Autonomous Robots for Agricultural Tasks and Farm Assignment and Future Trends in Agro Robots

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***Abstract*-- This article provides an overview of worldwide development and current status of precision-agriculture technologies based on literatures generated mainly during the past years. The topics include natural-resource variability; variability management; management zone; impact of precision-agriculture technologies on farm profitability and environment; engineering innovations; information management; worldwide application and adoption trend of precision-agriculture technologies; and potentials of the technologies in modernizing the agriculture in the world.**

A brief review of research in agricultural vehicle guidance technologies is presented. Application of new popular robotic technologies will augment the realization of agricultural vehicle in future.

Agricultural Robotics is the logical proliferation of automation technology into bio systems such as agriculture, forestry, green house, horticulture etc. Presently a number of researches are being done to increase their applications. Some of the scientist contributions are mobile robot, flying robot, forester robot, Demeter which are exclusively used for agriculture. A brief discussion is being done about the types of robots which increase the accuracy and precision of the agriculture.

***Index Term*-- Robotics, technologies, Agriculture, engineering innovation, worldwide trends**

I. INTRODUCTION

In the field of agriculture, various operations for handling heavy material are performed. For example, in vegetable cropping, workers should handle heavy vegetables in the harvest season. Additionally, in organic farming, which is fast gaining popularity, workers should handle heavy compost bags in the fertilizing season. These operations are dull, repetitive, or require strength and skill for the workers.

In the 1980's many agricultural robots were started for research and development. Kawamura and co-workers developed the fruit harvesting in orchard. Grand and co-workers developed the apple harvesting robot. They have been followed by many other works. Many of the works focus on structure systems design (e.g., mechanical systems design) of the robot and report realization of the basic actions in actual open fields. However, many of the robots are not in the stages of diffusion but still in the stages of research and development. It is important to find rooms to achieve higher performance and lower cost of the robots.

Over history, agriculture has evolved from a manual occupation to a highly industrialized business, utilizing I wide variety of tools and machines. Researchers are now looking towards the realization of autonomous agricultural vehicles. The first stage of development, automatic vehicle guidance, has been studied for many years, with a number of innovations explored as early as the 1920s. The concept of fully autonomous agricultural vehicles is far from new; examples of early driverless tractor prototypes using leader cable guidance systems date back to the 1950s and 1960s. In the 1980s, the potential for combining computers with image sensors provided opportunities for machine vision based guidance systems. During the mid-1980s, researchers at Michigan State University and Texas A&M University were exploring machine vision guidance. Also during that decade, a program for robotic harvesting of oranges was successfully performed at the University of Florida. In 1997, agricultural automation had become a major issue along with the advocacy of precision agriculture. The potential benefits of automated agricultural vehicles include increased productivity, increased application accuracy, and enhanced operation safety. Additionally, the rapid advancements in electronics, computers, and computing technologies have inspired renewed interest in the development of vehicle guidance systems. Various guidance technologies, including mechanical guidance, optical guidance, radio navigation, and ultrasonic guidance, have been investigated.

Agriculture involves the systematic production of food, feed, fiber, and other goods. In addition to producing food for humans and animals, agriculture also produces cut flowers, timber, fertilizers, animal hides, leather, and industrial chemicals.

Agriculture comes from two Latin words:

- **ager** which means a field.
- **culturia** which means cultivation, the tillage of the soil. A lot of the world's workers (42%) are involved in agriculture in some way.

A robot is a machine that can be programmed and reprogrammed to do certain tasks and usually consists of a manipulator such as a claw, hand, or tool attached to a mobile body or a stationary platform.

Autonomous robots work completely under the control of a computer program. They often use sensors to gather data about their surroundings in order to navigate.

Tele-controlled robots work under the control of humans and/or computer programs.

Remote-controlled robots are controlled by humans with a controller such as a joystick or other hand-held device. The word 'robot' came from the Czech word 'robota', which means forced labor, or work. It was first used in the play R.U.R., Rossum's Universal Robots, written in 1921 by a Czech playwright named Karel Capeck. Isaac Asimov was the first person to use the term 'robotics in "Runaround," a short story published in 1942.

