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Utilization of Computer Technologies in Agricultural Economics

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ABSTRACT: Computer vision is a field that involves making a machine "see". This technology uses a camera and computer instead of the human eye to identify, track and measure targets for further image processing. With the development of computer vision, such technology has been widely used in the field of agricultural automation and plays a key role in its development. This review systematically summarizes and analyzes the technologies and challenges over the past three years and explores future opportunities and prospects to form the latest reference for researchers. Through the analyses, it is found that the existing technology can help the development of agricultural automation for small field farming to achieve the advantages of low cost, high efficiency and high precision. However, there are still major challenges. First, the technology will continue to expand into new application areas in the future, and there will be more technological issues that need to be overcome. It is essential to build large-scale data sets. Second, with the rapid development of agricultural automation, the demand for professionals will continue to grow. Finally, the robust performance of related technologies in various complex environments will also face challenges. Through analysis and discussion, we believe that in the future, computer vision technology will be combined with intelligent technology such as deep learning technology, be applied to every aspect of agricultural production management based on large-scale datasets, be more widely used to solve the current agricultural problems, and better improve the economic, general and robust performance of agricultural automation systems, thus promoting the development of agricultural automation equipment and systems in a more intelligent direction.

KEYWORDS: computer , agriculture, economics, technology, automation, vision, development, efficiency

I.INTRODUCTION

Computers and Electronics in Agriculture provides international coverage of advances in the development and application of computer hardware, software, electronic instrumentation, and control systems for solving problems in agricultural economics, including agronomy, horticulture (in both its food and amenity aspects), forestry, aquaculture, and animal/livestock farming. Its new companion journal, Smart Agricultural Technology provides continuity for smart application being applied in production agriculture. Wireless technologies have numerous applications in agriculture. One major usage is the simplification of closed-circuit television camera systems; the use of wireless communications eliminates the need for the installation of coaxial cables.[6] In agriculture, the use of the Global Positioning System provides benefits in geo-fencing, map-making and surveying. GPS receivers dropped in price over the years, making it more popular for civilian use. With the use of GPS, civilians can produce simple yet highly accurate digitized map without the help of a professional cartographer.

In Kenya, for example, the solution to prevent an elephant bull from wandering into farms and destroying precious crops was to tag the elephant with a device that sends a text message when it crosses a geo-fence. Using the technology of SMS and GPS, the elephant can roam freely and the authorities are alerted whenever it is near the farm.[7] Geographic information systems, or GiS, are extensively used in agriculture, especially in precision farming. Land is mapped digitally, and pertinent geodetic data such as topography and contours are combined with other statistical data for easier analysis of the soil. GIS is used in decision making such as what to plant and where to plant using historical data and sampling.

Automatic milking systems are computer controlled stand alone systems that milk the dairy cattle without human labor. The complete automation of the milking process is controlled by an agricultural robot, a complex herd management software, and specialized computers. Automatic milking eliminates the farmer from the actual milking process, allowing for more time for supervision of the farm and the herd. Farmers can also improve herd management by using the data gathered by the computer. By analyzing the effect of various animal feeds on milk yield, farmers may adjust accordingly to obtain optimal milk yields. Since the data is available down to individual level, each cow may be tracked and examined, and the farmer may be alerted when there are unusual changes that could mean sickness or injuries.[8] The use of mobile technologies as a tool of intervention in agriculture is becoming increasingly popular. Smartphone penetration enhances the multi-dimensional positive impact on sustainable poverty reduction and identify accessibility as the main challenge in harnessing the full potential (Silarszky et al., 2008) in agricultural space. The reach of smartphone even in rural areas extended the ICT services beyond simple voice or text messages. Several smartphone apps are available for agriculture, horticulture, animal husbandry and farm machinery. RFID tags for animals represent one of the oldest uses of RFID. Originally meant for large ranches and rough terrain, since the outbreak of mad-cow disease, RFID has become crucial in animal identification management. An implantable RFID tag or transponder can also be used for animal identification. The transponders are better known as PIT (Passive Integrated Transponder) tags, passive RFID, or "chips" on animals.[9] The Canadian Cattle Identification Agency began using RFID tags as a replacement for barcode tags. Currently CCIA tags are used in Wisconsin and by United States farmers on a voluntary basis. The USDA is currently developing its own program.

