

Robot innovation brings to agriculture efficiency, safety, labor savings and accuracy by plowing, milking, harvesting, crop tending/picking and monitoring

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Abstract

Purpose – This paper aims to review the dramatic entry of robotics into the field of agriculture.

Design/methodology/approach – Research of efforts around the world to apply robots to agricultural needs and participation in webcasts of the latest in agricultural robotic development projects.

Findings – Robots are enabling many new and innovative methodologies for performing traditional agricultural tasks of all types. Providing saving in labor, improved performance and faster field coverage.

Practical implications – Readers may be very surprised at the many tasks that robots are already addressing in the agricultural field around the world and the way just applications can have major benefits to farming.

Originality/value – A review of the wide range of the innovative application of robots to agricultural tasks worldwide.

Keywords Agriculture, Robotics, Crop picking/tending/harvesting, Feeding, Milking, Monitoring

Paper type General review

Farming has traditionally been a very labor-intensive activity. Even with the advent about a century ago of motorized vehicles such as plows, combines, harvesters and such, a human driver was always required. That day has now passed as robotics has arrived addressing all of such tasks as well as crop monitoring and even the very manual efforts such as fruit picking and milking.

Agriculture is benefitting from efforts in other fields such as unmanned vehicles for military and security tasks, vision-guided manufacturing, mobile robots and other autonomous robotic developments (Bloss, 2014). Researchers are taking advantage of the recent dramatic growth in intelligent computing power and sensor innovations that open new doors to previously what were considered impossible-to-address agricultural applications.

Another driving factor is the need to address farm labor shortages. As an example, the Japanese Government has recently announced plans to fund the development of unmanned farm tractors. Their support is based on research showing that more than 60 per cent of Japanese farmers are 65 years of age or older, and younger people are going into high-tech occupations and not farming. In the USA, data show that less than one per cent of the population is engaged

in farming. Feeding the population is a growing problem around the world. Robotics is answering the call.

Milking

Milking cows has been a very traditional labor-intensive task even after the advent of milking machines. Humans were still required to connect and disconnect the milking teat-cups on the cow. Milking machines reduced the human effort required per cow per milking, but humans were still needed in the barn. Now robotics has stepped up to automate the entire milking process.

As the cow steps into the milking stall, an radiofrequency identification tag signals the cow ID and the computer checks to see if this cow is ready for milking (Figure 1). Milking occurs twice a day, and timing is very important to maximize milk production. Once the cow has been approved as ready for milking, sensors signal to direct the robot to apply the four milking cups and start the milking process. When the milk flow is detected as done, the cups are removed and the cow is signaled to exit the stall.

Important in the process are the steps necessary for automatically ensuring the cow coming to the robot milking stall in a timely fashion. Typically farm fencing is positioned to guide the herd toward the feeding/milking station. Cows typically come to the feeding station periodically. Often the milking stall features tasty food that draws the cows in. Frequently, robotic milking is performed in zero grazing situations where the cows are never out in the fields but keep in barns.

An added benefit of robotic milking is the automated record keeping that can be part of the process. Sensors can monitor and record cow ID, milk volume, product quality and milking times automatically for better record keeping without human intervention.

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Figure 1 Lely Astronaut robotic milking system in action

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One problem still being addressed is the cost of the robotic milking equipment. Robotic milking stations are currently in the several hundred thousand US dollar bracket. Innovation and market forces will surely bring the price down soon. Recently, a farm in Germany installed 44 Astronaut robotic milking systems and milks 2,500 cows, helping prove benefits outweigh the initial cost.

A number of companies have introduced robotic milking equipment including DeLaval, Fullwood, GEA Farm Technologies, SAC, Lely and Boumatic.

Plowing and harvesting

Preparing the ground for crop planting and harvesting requires great amounts of time for farmers to cover the large fields. Each field may need a number of passes each season. As an example, plowing, then seeding, harvesting and, for crops like corn, removing the stalks after the harvest. Unmanned robotic tractors are arriving to autonomously address these major man-hour needs.

Kinze Manufacturing, Williamsburg, Iowa, has developed an autonomous farm tractor that is guided by GPS signals. The farmer creates a field map using a GPS recording system to document the borders of each field. This “map” is loaded into the computer onboard the tractor.

The tractor is equipped with the computer, a Wi-Fi system, sensors of various types and two-way communication with the farmer. If the Wi-Fi is out of range, a cell phone link is also included.

The sensor systems include video cameras (forward as well as sideways), radar, lidar (light detection and ranging) and a laser-based scanner. The radar system detects solid objects such as metal fence posts, animals or people in the way. The lidar system can detect wood or plastic objects. Other sensors include an incline meter that can signal if the tractor is

approaching a tip-over condition. The controller can also monitor an electronic scale in the trailer to avoid overloading.