The current state of agricultural robotics

Today agricultural robots can be classified into several groups: harvesting or picking, planting, weeding, pest control, or maintenance. Scientists have the goal of creating 'robot farms' where all of the work will be done by machines. The main obstacle to this kind of robot farm is that farms are a part of nature and nature is not uniform. It is not like the robots that work in factories building cars. Factories are built around the job at hand, whereas, farms are not. Robots on farms have to operate in harmony with nature. Robots in factories don't have to deal with uneven terrain or changing conditions. Scientists are working on overcoming these problems.

Uses for Agricultural Robots

The number or agricultural robots, agrobots, is increasing each year. The jobs they can do are also increasing with new technology in hardware and software. Robots are milking cows, shearing sheep, picking fruit, weeding, spraying, and cultivating, they use GPS and sensors for navigation. The new robots are getting smaller and smarter.

Fungicides: Robots can be used to combat plant diseases that cause a lot of damage to crops. Fungi are the most common causes of crop loss in the entire world. To kill a fungal disease you need a fungicide, a kind of pesticide. Fungal diseases interfere with the growth and development of a crop. They attack the leaves which are needed for photosynthesis and decrease the productivity of the crop and cause blemishes on the crops which make them worth less on the market. After the crops are harvested fungi can grow and spoil the fruits, vegetables, or seeds. Robots can treat plants that have been infected or destroy them if necessary. They could treat just the plants that need it, instead of covering the entire crop with fungicide.

Herbicide: Another use for robots is in weeding. Robots can pull weeds from around the plants or just cut the tops off. All of the material can be collected by a robot and brought to a composting site limiting the need for herbicides, chemicals that destroy or inhibit the growth of plants. Herbicides are intended to kill weeds but many times also damage the crops.

Pesticide: Pesticides are used to control insects that can be harmful to crops. They are effective but have many side effects for the environment. Insects also adapt to the toxin in a pesticide and the survivors breed and pass the resistant trait on to the next generation making stronger insects that are harder to kill. Robots could solve this by removing pests from the crops without using chemicals. They might suck them up with a vacuum. A bellow base air system makes a vacuum that doesn't require the large amount of power of regular vacuum systems. There are ways to kill the insects without chemicals. The robot could submerge them in a container with water or into one closed up to produce extreme heat in the sun. Microbial fuel cells could be used to reduce the insects to electrical power with bacteria. Pesticides kill everything. Robots could be programmed to rid particular pests and not harm anything else.

Mushroom Picking Robot

Mushrooms are a very difficult crop to grow. There is a lot of labor involved. Many mushroom farms are becoming extremely high tech. They use computerized systems and monitor all production phases. The robot mushroom picker is an ongoing research project at the University of Warwick in the UK. See Figure 1. Their goal is to develop farm machinery that can reduce the labor costs of producing farm crops, in this case, mushrooms. The robot picks the mushrooms using a small suction cap on the end of its robotic arm. The robot has a charged coupled camera on board to tell which mushrooms to pick in a tray or bed, since mushrooms mature at different times during a six to ten week period. It uses the camera to tell the exact size of the mushroom and only pick the correct ones. Mushrooms grow in dark, damp places that are often inhospitable to humans. This makes the robot a perfect choice to work on a mushroom farm. The robots can only work half as fast as a human, but it doesn't mind working in the dark, or for 24 hours a day.

There are many advantages to robotics as well as removing the high cost of labour. One is that it will do a job very repetitively and very much the same every time, so you can get some huge quality improvements in a number of areas. One of the key advantages in agriculture is that robots can work 24 hours a day – often when there's no light, which can be a big factor with certain crops." Dr. Ken Young; Dr. Ken Young works in the manufacturing engineering section of the University of Warwick, the Warwick Manufacturing Group.

Slugs are a nightmare for farmers. They eat leaves of growing crops like lettuce and put big holes in fruit like tomatoes. Ian Kelly and the University of West of England, Bristol, have invented a robot that will stop all of that. It is called Slugbot. It was TIME 2001 invention of the year. See Figure 3.