RFID tags are required for all cattle sold in Australia and in some states, sheep and goats as well. [10]

The Veterinary Department of Malaysia's Ministry of Agriculture introduced a livestock-tracking program in 2009 to track the estimated 80,000 cattle all across the country. Each cattle is tagged with the use of RFID technology for easier identification, providing access to relevant data such as: bearer's location, name of breeder, origin of livestock, sex, and dates of movement. This program is the first of its kind in Asia, and is expected to increase the competitiveness of Malaysian livestock industry in international markets by satisfying the regulatory requirements of importing countries like United States, Europe and Middle East. Tracking by RFID will also help producers meet the dietary standards by the halal market. The program will also provide improvements in controlling disease outbreaks in livestock.[11][12]

RFID tags have also been proposed as a means of monitoring animal health. One study involved using RFID to track drinking behavior in pigs as an indicator of overall health.[13]

Online purchasing order of agri-inputs and agri-equipments is a subset of E-commerce and economics in agriculture. Various image sensor technologies provide the data, in the most common case from a visible light digital camera.[14] Fluorescence imaging is also used in plant health monitoring – demonstrated by Ning et al 1995 in very early diagnosis of herbicide injury and attack by fungal plant pathogens.[14]

The FAO-ITU E-agriculture Strategy Guide[17] provides a framework to holistically address the ICT opportunities and challenges for the agricultural sector in a more efficient manner while generating new revenue streams and improve the livelihoods of the rural community as well as ensure the goals of the national agriculture master plan are achieved. The e-agriculture strategy, and its alignment with other government plans, was intended to prevent e-agriculture projects and services from being implemented in isolation. It was developed by the Food and Agriculture Organization (FAO)[18] and the International Telecommunication Union (ITU)[19] with support from partners including the Technical Centre for Agricultural and Rural Cooperation (CTA)[20] as a framework for countries in developing their national e-agriculture strategy/masterplan.

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The E-agriculture in Action series of publications, by FAO-ITU, that provides guidance on emerging technologies and how it could be used to address some of the challenges in agriculture through documenting case studies.

- E-agriculture in Action: Big Data for Agriculture [21]
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E-agriculture is one of the action lines identified in the declaration and plan of action of the World Summit on the Information Society (WSIS). The "Tunis Agenda for the Information Society," published on 18 November 2005 and emphasizes the leading facilitating roles that UN agencies need to play in the implementation of the Geneva Plan of Action. The Food and Agriculture Organization of the United Nations (FAO) has been assigned the responsibility of organizing activities related to the action line under C.7 ICT Applications on E-Agriculture.

Many ICT interventions have been developed and tested around the world, with varied degrees of success, to help agriculturists improve their livelihoods through increased agricultural productivity and incomes, and reduction in risks. Some useful resources for learning about e-agriculture in practice are the World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011),[25] ICT uses for inclusive value chains (2013),[26] ICT uses for inclusive value chains (2013)[27] and Success stories on information and communication technologies for agriculture and rural development[28] have documented many cases of use of ICT in agriculture.

The FAO-ITU E-agriculture Strategy Guide[29] was developed by the Food and Agriculture Organization and the International Telecommunication Union (ITU) with support from partners including the Technical Centre for Agricultural and Rural Cooperation (CTA) as a framework for countries in developing their national e-agriculture strategy/masterplan.

