Robotics in Crop Production

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INTRODUCTION

Automation Technology has proliferated in virtually every domain of human activity such as construction, manufacturing, communication, offices, households, transportation, warfare, exploration, and space travel. The investment in Automation Technology in agriculture is driven by various forces: The main motive for developing Agricultural Automation Technology is the decreasing labor force, a phenomenon common in the developed world. Other reasons are the need for improved food quality and security such as automated inspection of agricultural products for contaminants. Automation can also help solve problems with high volume seasonal labor such as harvesting of citrus fruits, grapes, and raisins.

An important part of Automation is the use of robots. Robotics in agriculture is not a new concept; in controlled environments (green houses), it has a history of over 20 years. Research has been performed to develop harvesters for cherry tomatoes, cucumbers, mushrooms, and other fruits. In horticulture, robots have been introduced to harvest citrus and apples. In dairy farming, milking robots are currently commonplace in the Netherlands. The pinnacle of highly automated crop production is without a doubt the Japanese ‘‘plant factory,’’ where vegetables are grown hydroponically under artificial lighting. Computers and robots control the process from outplanting seedlings, to root cutting, packaging, and weighing, and the produce is free of any blemish, disease, or insect damage. The automation level in plant factories is so high that over time they may become completely autonomous production facilities.

FIELD ROBOTICS

Use of field robotics is relatively new, although Hollywood produced a movie called ‘‘Runaway’’ in 1984 in which agricultural robots are projected as scouts plucking insects off corn leaves. In reality, the first field robot for agricultural applications came much later. Baerveldt and Astrand[1] developed an early field robot for weed control and Bak and Jakobsen[2] proposed a small field robot capable of traveling between crop rows to register the locations of crops and weeds using a camera and Global Positioning System (GPS) receiver. Hofstee, Grift, and Tian[3] developed a machine vision based algorithm for autonomous crop guidance.

Wageningen University in the Netherlands was the first to organize an Agricultural Field Robotics competition in 2003 where students, faculty, and research institutions were represented.[4] In the United States, the American Society of Agricultural and Biological Engineers (ASABE) is working on a similar concept.

Robotic Scouting

Farmers need information about the crop and soil status before and during the growing season. Robotic scouts can be used for this purpose. They can travel to a predetermined location, take a soil sample to determine moisture levels, use a cone penetrometer probe that is inserted to measure soil compaction, and use an electric probe to measure pH. During the growing season, robotic scouts can measure nitrogen and water stress in plants using optical sensors, as well as insect and weed infestations using cameras. Scouting robots can also serve to ‘‘ground truth’’ information from Remote Sensing images.

To facilitate robotic crop scouting, there is a need to develop robots that can navigate fields autonomously. An example of an autonomous scouting robot called AgBo is shown in Fig. 1. AgBo was designed to be F1 self-guided in corn, without the use of GPS. Instead, it employs a SICK range finder, which projects a horizontal laser sheet and computes distances to all objects contained in the sheet. This allows the robot to keep equal distances between objects on the left and right side and weave itself through a cornrow. At the end of the row, the robot turns through 180°, then ‘‘crabs’’ to the next row, and enters it. The robot features an electronic compass, independent wheel steering, tilt control, and six microcontrollers connected through a Controller Area Network.

A second robot for scouting is AgTracker, which was developed with simplicity and low cost in mind (Fig. 2). F2 For instance, the guidance, sensor, and remote control interface are all performed by a single microcontroller. AgBo and AgTracker are described in detail in Ref.[5].

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Fig. 1 Tony Grift (l) and Yoshi Nagasaka (r) pose with AgBo, a sophisticated crop-guided Agricultural Robot developed at the University of Illinois, U.S.A.

Robotic Operations

Although individual robots are too small to carry out tasks that require high lifting capacity such as bringing in fertilizers and removing the harvested grains, they can be used in situations where relatively little power is required. A good example of this is weeding, where weeds can be treated with a small amount of highly concentrated chemical (microspraying) or alternatively, mechanical weed control.

A major limiting factor of field robots is their energy consumption and hence, action radius. Although robots may be powered by fossil fuels, a far more elegant method consistent with their use to lessen the environmental impact of farming is using locally available sources such as sunlight. If robots are used for harvesting, they may even consume some of the crops for their own operation. Indeed, this is similar to using biological counterparts such as a horse harvesting hay.

Fig. 2 AgTracker, a simple, low-cost crop-guided Agricultural Robot.

Multiple Robot Systems

The similarity between biological organisms and autonomous robots may be drawn further. Multi-Robot-Systems are popularly termed FlockBots, and they aim to solve a task by using cooperation and communication among the members of the Flock. FlockBots offer advantages such as capacity-on-demand: since many problems in agriculture come in patches, it makes sense to distribute the robot power and intelligence where needed at the right time.

A second advantage is using the synergy in a FlockBot system to optimize operations. For instance, one robot may detect a large weed area, and request other robots to assist in treating it. There have been many scenarios such as these studied in software in Genetic Programming where the members of an artificial ecosystem optimize their performance by learning and sexual reproduction. In the robotic case, robotic ‘‘fitness’’ is determined by the ability to carry out certain tasks such as weeding. Reproduction may be implemented by combining methods of two robots into a new virgin robot, and observe how it performs by combining the ‘‘genes’’ of both ‘‘parents.’’ The best performing robots are allowed to have more ‘‘offspring’’ than the lesser ones, and therefore over time, the Flock will increase its performance or Flock fitness. To avoid ‘‘getting stuck’’ in an inbred robotic community, small random changes (spontaneous mutation) may be implemented during reproduction, which may result in a superior robot, which is allowed to reproduce more vigorously than others and hence bring the FlockBot ecosystem to a new level of performance.

An essential component of the FlockBot concept is communication. As an example, Fig. 3 shows an F3
AgAnt, a small walking robot with Bluetooth functionality allowing communication among robots as well as Internet access through a wireless connection. The Internet can be used by the Flock for operation planning. For instance, if the robots decide to perform a weeding operation, they may consult a weather map to evaluate if upcoming weather patterns will interfere.

Wireless communication usually takes place using a fixed protocol, but in the case of the evolving FlockBot system, it is more logical to have the robots develop their own protocols and dialects, which may be more efficient than designed ones.

FARM OF THE FUTURE?

The question whether farms of the future may be partially automated, let alone whether biological

Fig. 3 AgAnts illustrate the concept of FlockBots to be used as scouts in farming.

ecosystems will be cared for by mechanical ecosystems, is speculative. The ‘‘lights-off’’ factory that was envisioned during the Industrial Automation era never came to fruition since there are many situations where the use of human labor is still the most effective and economical way to perform tasks. However, the trend of changing farming operations to optimize income, minimize environmental impact, and produce sustainable farming operations will continue and Automation Technology can play a major role in this process. Whether the robotic technology will be adopted widely in farming depends on many factors such as cost of machinery, effectiveness, added benefit to farmers, ease of operation, reliability, interchangeability, standardization, safety, and legislation. It is most likely that machinery manufacturers will focus on integrating Automation Technology in their machines, and focus on systems optimization. Researchers in academics will in contrast carry the application of robots for scouting and smaller operations, including the FlockBot concept.

Future funding for Agricultural Robotics may come from an unanticipated source: The United States government has committed itself to returning to the Moon as a stepping-stone to creating human settlements on Mars. The only way that human life can be sustained in such an environment is to have agriculture in place, even before humans arrive. Therefore, there is an urgent need to develop a completely automated farming system that can be launched and put into operation without human intervention. This effort may form the ultimate challenge in agricultural automation from which technologies can spin off to benefit humanity on *terra mater*.

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