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A Brief Overview and Systematic Approch for Using Agricultural Robot in Developing Countries

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To ensure the food security it is imperative for all countries to consider on agriculture sector in high priority as numbers of people are increasing in every year but the agricultural field remains same. As a result robotics and automation systems are extensively applied to agricultural sector. Several motivations are behind the investment to incorporate robotics in agricultural sectors like decreasing labor forces, saving time and cope up with the high product demand. Apart from those, increasing food quality, production security and finally reducing end product cost are also vital parameters for automation revolution in agriculture. Moreover, farmers are getting exemption from extensive physical effort. In fact, those phenomenons are especially considerable and important for developing countries such Bangladesh. This research represents a review on some common robotic technology that is used in agriculture sector of Bangladesh and also other developing countries. In addition to that, this research also discuss about technical point of view regarding advantages and disadvantages of those agro-based robots and way to improve that technology considering particular country farming situation. A review on recent agro-based robotic technology used in developed countries is also presented here. Finally, future scope of utilizing those advance technology in similar areas in Bangladesh has been discussed.

Keywords: Robotics; Agriculture; Developing Countries; Sensors

1. Introduction

Automation technology has integrated every domain of human activities such as industrialization, communication, corporate offices, regular household activities, education, transportation, construction, satellite, warfare and so. Nowadays robotics and automation systems extensively applied agricultural sector. Several motivations are behind the investment to incorporate robotics in agricultural sectors like decreasing labor forces, saving time and cope up with the high product demand. Apart from those, increasing food quality, production security and finally reducing end product cost are also vital parameters for automation revolution in agriculture. Moreover, farmers are getting exemption from extensive physical effort. In fact, those phenomenons are especially considerable and important for developing countries such Bangladesh. Most used agricultural robots in developing countries are: mowing grass, spraying pesticides and monitoring crops. This research represents a review on some common robotic technology that is used in agriculture sector of Bangladesh and also other developing countries. In addition to that, this research also discuss about technical point of view

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regarding advantages and disadvantages of those agro-based robots and how to improve the technology considering counties farming situation. Finally, we have reported future scope of utilizing those advance technology in similar areas in Bangladesh.

2. Methodology

This research is conducted from BRAC University Robotics Research Lab, Bangladesh in order to put some contribution reviewing applied robotics technology in agricultural sectors of Bangladesh and other developing countries like us.

This research work was distributed into two teams. One team was focused on research review of published papers on agricultural development in Bangladesh and some other developing countries. Another team was concerned on field level data analyses that are collected from used technologies in farming areas of Bangladesh. Finally, we have integrated two team's results to make a final review on agriculture based robotic technology developing countries. In addition to that, research teams reviewed on advance robotic technology used in developed in their agricultural purpose. After that, we made an analysis how those technologies can be implacable in agricultural sectors in Bangladesh.

3. A Brief Status of Current Robots in Harvesting

From several decades researches has been performed to develop robots for using in agriculture sector. Cherry, tomatoes, cucumbers, mushrooms, and other fruits are harvesting using different types of robots in different countries .Moreover, Tillett (1993) suggests that in horticulture, robots have been introduced to harvest citrus and apples. In dairy farming, milking robots are currently commonplace in the Netherlands whereas