The robot can track, capture and dispose of slugs. About the size of a lawn mower. Slugbot features a 1.5m long robotic arm, mounted on a turntable, which shines a red light that lets the robot detect the slugs. It is hard to see slugs in the daytime, but the red light makes them visible. Grass and vegetation appear dark under a red light, but the slugs show up as brightly lit. The robot has a CMOS image sensor that can detect the bright slugs. The arm then picks up the slugs and deposits them into a hopper where bacteria decompose the slugs. The robot uses a GPS system to find the station to deposit the slugs. Ultrasonic sonar and touch sensors are used by Slugbot to navigate and avoid obstacles. The energy from the decomposing slugs is then used to refuel Slugbot. This is a practical use for the microbial fuel cell which is under development. See Figure 4. Slugbot is currently in the prototype stage. One goal of the project is to make a robot that is self-sufficient like an animal in both information and energy. Slugs were picked because they are a real problem for agriculture, they are soft without a shell or skeleton, they are large in comparison to many pests, and most of all, they are slow enough for Slugbot to catch.

Slugbot was just the first phase of the research being done. Now the university has moved on to the creation of Ecobot II. See Figure 5. The objective here is to create energetically autonomous robots. These robots would get all of their on board power from microbial fuel cells and carry no batteries. Ecobot I was a sugar eating robot and Ecobot II eats dead flies or rotten fruit. The University of Illinois engineering department has developed several agricultural robots. One of them is Ag Ant. See Figure 6. The Ag Ant robots are small and are very inexpensive. They are designed to replace larger more expensive farm machinery. The Ag Ants are only 1 foot long and with most things (besides nanos) smaller is less expensive. They move around using mechanical legs. Ag-Ants are autonomous and can direct themselves down rows of corn using sensors. The sensor tells the robot when they reach the end of the row and need to turn around and move into the next row. Some common tasks that Ag Ant robots could do would include finding weeds, insects, or disease, sampling the soil for nutrients, and application of pesticides or herbicides.

Tony Grift is a University of Illinois agricultural engineer. He is working on this project. See Figure 7. He says that the way they are solving farming problems is a “smaller and smarter” approach. The Ag Ant is about one foot long and has mechanical legs that it uses to walk through fields.

The university wants to create a robotics ecosystem out of the robots. They pattern this after groups of bees. One bee goes out and finds a source of nectar and then comes back and tells the other bees where to go. The Ag Ants can do the same. One robot might find weeds and then transmit the location to other Ag Ants that would come to help attack the weeds. It’s like creating an army of robots that can go out and survey a field, collect information, and send back data. Then a group of robots complete the necessary task. Grift said, “Instead of applying all of this spray that might drift everywhere, a robot could actually ‘spit’ chemical at the plant with great precision, using a very small amount of chemical.”

II. FEATURE OF AGRICULTURE VEHICLE DEVICES

The agricultural environment offers a very different navigation system for agricultural vehicles is now regarded as an important advance in precision agriculture and a promising alternative to the dwindling farming labor force, in addition to satisfying the quest for higher production efficiency and safer operation/ set of circumstances from that encountered by a laboratory mobile robot. In one respect, operation is simplified by the absence of clutter typically present in the indoor environment; however, a number of additional complications are raised. For example, the operating areas are large; ground surfaces may be uneven; depending on the operation, and wheel slippage may be far from negligible. Cultivation may interfere with underground cables, colors may change with plant growth, and soil quality may vary. Environmental conditions (rain, fog, dust, etc.) may affect sensor function; moreover, a low-cost system is required. These disadvantages make it more difficult to realize agricultural automation. Companies are unwilling to invest in commercialization because it is not seen as a worthwhile money-making venture, and farmers are not financially able to participate. Other major reasons include the need to improve the technology and decrease the cost [24]. Compared with these complicating factors, agricultural farm fields have several advantages for developing autonomous guidance systems. For example, the working areas generally do not change; landmarks can be easily set up around the corners of a field and be taken as a stationary environment. The crops are always the same plants at the same places and can be easily distinguished. Therefore, even though there are more disadvantages than advantages for realizing agricultural vehicle autonomous guidance, there are enough research achievements to promote its development.

