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Introduction to Robotics Agriculture in Pest Control: A Review

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Abstract - Agriculture is one of the latest industries that uses robotic technologies. Cultivation of crops with high yield and quality can be enhanced when technological sustenance is involved. Pests are nuisance and cannot be completely eliminated, but with effective control and management. damages caused by pests could be minimized below economic threshold. Automation in agriculture is stable and accurate and is mainly incorporated in mechanized farming system. However its numerous application in different agricultural practices is not well noticed. Hence this paper attempts to provide profound awareness on robotic technology in agriculture. Robots could have a specific or multiple functions and, most commonly, they are made up of five basic components; sensors, effectors, actuators, controller and arms. Use of automation in weeding, weed mapping, micro spraying, seeding, irrigation and harvesting are progressions which promote sustainable agriculture and food security. In future, solar robots with battery inverter may be invented.

Keywords: Pest, agriculture, automation machine, sensor, weed controller, micro sprayer.

Introduction

Pest refers to any agent insects, microbes, plants, animals and abiotic factors that cause damage to our crops. They are generally a nuisance, diseases and detrimental to crops, damaging property or make lives difficult to humans. Depending on the situation, insects can be considered as pests and harmful at certain periods of time and beneficial at another. Therefore an insect is usually considered a pest when it is in competition with humans for some resources and when a significant number is presents.

Farming is labour intensive and often occupied with manual infuriating hard work. Agriculture could perhaps be one of the latest industries that makes use of robotic technology and automation machines. Unlike manufacturing and mining industries which embrace new technologies more quickly because of continuous dependence on the machinery throughout the year, the use of equipment in agriculture is limited or applied during certain agronomic practices such as ploughing, planting, pesticides application, harvesting, etc. In the current agricultural trend, robotics or real-time machines are commonly used in the plant factory concepts, but these require large investment and modern facilities. Farmers have been keenly interested in ways to make their work easier. Many of the labour saving devices and simple-operated machines in agriculture have been developed by farmers themselves (Sistler, 1987).

Cultivation of crops for optimum yield and quality produce is highly methodical but can be improved by the aid of technological support. Technology plays an ever increasing role in global businesses especially as it relates to agriculture equipment, data collection for surveys as well as accessing and obtaining vital information regarding their crop land (Rocky Mountain Dealership, 2015). The aim of the review is to promote awareness among students and young scientist on relative technological advancement in farming and how robotic agriculture can be used to control pest particularly on prototypes of robots such as weeding, fertilizing and harvesting robots.

Pest management

Countries that are sufficient in food production for more than a decade are now faced with problems ranging from high food demand, pest invasion, pollution and occurrence of natural disasters such as flooding, drought, wildfire etc. These factors lead to destruction, wastage and deficient food production. Exposure to the herbicide glyphoshate can severely reduce seed quality (Lucke, Landiver, & Moseley, 1995) and clopyralid herbicide can reduce yield in potato plant (Wasim, Sengupta, & Ashim, 2009). Crops can also suffer indirect consequences of pesticide applications when harm is done to soil microbes and beneficent insects. As much as 80 – 90% of an applied pesticide can be volatilized within a few days of application (Majewski, Foreman, Goolsby, & Nakagaki, 1998). Pesticide drift may result in soil and groundwater contamination, affect fertility and non-target vegetation. An important lingering problem is the incessant application of pesticides. Often, when applying herbicides, farmers tend to apply the highest label-approved rate or sometime exceed it (López *et al*., 2012) thus creating concern on ecological impact and biological magnification. However nowadays, consumers are increasingly demanding for natural, quality produce without any or limited chemical treatment (Blasco, Aleixos, Roger, Rabatel, & Molto, 2002). It is impossible to eliminate pest completely. However an effective pest control strategy requires some information or knowledge about the pest including its life cycle and habit.