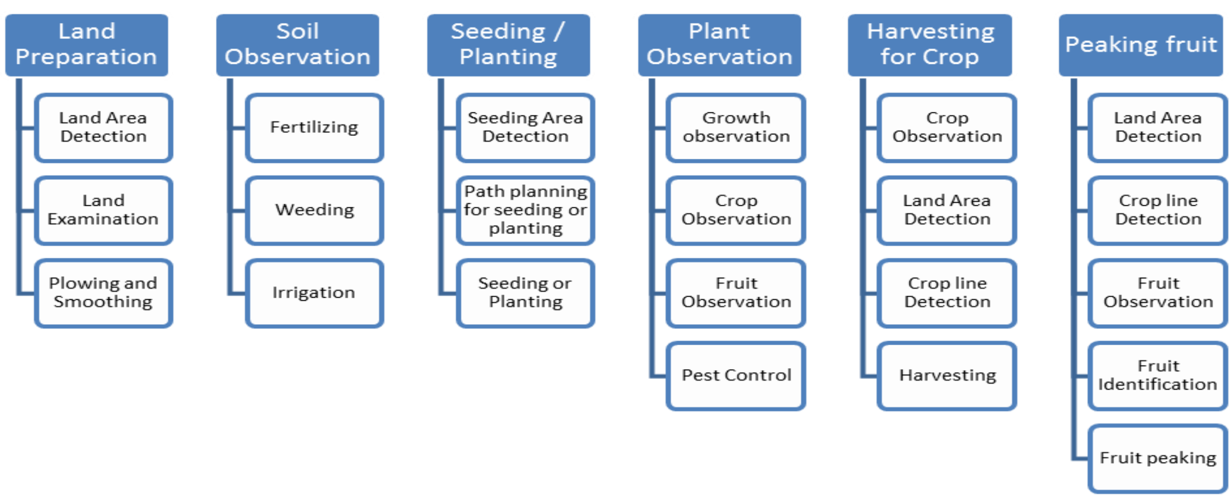

Figure 1: Various Sections of Implementation of Robotic System in Agricultural Sector

Bangladesh and other developing countries are still following conventional procedure (Wallin, 1997). Example of Advance automated engineering is Japanese ‘‘plant factory,’’ where vegetables are grown hydroponically under artificial lighting .Nowadays, Bangladesh, India, China, Thailand, Japan and others agricultural based countries are using rice cutter and other crop cutter machine in order to manage their cultivations (Shan, Johnson-Beebout & Buresh 2008). Computers and robots control the process from out planting 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. Considering Agriculture aspect we have divided the scopes of robotics (Fig.1) in followings section.

4. Sectors of Using Agricultural Robot

A. Land Preparation

For detecting agricultural land area GPS module plays a significant role (Li & Yeh 2014). Other than that, number of sensors are already have implemented for soil examination and yet to do lots of research on that. In addition, reasoning is becoming a big challenge for soil examining robot. Till now, robots are used for cropping or land specification. Unfortunately, there are no robots for direct soil testing. There is no general robot for soil testing. For plowing and smoothing tractors are converted into GPS guided mobile robots.

Competence Analysis for land preparation:

- Land Area Detection by GPS Technology
- Land Examination by Soil Testing Sensor using Perception

B. Soil Observation

For Soil testing, perception and reasoning, the drivers and barriers are same as soil examination. The challenge of crop line detection can be solved by image processing. Some individual GPS guided fertilizing Robot is implemented nowadays but lots of researchers are trying to integrate this feature into a combined tractor (Wang, Zhang & Wang 2006). Weeding status and Perception can be successfully observable and applicable using image processing method. On the other hand, sensing moisture, humidity and temperature and irrigation are not a challenge anymore. Competence Analysis for soil observation:

Fertilizing	Weeding	Irrigation
•Soil Test by Soil Testing Sensor using Perception •Fertilization by GPS guided Fertilizing Robot that can detect crop line	•Weeding status Checking by Camera where perception is done by image processing •Weeding by GPS guided weeding Robot that can detect crop line	•For irrigation Temperature, Humidity and Moisture are the most important issue. The watering valve and pump are controlled by the perception of these three sensors

C. Seeding / Planting

Seeding area detection, path planning, seeding and finally planting robots are using in a full swing in different countries. GPS and Image processing technology is playing a vital role for this application (Zahedi & Zahedi 2012).

Competence Analysis for seeding and planting:

- Seeding Area Detection by GPS
- Path planning for seeding or planting by the perception of GPS and image processing.
- Seeding or Planting by GPS controlled Seeding or Plantation Robot

D. Plant Observation

Robots are used for Monitoring plants and their growth. Based on the certain condition they also take necessary steps. Those steps are usually taken based on the available information and data base programmed in the embedded system from beginning. Pest control system also depends on the pre-installed data on embedded system. There are some GPS guided pest controls spraying Robots that are using in the advance countries but rarely seen in developing countries like Bangladesh.