The most common application of the tractor is to haul a trailer (with 27,000 kg capacity) for unloading a grain-harvesting combine (Figure 2). By unloading the combine in the field, valuable time is saved, as the robot tractor and trailer can deliver the grain to a waiting-over-the-road trailer and tractor rig used to haul grain to the elevator. The combine can then continue harvesting with minimum time lost for unloading.

The controller creates its field map noting location of the take-away trailer, obstacles such as creeks, gates or others. The farmer (human operator) can monitor operations live with the video signals and communicate with the combine operator. If necessary, the farmer can take over driving the tractor by remote control if necessary. Other features include the ability of the farmer to send speed directives and a “go to” location signal to the tractor to direct the tractor to a time-efficient location for the next combine unload procedure. The tractor has the ability to create a field-plowing pattern for its own operation.

Crop picking/tending

Once seeds are in the ground that is only the start of labor-intensive activities in the field. Often a crop may need thinning to ensure maximum crop production. Of course fruits are usually handpicked. Robots are now being deployed to address some of these activities.

Lettuce is a crop that is started with seeds and then to maximize production, weak plants need to be removed and healthy plants fertilized. Vision Robotics has developed a robotic answer to these “stoop labor” activities. Lettuce is known as the most important crop in California. In 2010, the state of California reported production at 1.6 billion dollars and that represents more than 70 per cent of all lettuce grown in the USA.

Figure 2 Robotic tractor grain hauling system at work unloading a combine harvest machine in the farm field



Source: © Kinze Manufacturing used with permission

Workers who do this manual lettuce tending are typically paid by the acre so they work fast and have little incentive to work expertly. Robots are starting to address this need.

The Vision Robotics lettuce tender at this time is a towed trailer that has units to tend six rows at a pass (Figure 3). Each

tending unit uses cameras to identify the lettuce shoots to be fertilized and the ones to be removed. Each tending unit is enclosed to remove the problem of external sunlight and shadows affecting the camera sensing. Robotic sprayers are then directed to each shoot. To remove a shoot it is over

Figure 3 Robotic Lettuce thinning system



Source: © Vision Robotics Corp. used with permission

fertilized, which kills the shoot. The healthy shoots are given a regular amount. The effective movement rate down the row is from 2.4 to 3.8 kph.

Vision Robotics has also developed a grape vine-trimming robot (Figure 4). Grape vines must be trimmed each year to maximize grape product for the next growing season. Grape vines must be carefully trimmed or the trimming may result in less grape production. Laborers used for this trimming are low-paid and not highly skilled, resulting in potential miss-trimming. The robotic trimmer can be programmed with “trimming rules”, which can bring quality control to the process while also reducing labor costs.

The vine trimmer operates inside a tent that rides along with the robot. The tent eliminates problems of lighting and shadows (Figure 5). Inside, the robot has two cameras examining the vine

and deciding how the four robot trimmer arms should move to complete the trim. The towing tractor moves forward 45 cm per cycle. At each stop, an examine-and-trim process occurs. At the end of each vine row, an operator moves the rig to the next vine row and initiates the next trim.

Another robotic lettuce trimmer project can be found at Blue River Technology, a startup company in the Silicon Valley of California. The team here calls their lettuce trimmer the “Lettuce Bot”. Development was driven by the desire to reduce field labor and to improve the actual lettuce thinning process. Their system is towed behind a tractor and uses complex computer-vision algorithms and a database of images taken from different angles to identify the desired plants. A simple light shield blocks the sun and shading which might disrupt the selection process. The Lettuce Bot is a 3.6- by 2.1-m trailer towed behind a tractor

Figure 4 Overall view of tent covered robotic vine trimming system in operation moving down a vineyard row



Source: © Vision Robotics Corp. used with permission

Figure 5 Inside the sun and shadow protecting tent of a robotic vine trimmer in action



Source: © Vision Robotics Corp. used with permission

(Figure 6). Cameras examine the lettuce shoots and direct the fertilizer application process.

The Lettuce Bot can thin the lettuce plants in an entire 15-acre (6-hectare) field in two hours, which if done with manual labor would take all day and 25 people to complete. The team is looking at other robotic agricultural applications like picking delicate market-ready fruit such as strawberries, cherries and table olives. The Blue River team is also looking at other agricultural applications such as applying their technology to tomato plant thinning and weeding. This application is much tougher, as weeds are much more difficult to differentiate from tomato plants.

Fruit, especially, has always been seen as a very “hands on” labor-intensive activity. Three skills were needed: find the item to be picked, assess if the item was ripe and ready to pick and then to pick and place it in the collection container. Frequently fruit picking also required either climbing a ladder or bending over to pick from ground level, such as with strawberries. Robotic crop picking is more than motion but includes locating randomly located items such as on tree limbs, assessing ripeness and then creating in real-time motion commands for the picking and placing function.