The most important key component in pest control is correct identification of the pest and its life cycle (Alston, 1996). Understanding detail of how natural enemy species diversity affect pest-control functioning is difficult and pest control is an important component in ecosystem (Zhang, Taylor, Kremer, Carney, & Sott, 2007) Pest management includes intelligent selection and use of pest control tactics that will ascertain favourable economic, ecological and sociological consequences (Metcalf & Luckmann, 1994). Likewise control actions include monitoring of pest increase, judicious application of pesticides or effective communication that no action is necessary. This, however, could be accomplished by the use of multiple actions in a compatible manner to maintain pest damage below the economic injury level while providing protection against hazards to humans, plants, animals and environment. The general practices of pest management have been outlined:

a. Determining how the life system of a pest needs to be modified to reduce its numbers below economic threshold.
b. Applying biological knowledge and current technology to achieve the desired result.
c. Devising procedures for pest control suitable to current technology and compatible with economic and environmental quality i.e economic and social acceptance.

The pest control tactics include monitoring of pest increase, judicious use of pesticides and effective communication that no action is necessary. However, pest management concept dictates a tolerant approach to pest status. Insect management is people oriented and a successful pest management depends largely on influencing the people who control the pest at all pest-control actions (Metcalf & Luckmann, 1994). However, in agricultural environment according to Metcalf & Luckmann (1994) the most important components of pest management include:

a. Identifying the pest to be managed in the crop production system.
b. Defining the management unit.
c. Developing pest management strategy.
d. Developing reliable monitoring techniques.
e. Establishing economic threshold.
f. Evolving descriptive and predictive models.

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Robotic technology in agriculture

A robot is an automatic device that performs functions normally ascribed to humans or simply a machine in the form of human. It is a machine that senses the environment, processes and responds to the sensor's information with a computer command. They are man-made mechanical devices that can move by themselves and whose motion must be modelled, planned, sensed, actuated and controlled by programming. It will perform its task or functions day and night without complaining. Most of the robots have at least five parts viz; sensors, effectors, actuators, controller and common-effectors (arms). Robots never grow tired but can still have a risk of malfunctioning when maintenance is not conducted properly. Agricultural robotics is the logical proliferation of an automation technology into bio-systems such as agriculture, forestry, green house, horticulture (Karthik & Chandra, 2014) and presently a number of researchers and publications are being conducted across the globe (Scopus: 2015) to increase their applications (Figure 1).

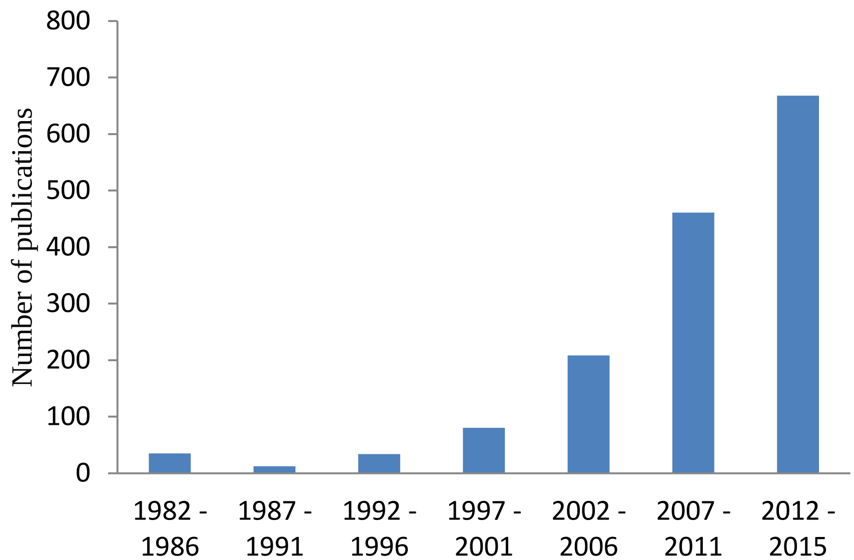

Figure 1 (a): Number of publications on robotics in Agriculture from 1982 to 2015 (Source: Scopus 05/09/2015).

