

## Fields of automation

*Robotics: A new generation of agricultural equipment promises to take more of the toil out of farming by automating the business of growing fruit.*



*Inspecting a tomato plant at MIT - Jason Dorfman*

In the early 1830s, spurred on by his hatred of sweaty field work, Cyrus McCormick took an idea his father had been working on at the family farm in Virginia and produced a mechanical reaper. Others devised similar machines. Despite initial scepticism, farmers eventually bought them in droves. With one person riding the horse that pulled the reaper, and another raking the cut stalks off the back, the machines could harvest as much grain in a day as a dozen men breaking their backs with reaping hooks.

Mechanical reapers became even more efficient when adapted to bale the stalks into sheaves, too. Development continued: today a driver in the air-conditioned cabin of a combine harvester may be guided by satellites as he cuts, threshes and pours clean grain into a fleet of accompanying trailers. One machine, the New Holland CR9090, holds the record after harvesting a colossal 551 tonnes of wheat in just eight hours from a farm in Britain in 2008. Given that such machines cost around £350,000 (\$580,000), agricultural automation must make economic sense—because farmers don't spend money on frivolities.

But there are farms where people like McCormick still dream of taking hard, manual work out of agriculture. These farms grow crops that mostly have to be tended and picked by hand, such as apples, oranges and strawberries. In rich countries it is becoming increasingly difficult to find people to do this at wages farmers say they can afford. Seasonal demand adds to the problems: in California, where some 450,000 people, mostly immigrants, are employed on fruit farms at the peak of the harvest, growers often leave some produce to rot. Even Japan's exquisite and expensive strawberries are becoming too costly to pick because of a shortage of workers, in part caused by an ageing population. Despite worries about food shortages in the coming years, many farmers are more worried about labour shortages.

Just as the mechanical reaper transformed the economics of cereal farming, a new wave of agricultural automation promises to do the same in other areas of horticulture. Because picking apples is very different to plucking strawberries, the machines are taking various forms. Some have giant mechanical arms and are towed behind tractors through orchards and vineyards. Some are fully autonomous and able to scurry around on their own, even in paddy fields, like the robotic rice-planter developed by Japan's National Agricultural Research Centre. Others trundle about inside experimental greenhouses.

Whatever shape they come in, agribots share several underlying technological advances which have their origins in factories. Automating factories is easier than automating farms, which are far less predictable environments: the weather constantly changes, the light alters, the ground can turn from grass to mud, and there are animals and people wandering around. Moreover, unlike car parts, fruit does not come in standard sizes. It moves around on branches in the wind, changes shape and colour, and can be hidden by leaves. But improvements in vision and other sensing systems, coupled with the increase in the power of computing, have made robots cleverer, safer and more dexterous.

Yet farmers, like factory owners, will want a return on their investment. "It is actually not hard to pick an orange, but it is very hard to pick an orange cost effectively," says Tony Stentz of the Robotics Institute at Carnegie Mellon University in Pittsburgh. Because robots can work all day without a break, they have one advantage over manual labour. But it is their potential for accurate information-gathering that is proving to be an equally important talent.

Crop-tending robots that use vision systems, laser sensors, satellite positioning and instruments to measure things like humidity can build up a database of information about each plant. This can be used to detect the onset of disease, says Dr Stentz. A "smart sprayer" can then deliver precise amounts of chemical to only those plants that require attention instead of spraying an entire field. By observing the development of each plant, crop yields can be predicted more accurately. Automated harvesters will then use the database to identify and gather individual produce whenever it is ready for harvest.

On a small scale it is already possible to see fully automated horticulture in action. The Massachusetts Institute of Technology (MIT) has an experimental greenhouse growing cherry tomatoes on raised platforms. It is managed entirely by small robots. Each plant is equipped with sensors which keep track of its condition. If a particular plant is getting a bit dry, one of the robots is summoned to water it. When a tomato is identified as being ripe, the robot uses its vision system to locate the fruit on the vine and pick it with a mechanical arm.