Robots find applications in the so-called “4D tasks,” tasks that are dangerous, dull, dirty, or dumb. An example of a task that may be too dangerous for humans to perform is the disposal of unexploded ordinance. Many industrial automation tasks like assembly tasks are repetitive and tasks like painting are dirty. Robots can sometimes easily perform these tasks. Human workers often don’t like tasks that don’t require intelligence or exercise any decision-making skills. Many of these dumb tasks like vacuum cleaning or loading packages onto pallets can be executed perfectly by robots with a precision and reliability that humans may lack. As our population ages and the number of wage earners becomes a smaller fraction of our population, it is clear that robots have to fill the void in society. Industrial, and to a greater extent, service robots have the potential to fill this void in the coming years. See Figure 5.2 for the ratio of robot to human workers in the manufacturing industry.

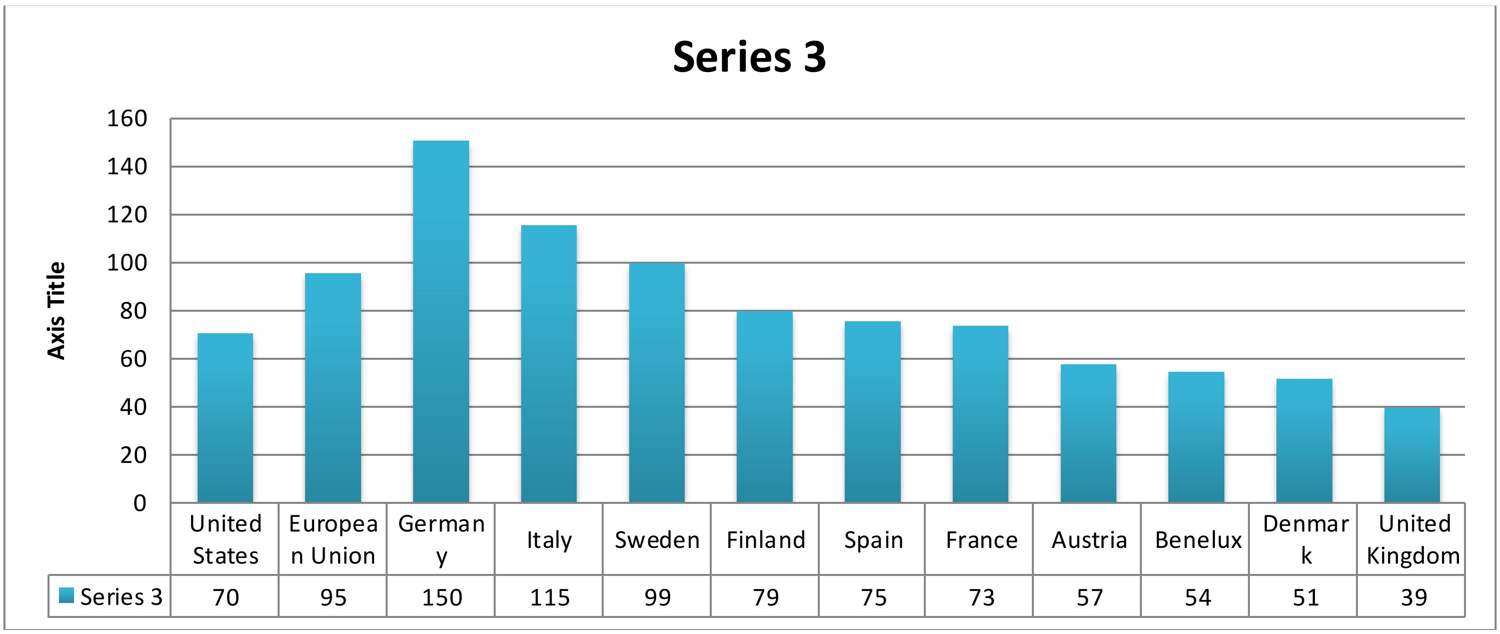

Fig. Number of industrial robots for every 10,000 human workers.

A second reason for the deployment of industrial robots is the trend toward small product volumes and an increase in product variety. As the volume of products being produced decreases, hard automation becomes a more expensive proposition, and robotics is the only alternative to manual production.