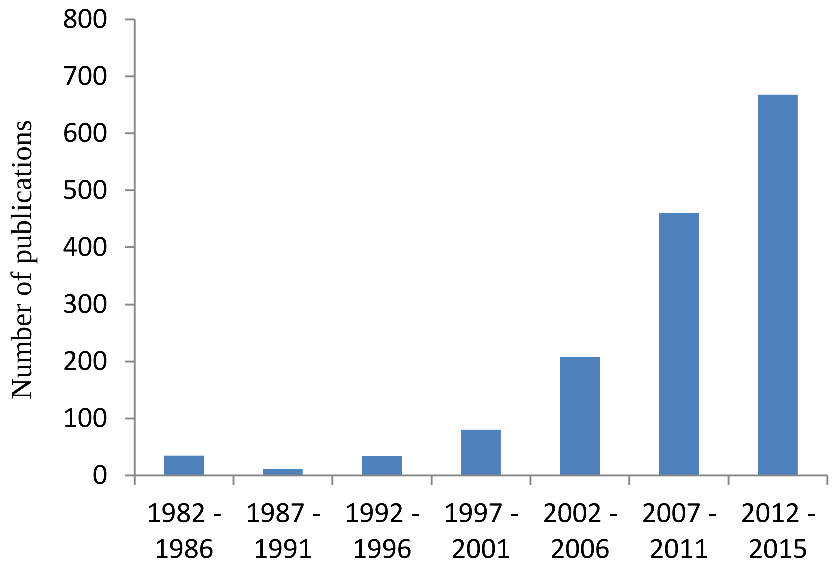

Figure 1 (b): Number of publications from 2009 to 2015. (Source: Scopus 05/09/2015).

Impairment of normal physiological functions producing characteristic symptoms is termed disease and an evidence of its existence is caused by pathogens. In most cases, pest or diseases are observed or seen on the leaves, shoot, stem, flower or roots and identification of the plant organ for pest and finding out the percentage of infestation incidence symptoms of the pest attack plays an essential role towards successful cultivation of crops.

History of development in robotics

Early in the history, manpower began to be replaced by animals. The advent of the horse-drawn reaper in 1831 to replace the scythe and later animal power was replaced with machine power (steam engines) in 1890 (David, Christophe, & Morgan, 2011). By 1930 farm machinery began making transition and the larger more comprehensive machines for large scale were developed (Sistler, 1987). One of the earliest descriptions of automata appeared in China between 1023 – 957 BC. Robotics seems to be the technology of the future but it actually has its roots back in the ancient history. The Muslim inventor Al-Jazari is credited with inventing a robot in 1206. In his book titled 'Book of Knowledge of Ingenious Mechanical devices' he described how he had built devises such as Elephant clock, candle clock and many others (David, Christophe, & Morgan, 2011). In 1495, Leonardo da Vinci designed the first humanoid robot (Mechanical knight) and since then a lot of development and advancement were made (David *et al*., 2011).

Robotics in weeds control.

Weeds are referred to as unwanted plants that compete with our crops for nutrients, space, sunlight and moisture and therefore have detrimental impact on crop quality and yield (Oerke, 2006). There are a number of factors that affect the magnitude of yield and quality loss in crop production and these include density of weeds against crop (Matt, Mohlar & Staver, 2004), relative weed seeds germination rate, allelopathic weeds invasion (Bhowmik & Doll, 1981), seeds dispersal advantage (Maxwell & Claudio, 1992). On a global scale a potential crop yield loss of 43% was estimated when weeds are not controlled (Oerke, 2006). For instance, when banyarndgrass (*Echinochloa cruss-galli* L.) were allowed to compete with cotton during the first 9 weeks after emergence and then the field were kept weed-free for the remainder of the season, a yield loss of 60 and 69%, respectively were observed (Baratto *et al*., 2005). In a related concern Heisel *et al*. (2002) reported that sugar beet yield with weeds at 2cm distance was approximately 20% lower compared with weeds at 8cm distance from the beet plant and concluded that the effect of weed species (*Sinapsis arvensis and Lolium perenne*.) decreased linearly within a distance of

2 – 8cm from the sugarbeet. These studies ascertain the compelling impact of weeds to crop growth and yield.

Typical weed control methods include among others mechanical/physical methods; herbicide application; pre-emergence or post-emergence tillage; cultural control; and biological control (classical and non-classical). Although the technology for tractor-mounted real-time weed detection and control has yet to exist, the concept of automated selective spraying of weeds in agricultural fields has a great potential for reducing economic and environmental costs while maintaining high level of weed control (Thompson, Stafford, & Miller, 1991). Different technologies for weed detection, management and spatial variable application of herbicide studies had been introduced during the last decade and importantly a broad range of new technologies for precision agriculture has been developed and implemented in agricultural practices (Christensen *et al*., 2009).