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II.DISCUSSION

In August 2003, the Overseas Development Institute (ODI), the UK Department for International Development (DFID) and the United Nations Food and Agricultural Organization (FAO) joined together in a collaborative research project to look at bringing together livelihoods thinking with concepts from information and communication for development, in order to improve understanding of the role and importance of information and communication in support of rural livelihoods.[31]

The policy recommendations included:

- Building on existing systems, while encouraging integration of different technologies and information sharing

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- Determining who should pay, through consensus and based on a thorough analysis of the costs
- Ensuring equitable access to marginalised groups and those in the agricultural sector
- Promoting localised content, with decentralised and locally owned processes
- Building capacity, through provision of training packages and maintaining a choice of information sources
- Using realistic technologies, that are suitable within the existing infrastructure
- Building knowledge partnerships to ensure that knowledge gaps are filled and a two-way flow of information allows knowledge to originate from all levels of the network and community.

The importance of ICT is also recognized in the 8th Millennium Development Goal, with the target to "...make available the benefits of new technologies, especially information and communications technologies (ICTs)" to the fight against poverty.

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FAO hosted the first e-agriculture workshop in June 2006, bringing together representatives of leading development organizations involved in agriculture. The meeting served to initiate development of an effective process to engage as wide a range of stakeholders involved in e-agriculture, and resulted in the formation of the e-Agriculture Community, a community of practice. The e-Agriculture Community's Founding Partners[34] include: Consultative Group on International Agricultural Research (CGIAR); Technical Centre for Agriculture and Rural Development (CTA); FAO; Global Alliance for Information and Communication Technologies and Development (GAID); Global Forum on Agricultural Research (GFAR); Global Knowledge Partnership (GKP); Gesellschaft fur Technische Zusammenarbeit (now called Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ); International Association of Agricultural Information Specialists (IAALD); Inter-American Institute for Cooperation on Agriculture (IICA); International Fund for Agricultural Development (IFAD); International Centre for Communication for Development (IICD); United States National Agricultural Library (NAL); United Nations Department of Economic and Social Affairs (UNDESA); the World Bank.

An agricultural drone is an unmanned aerial vehicle used in agriculture operations, mostly in yield optimization and in monitoring crop growth and crop production. Agricultural drones provide information on crop growth stages, crop health, and soil variations. Multispectral sensors are used on agricultural drones to image electromagnetic radiation beyond the visible spectrum, including near-infrared and short-wave infrared. As drones entered use in agriculture, the Federal Aviation Administration (FAA) encouraged farmers to use this new technology to monitor their fields. However, with the unexpected boom of agricultural drones, the FAA quickly retracted such encouragement, pending new rules and regulations. With incidents such as drones crashing into crop dusters, the FAA and the AFBF (American Farm Bureau Federation) began discussions to agree on regulations that would allow the beneficial use of such drones in a safe and efficient manner.

In 2016, the FAA published rules for commercial drone operations.[1] These rules require that commercial drone operators pass a knowledge exam, register their aircraft, and fly in accordance with published restrictions.[2] While satisfied overall with the rules, the American Farm Bureau Federation would like small adjustments to some of the restrictions that have been implemented.

Many countries, such as Malaysia, Singapore and Australia, have implemented laws regarding the use of drones. Such laws are still nonexistent in many countries around the world, and 15 countries have outlawed all drone operations.[3] The EU

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plans to implement a common set of drone regulations for all of its members.[4] The use of agricultural drones has ethical and social implications. One benefit is that they are able to monitor and control the use of pesticides properly. This allows minimizing the environmental impact of pesticides. However, drones do not require permission to fly over another person's property at altitudes of under 400 feet (120 m). They may have microphones and cameras attached, and the resulting concern for potential privacy violation has caused some opposition towards drones. One other improvement with using drones is the precision that they operate with.