III. MARKET ANALYSIS AND TRENDS

Industrial robots account for a $4 billion market with a growth rate of around 4%. Most of the current applications are either in material handling or in welding. Spot welding and painting operations in the automotive industry are almost exclusively performed by robots. See Figure 5.3. Industrial robots are improving in quality and the ratio of price to performance is

falling. As Figure 5.4 shows, while prices have fallen over 40% over the last 15 years, the accuracy and payload rating of robots have almost doubled in the same period.

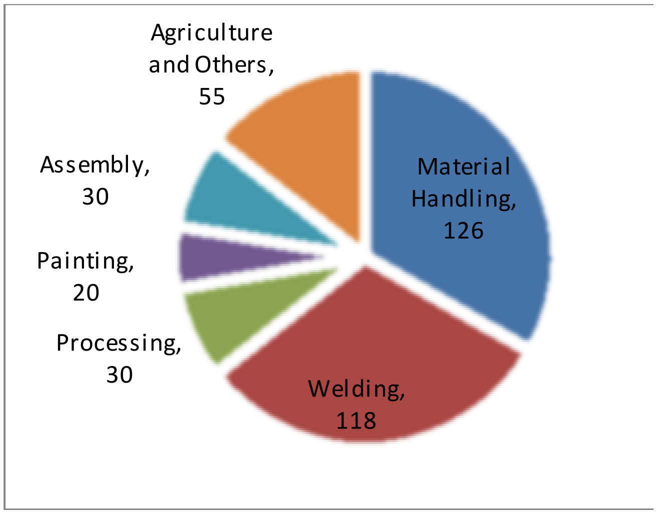

Fig. Industrial Robot Sales (2004).

According to the United Nations Economic Commission for Europe (UNECE), there are over 20,000 professional service robots in use today valued at an estimated $2.4 billion (see Table 5.1). If personal entertainment robots and domestic robots like vacuum cleaners are included, this number is well over $3.5 billion. The UNECE estimates that the annual sales of service robots (both professional and personal) in 2005 will be around $5B.

TABLE
SERVICE ROBOTS INDUSTRY: NUMBER OF UNITS CURRENTLY IN OPERATION AND ESTIMATED VALUE.

Category	**No. Units**	**Value ($ millions)**
Field (agriculture, forestry, mining)	885	117
Cleaning/maintenance	3370	68
Inspection	185	21
Construction, demolition	3030	195
Medical robotics	2440	352
Security, defense	1010	76
Underwater	4785	1467
Laboratory	3060	37
Others	2295	110
Total	21060	2443

CONCLUSIONS

This paper provides a brief review of the research on technologies in agricultural vehicles over the past 20 years. Although the research developments are abundant, there are some shortcomings (e.g., low robustness of versatility and dependability of technologies) that are delaying the improvements required for commercialization of the guidance systems. It can be concluded that either GPS and machine vision technologies will be 'fused' together or one of them will be 'fused' with another technology (e.g., laser radar) as the trend development for agricultural vehicle guidance systems. The application of new popular robotic technologies for agricultural guidance systems will augment the realization of agricultural vehicle automation in the future.

In agriculture, the opportunities for robot-enhanced productivity are immense – and the robots are appearing on farms in various guises and in increasing numbers. The other problems associated with autonomous farm equipment can probably be overcome with technology. This equipment may be in our future, but there are important reasons for thinking that it may not be just replacing the human driver with a computer. It may mean a rethinking of how crop production is done. Crop production may be done better and cheaper with a swarm of small machines than with a few large ones.

One of the advantages of the smaller machines is that they may be more acceptable to the non-farm community. The jobs in agriculture are a drag, dangerous, require intelligence and quick, though highly repetitive decisions hence robots can be rightly substituted with human operator. The higher quality products can be sensed by machines (colour.firmness, weight, density, ripeness, size, shape) accurately. Robots can improve the quality of our lives but there are downsides.

ACKNOWLEDGEMENTS

In particular, we acknowledge the efforts of mechatronic laboratory of Istanbul Aydin University and Iran international inventors' robotic team, Islamic azad university of Ahar branch, Tabriz branch and urmia branch. This research is prepared by Iran Young Research Club (BPJ) under contract Islamic Azad University, Makou Branch.

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