Prof Flemmer at Massey University in New Zealand has been very busy solving crop-related tasks with robots. Kiwi

Figure 6 Lettuce Bot robotic lettuce thinner ready to move to the field to fertilize good young plants and remove weaker unsuitable plants



Source: © Blue River Technology used with permission

Figure 7 Robotic Kiwi fruit harvester



Source: © Prof. Flemmer, Massey University used with permission

fruit is a major crop grown in New Zealand. The fruit grows on latticework-style tunnels with the fruit hanging in bunches on the underside of the lattice. Prof Femmer has developed a prototype robotic Kiwi picker to gather the fruit.

The Kiwi picker uses four robot arms (Figure 7). Each arm is driven with stepper motors directed by a microprocessor. Each arm and control weighs about 13 kg. Each arm has 46 cm of vertical movement and 114 cm of horizontal movement. The arms are mounted in a line orthogonal to direction of travel on 57 cm center distance and provide fruit picking overlap.

Two video cameras search for the kiwi fruit and provide input to the robot arm controllers. Two additional cameras

look forward and provide navigation input. For more information on the Kiwi picker or for the robotic fruit packers described below, please e-mail p.c.flemmer@massey.ac.nz

Vision Robotics pioneered robotic fruit picking with their development of an autonomous orange picking robotic system several years ago (Bloss, 2008). The Vision Robotics system used 40 cameras, 20 per side, searching for oranges, and eight robot arms, four per side, picking the oranges as the tractor and trailer rig moved continuously down the rows of trees in an orchard. The rig could autonomously navigate the orchard row but needed a human to move to the next row and initiate.

Figure 8 Robotic fruit pickup end of arm vacuum gripper made of soft elastomeric material to handle fruit without bruising during labeling and packing



Source: © Prof. Flemmer, Massey University used with permission

Crop monitoring

Unmanned drone aircraft developed for military or security tasks have found their way on to the farm. Farmers need to monitor conditions on fields that may measure hundreds of acres or hectares. Manned aircraft have been used for many decades to spray crops to prevent pest damage and now the farmer with his drone can assess from his farmhouse porch when such procedures are needed.

The unmanned drone is very similar to a remote control model plane but with added features such as onboard video camera sending real-time images to the operator (farmer) monitoring the signals. The video camera can be adjusted for color sensitivity to maximize its ability to detect the conditions of interest.

Other developing drone applications include the use of larger unmanned aircraft to carry and dispense insecticides. Such drones would allow the farmer to spray fields as soon as he detects the need without the delay or cost which might occur when the farmer would need to contract with a third party (aircraft spraying service) for such an application.

A team at University of California Davis is working on applying a 90-kg robotic drone to fly over fields and apply pesticides to vineyards. Vineyards are often on hillsides and not suitable for tractor-pulled pesticide application units. An airborne pesticide delivery will be a much more effective and timely means of treating such vineyards in a very cost-effective manner.

Another drone application being studied might be to herd cattle remotely and/or to look for wayward cattle. The robot would be ideal to handle cattle herds in rough and or wooded areas difficult to reach in a motorized vehicle or even on horseback.

Other agricultural robotic applications

Another development by Prof Flemmer in New Zealand is the Kiwi fruit robotic packing system. The system examines each kiwi to locate and judge the ripeness of each fruit in a bin. The system then labels each fruit and places it in protective nest-like shipping crates, based on ripeness. Judging ripeness allows the less ripe fruit to be placed in a crate to be stored longer and the more ripe fruit to be placed in a crate to be shipped first for sale. Such automatic sorting is important for reducing the loss of overripe fruit in storage.

Important to the robot pick and place operation is the gentle ability to pick up each kiwi fruit without bruising the fruit. A soft elastomeric gripper is directed to each fruit by a video camera system and real-time computer-generated commands (Figure 8). Success with the kiwi fruit packer has led to the development of a similar system for picking and packing apples.

While not quite fully robotic, Raven Industries has developed a hands-free tractor driving system. The farmer can apply the SmarTrax™ MD steering device to the steering wheel and the tractor will steer itself along a straight line as entered by the farmer on the computer screen. The SmarTrax system includes GPS for guidance and farmer brake pedal stop control.

The system can be engaged at up to speeds up to 29 kph and can operate at speeds up to 43 kph. The system compensates for side-to-side roll, front-to-back tilting and twisting or turning of the tractor with a 3D terrain adjustment feature.

The control monitor for the operator includes capability to uncover up to five memory locations and diagnostic LED signal lights. The system is easy to install and can be conveniently moved from vehicle to vehicle as needed. To install the vehicle, steering wheel is removed. A slim motor is attached with a RENCO RCML 15 rotary encoder. Then the steering wheel is reattached on top of the motor/encoder. The control and monitor are mounted nearby in clear view of the driver.

Not only does the SmarTrax drive the farm unit, it can operate in conditions such as in the dark, when the weather is very windy or dusty and impairs the driver's vision. For more information on SmarTrax, visit the website www.ravenind.com

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