These technologies can be categorized into three (3) classes:
a. Crop and yield monitors and related software (e.g GreenStar™, Yara N-sensor™ etc).
b. Precision Agricultural Technologies (e.g AgroGuide™ ,FarmWorks™ etc).
c. Automatic control systems (e.g AutoFarm™, TruPath™, Autopilot™ etc).

Generally, applicable system requires technologies that can handle high level of complexity using artificial intelligence agent: a system that detects or perceives environmental changes and takes actions that maximize its chance of success. There are basically three principle components of designing automatic weed system:
a. A sensor system which identifies localized and measures important physical and biological properties of the agricultural system.
b. A management model processing data and information system on biological efficacies of control methods, optimizing treatments, environmental constraint, density and composition of pest and decision-making algorithms.
c. Actuator, a precision control implement e.g sprayer, e-nose etc

Weed sensing system

Weeds generally cause suppression in crop growth. There is an increasing concern on rampant application of herbicides and pesticides in agricultural system due to its negative impact on ecosystem. Using good precision in spraying method or alternatively using manual weeding could eliminate weeds. Experiences from the use of auto steering shows that the working conditions of the operator is improved significantly in terms of reduced strain and improved work quality (Sørensen *et al*., 2007).

Mechanical, efficiency of herbicides and other control methods vary significantly among weed species (Alhassan, Dadari, Babaji, & Shebayan, 2015). Therefore it is essential to identify weed species to maximize economy with a minimum environmental impact. There are two categories involved in sensing techniques: First, aerial-based and ground-based sensing using digital cameras or non-imaging sensors (Reynier, Vrindts, & Josse, 2006). However, in large areas, the most cost effective approach may be remote sensing using aircraft or satellites to provide a large area or farm with maps of weed occurrence (Lamb & Brown, 2001). Secondly, use of multi-spectral images sensors such as digital cameras on ground-based mobile platform. With sufficient spatial resolutions, image collected with ground-based camera system are able to segment vegetation from soil background and therefore delineate individual weed plants from crop (Thorp & Tian, 2004).

Segmentation (making distinction between plant and soil background) is the first step in automated crop and weed sensing. Important technologies such as global positioning system GPS, machine vision, variable rate application techniques and robotics provide the technologies required for successful implementation of automatous mobile agricultural robots for weed control in row crops (Slaughter, Giles,

& Downey, 2008). Most of the robots have at least five parts viz; sensors, effectors, actuators, controller and common-effectors (arms).

Types of robots.

a. Mobile robots.
   Mobile robots are able to move and perform a task such as search areas, a prime example is the Mars explorer which is specifically designed to roam the Mars surface, searching in collapse buildings or dangerous areas, mining etc

b. Rolling robots.
   Rolling robots are robots that can move quickly in searching areas. They have wheels and are usually helpful in flat areas. They are mostly used in excavations and drillings.

c. Stationary robots.
   Stationary robots perform their task without moving an inch. They are commonly used in industries and plant housing.

d. Autonomous robots.
   Autonomous robots are self-supporting robots that run programs that give them command on to perform an action, learn new behaviours, walk or avoid obstacles

e. Remote robots.
   Remote robots are simply robots that perform actions under human guidance. However due to limited memory and brain capacity, an autonomous robots cannot perform a complicated task. Such activities are best performed by humans with real-brain power using remotes to control robots.
   (Source: www.slideshare.net/sivabenten1/ssr-16116198)

Insect traps for pest monitoring.

Monitoring population density of pest is crucial and very important and is a key towards successful crop protection in agriculture and forestry practices. Traditionally, farmers must usually perform periodical surveys of the traps disseminated through the field. This is a labour and time consuming activity particularly for large plantations areas. It would be of great advantage to have an affordable system capable of doing task automatically in an accurate and more efficient way (López *et al*., 2012). A sound integrated pest management depends on the accuracy and precision of population monitoring techniques, and pest control has always been a troublesome and challenging task.