Other companies might start flying their drones in unregulated areas to survey their competition and the condition of their crops and agricultural yield[5] There is a large capacity for growth in the area of agricultural drones. With technology constantly improving, imaging of the crops will need to improve as well. With the data that drones record from the crops the farmers are able to analyze their crops and make educated decisions on how to proceed given the accurate crop information. Software programs for analyzing and correcting crop production have the potential to grow in this market. Farmers will fly a drone over their crops, accurately identify an issue in a specific area, and take the necessary actions to correct the problem.[6] This gives the farmer time to focus on the overall task of production instead of spending time surveying their crops. Additional uses include keeping track of livestock, surveying fences, and monitoring for plant pathogens.[7]

Both the purchase and maintenance costs of modern drones make them too expensive for small farms in developing nations. Pilot programs in Tanzania are focusing on minimizing those costs, producing agricultural drones simple and rugged enough to be repaired locally.[8]

A research team from Washington State University has developed an automated drone system that deters pests like crows or European starlings from feeding on grapes and other crops. The birds could be scared off by the drone's noise, but researchers also could include distress calls and predatory bird noises.[9]

III.RESULTS

An agricultural robot is a robot deployed for agricultural purposes. The main area of application of robots in agriculture today is at the harvesting stage. Emerging applications of robots or drones in agriculture include weed control,[1][2][3] cloud seeding,[4] planting seeds, harvesting, environmental monitoring and soil analysis.[5][6] According to Verified Market Research, the agricultural robots market is expected to reach $11.58 billion by future. Fruit picking robots, driverless tractor / sprayers, and sheep shearing robots are designed to replace human labor. In most cases, a lot of factors have to be considered (e.g., the size and color of the fruit to be picked) before the commencement of a task. Robots can be used for other horticultural tasks such as pruning, weeding, spraying and monitoring. Robots can also be used in livestock applications (livestock robotics) such as automatic milking, washing and castrating. Robots like these have many benefits for the agricultural industry, including a higher quality of fresh produce, lower production costs, and a decreased need for manual labor.[8] They can also be used to automate manual tasks, such as weed or bracken spraying, where the use of tractors and other human-operated vehicles is too dangerous for the operators. The mechanical design consists of an end effector, manipulator, and gripper. Several factors must be considered in the design of the manipulator, including the task, economic efficiency, and required motions. The end effector influences the market value of the fruit and the gripper's design is based on the crop that is being harvested. An end effector in an agricultural robot is the device found at the end of the robotic arm, used for various agricultural operations. Several different kinds of end effectors have been developed. In an agricultural operation involving grapes in Japan, end effectors are used for harvesting, berry-thinning, spraying, and bagging. Each was designed according to the nature of the task and the shape and size of the target fruit. For instance, the end effectors used for harvesting were designed to grasp, cut, and push the bunches of grapes.

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Berry thinning is another operation performed on the grapes, and is used to enhance the market value of the grapes, increase the grapes' size, and facilitate the bunching process. For berry thinning, an end effector consists of an upper, middle, and lower part. The upper part has two plates and a rubber that can open and close. The two plates compress the grapes to cut off the rachis branches and extract the bunch of grapes. The middle part contains a plate of needles, a compression spring, and another plate which has holes spread across its surface. When the two plates compress, the needles punch holes through the grapes. Next, the lower part has a cutting device which can cut the bunch to standardize its length.

For spraying, the end effector consists of a spray nozzle that is attached to a manipulator. In practice, producers want to ensure that the chemical liquid is evenly distributed across the bunch. Thus, the design allows for an even distribution of the chemical by making the nozzle to move at a constant speed while keeping distance from the target.

The final step in grape production is the bagging process. The bagging end effector is designed with a bag feeder and two mechanical fingers. In the bagging process, the bag feeder is composed of slits which continuously supply bags to the fingers in an up and down motion. While the bag is being fed to the fingers, two leaf springs that are located on the upper end of the bag hold the bag open. The bags are produced to contain the grapes in bunches. Once the bagging process is complete, the fingers open and release the bag. This shuts the leaf springs, which seals the bag and prevents it from opening again.[9]

