we buy a couple of scooters and pull them apart, we can repurpose them as a tractor and then see what happens.

Have you heard about Obi? It is a world phone, built by an ex CEO of Apple who wants to see if it is possible to build high performance, high quality phones for the developing world, costing less than $200. The interest in this for me is not phone calls but that the phone is a computer with a collection of sensors on it, and if it is cheap that will help keep down the cost of devices it is attached to.

Machine learning is no longer confined to the university world. There are open-source machine-learning algorithms available for use: OpenAI by Elon Musk; TensorFlow by Google and Microsoft; and Baidu have PaddlePaddle. In other words, learning how to use these machine-learning algorithms is quite easy now. They are becoming tools; you do not have to code them before you begin. The other open-source activity that is going on is OpenBuilds, which is focusing on people who are using 3D printing and other techniques to design and build hundreds of different machines. OpenBuilds is open-sourcing that kind of activity on the web so people can then redesign and rebuild as well.

My message here is that for a third iteration of Digital Farmhand we will be seeing how much off-the-shelf software and platforms we can put together to drive it and make it low cost. It may be that there is not a commercial future in building these bots and selling them, but instead it would be better to open-source the designs so people can modify them for their needs.

Final points

We hope the Digital Farmhand will turn into a farm assistant: think of Siri (the digital assistant in iPhones) on steroids, working for agriculture. It will be a system that can offer suggestions and come back to you and show what it wants to do next. Working with a system on that very personal level becomes a very significant change, because it means being able to provide agronomy and learning continuously in real time on the farm. That is really what we are heading towards.

Second, in terms of policy, what I have seen with other industries and what I am starting to see with agriculture, is that when a policy is put in place it is often expected to hold for some years, say the next two decades. But technology is changing every few months. Therefore, it is important to be thinking about how to make policy in an innovative manner, being constantly agile.

Salah Sukkarieh is the Professor of Robotics and Intelligent Systems at the University of Sydney and is an international expert in the research, development and commercialisation of field robotic systems. Over the last 10 years he has been developing robotic and digital technologies for agriculture focusing on how technology can be used to enhance sustainability and quality of life for growers. Salah has secured a number of large-scale R&D projects from the horticulture, grains and grazing livestock industries and has demonstrated operational systems around Australia. He was selected as one of 11 LAUNCH Food Innovators, from 280 worldwide applications, for his research and technology in 2017 and was recognised as one of Australia's Most Innovative Engineers, by Engineers Australia, in 2016. Salah is a Fellow of the Australian Academy of Technology and Engineering.