A good and effective technique of insect-pest control monitoring is basically centered on the application of insect-traps. Depending on the types of insect. each trap is accurately installed with pheromones and related chemical substances that invite the targeted insects to be captured (Kamminga, Koppel, Herbert, & Kuhar, 2012). Traps are constructed in such a way that no insect entering it can be able to escape and therefore the pest monitoring device will periodically gather surveillance information on each trap and take count on the respective individual insect. Captured in this way, an efficient pest control management system is realized and achieved (López *et al*., 2012). Data collection on the trap may require excellent field survey and periodic inspection where optical observation could be made by operator (human) in order to record and evaluate the number of insect-pest captured. The periods between two consecutive trap inspection or survey should be normally within the range of 15 to 30 days. This method is costly and labour intensive and all monitoring traps cannot be synchronized to measure the target pest population and hence offer poor temporal resolution and measurement and consequently the dynamic pest population density in the field cannot be accurately monitored (López *et al*., 2012). To curtail this, an image visual-sensor network technology capable of performing routine automatic pest monitoring is established based on low cost system using battery powered wireless visual-image sensor that accurately and precisely inspect the insect population density using high resolution image (Figure 2).

Figure 2: Image scanning robot (Source: http://www.roboticsbusinessreview.com)

The emergence of an electronic nose in identification of disease and grading of odour contribute immensely in monitoring of growth of the disease (Gardner, Shin, & Hines, 2000). An e-nose may be able to recognize characteristic smells from diseases and bacteria cell because cell metabolism is the biological oxidation of organic compounds to yield ATP and secondary metabolites (Gardner *et al*., 2000). An e-nose, as described by Maul *et al*. (1998) consists of a sampling head equipped with 12 polymer sensors, glass sampling vessels and purging valves. Each polymer sensor changes its electrical conductivity upon exposure to volatile compounds present in the headspace of the sampling vessel. Volatile organic compounds profile emitted from plants often changes in response to environmental factors and monitoring the change of such profile could provide a non-destructive means of plant health measurement (Laothawornkitkul *et al*., 2008a). This could however provide a quick and effective measure that could be used for an outdoor detection and analysis of phytochemicals emitted from plants under stress or pest attack. E-nose technology has been used in a variety of applications including food quality measurement, animal disease diagnosis, microorganism identification and plant status monitoring and eventually confirmed that e-nose is a potentially valuable technology for remote sensing of pests and diseases (Laothawornkitkul *et al*., 2008b).

Mesh Eye is a powerful smart camera with a good resolution that speck intelligence surveillance system with the capacity to revolve continuously in relation to the range, size, position of a moving target within the range if its field (Hengstler, Prashanth, Fong, & Hamid, 2007). Data image capture will then trigger colour camera module and thereby procure high image resolution of the object. It uses applications such as radio transceiver, thumb processor, Agilant 2700VGA camera module and 256KB of flash memory among others. Image processing can be used in agricultural applications for the following purposes:

a. To detect diseases on leaf, stem and fruit.
b. To quantify affected area by the disease.
c. To find shape of affected area.
d. To determine colour of affected area.
e. To determine size and shape of fruits.

(Patil & Kumar, 2011)

Application of robotics in agriculture

Availability of technology makes robotic construction feasible to copy animal structures. The use of robot is no longer limited to industrial environment. Robots have been used to replace human job especially in the industrial manufacturing sector (Ayub, Kushaini, & Amir, 2015). Robotic technologies such as fruit harvester (Autonomous Fruits Picking Mechine, AFPM) are highly mechanized and labour intensive.

Mobile robots have become a new frontage in robotic technology. Currently, autonomous vehicles capable of self-guidance comprising reliable and autonomous navigation in unstructured environments are underway (Garcia-Alegre & Garcia-Perez, 2001). Such product would have definite cost, high quality, workability, and output advantages over manual processes. For instance, in Sweden, an intra-row weeding robot in sugar beets had been developed (Åstrand & Baerveldt, 2002). Israel has a multi-functional prototype robot for transplanting and spraying (Edan & Bechar, 1998). Recently mobile robot for timber searching was developed in USA (Jone, Magnus, & Nordlander, 2002).

Generally, applications of robots are recently sporadically spreading every day as the opportunity of replacing human operators provides effective solutions and return on investment. However robots are especially important when the duties that are needed to be performed are potentially dangerous or harmful for workers or when conservative issues need to be addressed.

Weed controller.