Daniela Rus, director of MIT's Distributed Robotics Laboratory, says there are a number of ways in which automated systems could improve crops and "remove some of the hard tedious work from greenhouses". A plant-centred system using sensors would record not just an individual plant's progress but also the condition of the soil it is growing in. If nutrients are needed they can be delivered precisely, which would cut down on inputs.

Greater mechanisation may prompt farmers to change some of their ways and the varieties they grow. An example is Californian raisins, which are traditionally harvested by hand. Workers cut off bunches of grapes and lay them on trays between the rows to dry. As many as 50,000 people used to be required for the harvest. But due in part to declining acreage and increased mechanisation, that has now fallen to 20,000-30,000.



*Robotic research bears fruit - Vision Robotics/Jason Dorfman*

Mechanisation has come about in a number of ways, according to a report by Philip Martin of the University of California, Davis. Growers, sometimes using varieties that reach optimal sugar levels earlier, slice the canes holding the bunches of grapes so they begin to dry while still on the vine. Modified grape harvesters with rotating fingers then knock off the raisins. If completely dry they are gathered immediately, and if not they are laid onto a continuous paper tray in the vineyard to dry.

About 35% of Californian raisins were harvested in 2008 using the continuous-tray system and another 15% dried completely on the vine. The university reckons the traditional hand-harvesting method cost \$494 an acre in 2006, compared with \$282 an acre in 2008 for the mechanised continuous-tray method. Newly planted vineyards could be even more efficient by using a higher density of vines trained to grow over trellises designed to help with mechanical severing and harvesting.

Even pruning can be mechanised. Vision Robotics, a company based in San Diego, has demonstrated a prototype vine-pruning robot. Good pruning requires skill to balance the growth of the vine. The vines also need to be trimmed at certain locations and at precise angles to grow the best grapes for winemaking. The robot is a bit slower than a good human pruner, but it will speed up. It should be able to prune vines at about half the cost of manual labour, says Derek Morikawa, the chief executive of Vision Robotics.

The company is also developing apple- and orange-picking robots with multiple arms. These too rely on building 3-D models of trees and the fruit growing on them. Mr Morikawa thinks the crop-scouting ability of such automated machines will prove highly valuable. Supermarkets, for instance, like uniformity so if they want, say, apples of a certain size and in a particular state of ripeness, a farmer could use the model to identify exactly where such apples are growing.

The take-up of mechanisation will depend on where the produce is going and how carefully machines can pick it. Light bruising from mechanical harvesting may be acceptable for fruit going to the juicer, but not for fruit displayed on a supermarket aisle. Even though grape harvesters, which shake or knock grapes from vines, have been around for about 40 years, some growers still pick by hand.

To compete with hand-picking, robot harvesters will need to twist, pluck, cut or suck produce from stems and handle it as gently as possible. Many factory robots are already capable of doing things like this, and some already sort soft fruit passing along conveyor belts. But operating outside on a farm is much harder. For one thing, lightweight mechanical arms are needed to reach high into trees and pick with precision, despite wind and uneven terrain. Inside a sheltered greenhouse, however, robots feel more at home.

Oranges are not the only fruit

One of the most difficult challenges is to produce a strawberry-picking robot. Strawberries are delicate and go through different shades of red while they ripen on the vine. Moreover, they ripen at different times. There are strawberry harvesting machines, but they are mostly towed contraptions on which people lie down in order to pluck berries. But researchers at Miyazaki University and Kyoto University in Japan are working on robot versions.

These are designed to operate in greenhouses adapted to automation. The strawberry plants grow on raised beds and the robots travel between them on rails. They rely on machine vision to determine when individual berries are ripe, cutting them from the plant and holding them with a gentle suction as they transfer them to a conveyor belt or basket. These robots are not yet as fast as human strawberry pickers, but they can work all day and all night.

This might seem to be an elaborate way to grow strawberries—as well as an expensive one. So it is no surprise that when Japanese growers were asked in a survey if they wanted such a system only a little more than 6% said they did. However, more than half thought they might need one in the future. Other farmers around the world are likely to agree with Japan's strawberry growers. Agribots will, like McCormick's mechanical reaper, face a lot of initial scepticism. But planting and picking they will come.

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