Competence Analysis for plant observation:

- Growth observation, Crop Observation, Fruit Observation by Size, Shape and Color Sensing by high performance Camera
- Perception by Image Processing
- Reasoning by AI algorithm

A. Harvesting

Advance image processing and high performance camera is core requirement for identifying specific fruit's size, shape, color or others parameter. This technology is also required for crop observation. Land Area Detection, Vision based Crop line Detection and GPS Guided Harvesting Robot is not a big challenge for technology but the mechanical tools for cutting crop or peaking fruits is the most challenging portion for harvesting. Competence Analysis for harvesting crops:

Crop Observation	Land Area Detection	Vision based Crop line Detection	Harvester
•Size, Shape and Color Sensing •by high performance Camera •Perception by Image Processing •Reasoning by AI algorithm	GPS	•Perception •Reasoning	GPS Guided Harvesting Robot

5. Recent Progress

A. Land Preperation

•Land Area Detection ○GPS Technology	 Solved
•Land Examination ○Soil Sensor ○Perception	 Partially Solved Partially Solved
•Plowing and Smoothing ○GPS Guided Plowing tractor	 Solved

B. Soil Observation

•Fertilizing ○Soil Test by different type of Sensors ○Perception ○Crop line detection ○GPS guided Fertilizing Robot	 Partially Solved Partially Solved Partially Solved Partially Solved for specific crop
•Weeding ○Weeding status Checking by Camera ○Perception by Image Processing ○Crop line detection ○GPS guided Weeding Robot	 Partially Solved Partially Solved Partially Solved Partially Solved for specific crop
•Irrigation ○Temperature Sensor ○Moisturizing Sensor ○Perception ○Watering Valve or Pump Control	 Solved Solved Solved Solved

C. Seeding / Planting

•Seeding Area Detection – GPS	Solved
•Path planning for seeding or planting – GPS – Perception	Solved Solved
•Seeding or Planting – GPS controlled Seeding or Plantation Robot	Solved for specific crop

D. Plant Observation

•Growth observation •Crop Observation •Fruit Observation	Most challenging issues are being solved

E. Pest Control Harvesting for Crop

•Pest Control – Sensing – Perception using the knowledge base – GPS guided pest control Spraying Robot	Partially Solved

F. Harvesting for Crop

•Crop Observation ○Size, Shape and Color Sensing by high performance Camera ○Perception by Image Processing ○Reasoning by AI algorithm ○Land Area Detection by GPS	Partially Solved Partially Solved Partially Solved Solved
•Vision based Crop line Detection ○Perception ○Reasoning	Partially Solved Partially Solved
•GPS Guided Harvesting Robot	Partially Solved

G. Peaking Fruit

•Identification by Image processing ○Recognize the fruit ○Recognize Size and Shape ○Color Detection ○Griping Area Detection ○Cutting Area Detection •Perception •Reasoning •GPS Guided Fruit peaking Robot	Very few implemented Most challenging issues are being solved

6. Brief Overview of Sensors Used in Agriculture and Agricultural Robot

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites (Bevis et al. 2012). It is maintained by the United States government and is freely accessible by anyone with a GPS receiver. The GPS program provides critical capabilities to military, civil and commercial users around the world. In addition, GPS is the backbone for modernizing the global air traffic system. The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. GPS was created and realized by the U.S. Department of Defense (DoD) and was originally run with 24 satellites. It became fully operational in 1994 (Kaplan & Hegarty 2005). Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS III satellites and Next Generation Operational Control System (OCX). Announcements from the Vice President and the White House in 1998 initiated these changes. In 2000, U.S. Congress authorized the modernization effort, referred to as GPS III (Large, Molars & Boothe 2008). In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was in use by only the Russian military, until it was made fully available to civilians in 2007. There are also the planned European Union Galileo positioning system, Chinese Compass navigation system, and Indian Regional Navigational Satellite System (Grewal, Weill & Andrews 2007). This type of sensor can be used in agricultural robot to make system fully autonomous and self –guided.

Sonar (originally an acronym for Sound Navigation and Ranging) is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water, such as other vessels. Two types of technology share the name "sonar": passive sonar is essentially listening for the sound made by vessels; active sonar is emitting pulses of sounds and listening for echoes. Sonar may be used as a means of acoustic location and of measurement of the echo characteristics of "targets" in the water (Ainslie, 2010).

Acoustic location in air was used before the introduction of radar. Sonar may also be used in air for robot navigation, and SODAR (an upward looking in-air sonar) is used for atmospheric investigations. The term sonar is also used for the equipment used to generate and receive the sound. The acoustic frequencies used in sonar systems vary from very low (infrasonic) to extremely high (ultrasonic). The study of underwater sound is known as underwater acoustics or hydro acoustics (Etter, 2013). Agricultural robot having sonar can detect any obstacle during its movement and maintain the predetermined path.