The gripper is a grasping device that is used for harvesting the target crop. Design of the gripper is based on simplicity, low cost, and effectiveness. Thus, the design usually consists of two mechanical fingers that are able to move in synchrony when performing their task. Specifics of the design depend on the task that is being performed. For example, in a procedure that required plants to be cut for harvesting, the gripper was equipped with a sharp blade. The manipulator allows the gripper and end effector to navigate through their environment. The manipulator consists of four-bar parallel links that maintain the gripper's position and height. The manipulator also can utilize one, two, or three pneumatic actuators. Pneumatic actuators are motors which produce linear and rotary motion by converting compressed air into energy. The pneumatic actuator is the most effective actuator for agricultural robots because of its high power-weight ratio. The most cost efficient design for the manipulator is the single actuator configuration, yet this is the least flexible option.[10] The first development of robotics in agriculture can be dated as early as the 1920s, with research to incorporate automatic vehicle guidance into agriculture beginning to take shape.[11] This research led to the advancements between the 1950s and 60s of autonomous agricultural vehicles.[11] The concept was not perfect however, with the vehicles still needing a cable system to guide their path.[11] Robots in agriculture continued to develop as technologies in other sectors began to develop as well. It was not until the 1980s, following the development of the computer, that machine vision guidance became possible.[11]

Other developments over the years included the harvesting of oranges using a robot both in France and the US.[11][12]

While robots have been incorporated in indoor industrial settings for decades, outdoor robots for the use of agriculture are considered more complex and difficult to develop. This is due to concerns over safety, but also over the complexity of picking crops subject to different environmental factors and unpredictability.[13] There are concerns over the amount of labor the agricultural sector needs. With an aging population, Japan is unable to meet the demands of the agricultural labor market.[13] Similarly, the United States currently depends on a large number of immigrant workers, but between the decrease in seasonal farmworkers and increased efforts to stop immigration by the government, they too are unable to meet the demand.[13][14] Businesses are often forced to let crops rot due to an inability to pick them all by the end of the season.[13] Additionally, there are concerns over the growing population that will need to be fed over the next years.[13][15] Because of this, there is a large desire to improve agricultural machinery to make it more cost efficient and viable for continued use.[13] Much of the current research continues to work towards autonomous agricultural vehicles. This research is based on the advancements made in driver-assist systems and self-driving cars.[14]

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While robots have already been incorporated in many areas of agricultural farm work, they are still largely missing in the harvest of various crops. This has started to change as companies begin to develop robots that complete more specific tasks on the farm. The biggest concern over robots harvesting crops comes from harvesting soft crops such as strawberries which can easily be damaged or missed entirely.[13][14] Despite these concerns, progress in this area is being made. According to Gary Wishnatzki, the co-founder of Harvest Croo Robotics, one of their strawberry pickers currently being tested in Florida can "pick a 25-acre field in just three days and replace a crew of about 30 farm workers".[14] Similar progress is being made in harvesting apples, grapes, and other crops.[12][14][15] In the case of apple harvesting robots, current developments have been too slow to be commercially viable. Modern robots are able to harvest apples at a rate of one every five to ten seconds while the average human harvests at a rate of one per second.[16]

Another goal being set by agricultural companies involves the collection of data.[15] There are rising concerns over the growing population and the decreasing labor available to feed them.[13][15] Data collection is being developed as a way to increase productivity on farms.[15] AgriData is currently developing new technology to do just this and help farmers better determine the best time to harvest their crops by scanning fruit trees.[15]

IV.CONCLUSIONS

The FAO-ITU E-agriculture Strategy Guide[17] provides a framework to holistically address the ICT opportunities and challenges for the agricultural sector in a more efficient manner while generating new revenue streams and improve the livelihoods of the rural community as well as ensure the goals of the national agriculture master plan are achieved. The e-agriculture strategy, and its alignment with other government plans, was intended to prevent e-agriculture projects and services from being implemented in isolation. It was developed by the Food and Agriculture Organization (FAO)[18] and the International Telecommunication Union (ITU)[19] with support from partners including the Technical Centre for Agricultural and Rural Cooperation (CTA)[20] as a framework for countries in developing their national e-agriculture strategy/masterplan.

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