A laser rangefinder is a device which uses a laser beam to determine the distance to an object. The most common form of laser rangefinder operates on the time of flight principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender. Due to the high speed of light, this technique is not appropriate for high precision sub-millimeter measurements, where triangulation and other techniques are often used (Den Boef, 1987). Due to the noise of sonar's output, sometime it is impossible to determine the actual distance of an object and perform the specific task for agricultural robot, therefore, in that case, laser rangefinder can be used as a replacement of sonar sensor.

A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). The collected data can then be used to construct digital, three dimensional models. Many different technologies can be used to build these 3D scanning devices; each technology comes with its own limitations, advantages and costs. Many limitations in the kind of objects that can be digitized are still present, for example, optical technologies encounter many difficulties with shiny, mirroring or transparent objects (Surmann, Nüchter & Hertzberg 2003). Collected 3D data is useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies and video games. Other common applications of this technology include industrial design, orthotics and prosthetics, reverse engineering and prototyping, quality control/inspection and documentation of cultural artifacts (Qi et al. 1998). This sensor is mainly used for crop modelling in agricultural robot.

A thermo graphic camera or infrared camera is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 450–750 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm) (Cetas, 1978). With all the different types of soil sensors and measurement techniques on the market and the different technologies that they employ, choosing the right one can be a confusing and time consuming process. This section outlines the different types of technologies available as well as their advantages and disadvantages (Chan et al. 2004).

Soil probes that use the Coaxial Impedance Dielectric Reflectometry method of soil moisture measurement employ an oscillator to generate an electromagnetic signal that is propagated through the unit (usually by metal tines or other wave guide) and into the soil. Part of this signal will be reflected back to the unit by the soil, and the sensor will measure the amplitude of this reflected signal and the incident signal in volts (Zegelin, White & Jenkins 1989). The ratio of these raw voltages is used in a mathematical numerical solution to Maxwell's equations to first calculate the impedance, then both real and imaginary dielectric permittivity's which in turn is used to accurately estimate soil water content. The Stevens Hydra Probe is the only commercially available sensor to use the Coaxial Impedance Dielectric Reflectometry method along with complex computations in soil measurement, resulting in the Hydrarobe's high measurement accuracy. The soil measurement computations are performed by a microcontroller inside the Hydra Probe, making it easy to use as the probe can output results in standard engineering units (Topp et al. 1988).

There are many soil probes on the market today that use the Frequency Domain Reflectometry method of soil measurement. This method of measurement also uses an oscillator to propagate an electromagnetic signal through a metal tine or other wave guide, but with this method, the difference between the output wave and the return wave frequency is measured to determine soil moisture. Frequency Domain Reflectometry (FDR) probes are considered accurate but must be calibrated for the type of soil they will be buried in (Ledieu et al. 1986). They offer a faster response time compared to Time Domain Reflectometer (TDR) probes and can be connected to a standard data logger to collect readings. Examples of sensors in this category include the AquaSPY C-probe, and the Sentek EnviroSCAN Probe. While frequency capacitance type soil sensors are call “FDR” sensors, this is somewhat of a misnomer because many of these probe only use a single frequency and not a “domain” of many frequencies. The Delta-T Theta probe is a coaxial differential amplitude reflectometer and Decagon's ECHO probe is a time of charge capacitor type sensor (Robinson et al. 2008). Sensors that use the Time Domain Reflectometry (TDR) function in a somewhat similar way to FDR probes, but the mechanics behind the measurement system are different. TDR sensors propagate a pulse down a line into the soil, which is terminated at the end by a probe with wave guides. TDR systems measure the water content of the soil by measuring how long it takes the pulse to come back. Examples of this sensor include the Campbell CR616 and the IMKO Trime. TDR soil moisture measurement devices require a device to generate the electronic pulse and need to be carefully calibrated in order to precisely measure the amount of time it takes for the pulse to propagate down the line and back again (Robinson et al. 2003). They are also sensitive to the saline content of salt and relatively expensive compared to some measurement methods. However, TRD devices do respond quickly to varying soil moisture.

Gypsum blocks use two electrodes placed into a small block of gypsum to measure soil water tension. Wires connected to the electrodes are connected to either a portable hand-held reader or a data logger. The amount of water in the soil is determined by the electrical resistance between the two electrodes within the gypsum block. More water present in the soil will reduce the resistance, while less water will increase it. While gypsum blocks can be relatively inexpensive and easy to install compared to other types of soil sensors, they have to be replaced periodically as the gypsum disintegrates. Gypsum blocks are also more sensitive to having readings throwing off by soil with high salinity (salt content) (Stenitzer, 1993).

Neutron probes are another way to measure soil moisture content. A probe inserted in the ground emits low-level radiation in the form of neutrons. These collide with the hydrogen atoms contained in water, which is detected by the probe. The more water content in the soil, the more neutrons are scattered back at the device (Dalton et al. 1984). Neutron probes are very accurate measurement devices when used properly but are expensive compared to most other measurement methods and generally have to be registered with the federal government due to radioactive elements used to emit the neutrons.

Developed during the 16th and 17th centuries, a thermometer is a device that measures temperature or temperature gradient using a variety of different principles. A thermometer has two important elements: the temperature sensor (e.g. the bulb on a mercury thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the scale on a mercury thermometer). There are many types and many uses for thermometers, as detailed below in sections of this article (Zhang, Wang & Wang 2002).

A hygrometer is an instrument used for measuring the moisture content in the environmental air, or humidity. Most measurement devices usually rely on measurements of some other quantity such as temperature, pressure, mass or a mechanical or electrical change in a substance as moisture is absorbed (Hubbard, Rosenberg & Nielsen 1983).

Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of multiple soil moisture sensors. One common type of soil moisture sensors in commercial use is a Frequency domain sensor such as a capacitance sensor. Another sensor, the neutron moisture gauge, utilize the moderator properties of water for neutrons. Cheaper sensors -often for home use- are based on two electrodes measuring the resistance of the soil. Sometimes this simply consists of two bare (galvanized) wires, but there are also probes with wires embedded in gypsum (Kumar, Pramod & Sravani 2013). Soil moisture sensor then can be used in agricultural robot for measuring the moisture of soil easily.

The soil pH is a measure of the acidity or basicity in soils. pH is defined as the negative logarithm (base 10) of the activity of hydrogen ions (H+) in solution. It ranges from 0 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is basic. Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient (Surrey, 1964). The optimum pH range for most plants is between 6 and 7.5, however many plants have adapted to thrive at pH values outside this range. Agricultural robots having pH sensor is really efficient to measure the characteristics of soil.

7. Future Scenario

Accuracy and autonomy are still a controversial point mainly at the industrial and space fields, an still much more experimentation is needed to convince people from their fears to the risks inherent to higher increases of autonomy at the artificial systems, on what is been called the fourth or the fifth robots generation.

A. Expansion in product innovation

- Can have a high efficient multipurpose robotic arm.
- Can have more sensors for soil testing.
- Multipurpose GPS guided tractor can be introduced.
- Remote observation can be included.
- Can have more sensors for chemical reaction and smell understanding.
- Emphasis in image processing is needed for proper understanding for Crop and Fruit observation.
- More efficient AI algorithm is needed for accurate reasoning.
- Micro sized actuators and end effectors in necessary for any kind of Robotics Application

B. New jobs robots are going to perform

- Land Area Detection
- Land Examination
- Path planning for seeding or planting
- Growth observation
- Crop Observation
- Fruit Observation
- Plowing and Smoothing
- Seeding or Planting
- Fertilizing
- Weeding
- Irrigation
- Harvesting
- Fruit peaking

C. Emerging business prospects

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

8. New Idea of Agricultural Robot Focusing on Developing Countries

Due to the high manufacturing cost of robots, it seems to be very tough for farmers to use it in agricultural sector in developing countries. As one robots may be associated with one specific task, therefore, farmers need many robots to do their different task in agricultural field. To keep in that in mind a new model can be introduced which has an ability to do all task such as land preparation, soil observation, seeding/planting, plant observation, harvesting for crop and peaking fruit. The importance of this robot is to minimize the production cost and increasing productivity. Moreover, this will help a group of farmers or even government to buy such type of robot and that can be used to assign for specific area to help the general farmers.

9. Conclusion

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. Bangladesh is a low income generated country. A number of people are involved with farming and they wish to be with farming. Because of economic crisis they cannot even use technology for farming. Very few tractors are used for preparing land and few other local mechanical tools are used for other farming activities. Usually Robotic items are very expensive because of sophisticated parts and R&D cost as a result Bangladesh needs to be concentrated more to compensate the price to make it available even for general people to get the benefit in agricultural sector eventually.

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