A weed controller is a four-wheel-drive weed-seeking robotics that was developed with weeding functions. Crops growing in rows can be weeded by running a hoe between the crop rows. It posseses vision systems and an intelligent hoe that enables it identify the rows of crops and steer accurately between them hence considerably reducing the need for herbicides. Weeding robots are robotics running around the paddy field by using the information given from the direction sensor and the GPS receiver (Kameyama, Umeda, & Hashimoto, 2013). Weed identification is based on colour photography and weed maps.

Weed mapping.

Weed mapping involves a process of tapping locations, positions and density of weed species using facet of robotic vision. This method could be used to record weed infestation and distribution because typically weeds are patchy while crops are systematically planted in row. Another method is to use active shape recognition originally developed to recognize human faces, to classify weed species by the shape of their outline (Søgaard, 2005). Research has shown that up-to nineteen species of weed can be recognized by the machines. Colour pigmentation has also been noticed to be useful in weeds recognition (Tang, Tian, & Steward, 2000). The ultimate result is to obtain a weed-map that can be translated into a treatment-map,therefore serving as a template document for weed management. Intra-row weeding is a very uneasy and difficult task because it requires the location of the crop to be known so that the blades can be piloted effectively (Norremark, Griepentrog, Nielson, & Sogaard, 2008). Non-competitive with less threat weed plants can be ignored particularly when they are not close to the crop. Controlling biodiversity is an important prospect that might be realized when robotic weeding is adopted. A good example is Autonomous Christmas Tree Weeder.

Robotic gantry

Robotic gantry can be used for liquid or fertilizer spray and importantly can regulate its functions in accordance to the change in weather conditions (Blackmore, Stout, Wang, & Runov, 2005). This improve steadiness because a sensor could be mounted so that if windy the gantry could halt and wait until favourable conditions improved (Blackmore *et al*., 2005).

Microand macro sprayesr

These are machine vision with a micro spray that can identify locations and position of weeds individually and a set of plungers are arranged close together with ability to squirt a herbicide on to the weeds within the close to crop area (Sogaard & Lung, 2007). However, within close-to-crop area care must be taken to avoid any damage that could disturb the crops or soil. Research has shown that splashing can be reduced when a gel is used as a carrier rather than water (Lund & Søgaard, 2005). However, other experiments have shown that when appropriate quantity of herbicide is introduced in the right way and order at the right time then usage of herbicide can be effectively reduced to about 1 g/ha for an infestation of 100 weeds/m^2 (Graglia, 2004). Micro-sprayer system research is presently under development.

Macro-sprayer can be utilized efficiently especially under large farms area (Blackmore *et al*., 2005). Most of the manufacturers tend to produce equipment used for larger and bigger machines. The robotic gantry can be multi-purpose for either liquid spray or fertilizer application and it could be enabled to automatically regulate its functions according to the weather fluctuations and conditions and if rainy or windy it could suspend its activity until favourable conditions improved.

Robotic irrigation

Irrigation is an important component that is practiced mainly during off-raining season. It involves watering of plants periodically or when the need arises. Robots are also being employed for irrigation purposes. A robot irrigator is a mechatronic sprinkler that imitates revolving rain-gun, and it was sufficiently developed to supply alterable rates of water and chemigation over a pre-defined area (Blackmore *et al*., 2005). When the airborne water was blown down the wind a jet angle could be adjusted to compensate by measuring the instantaneous wind speed and direction (Turker, Blackmore, & Weatherhead, 1998). These machines cannot supply the required water in the right proportion in the farm but could be served to irrigate many field locations.

Selective harvester

Discriminate harvesting by farm implement is one of the earlier introduced machines devised specifically for crop harvest. It employs harvesting part of the crop that meets certain threshold or quality. It is however recognized and considered to be a type of pre-sorting based perception and sensitivity of sensor elements. For example, a harvester can select farm produce such as fruits that meet size requirement or quality attribute for harvest, in this way, only crops with prescribed requirement criteria are harvested hence effectively minimize waste. Robotic ability to conduct selective harvesting efficiently depends on two important factors (Reed, Miles, Baldwin, & Noble, 2001). Firstly, its capacity and ability to sense the size or colour quality factor prior to harvest or produce physiological maturity that are related to ripeness and flavour; and secondly to harvest produce without damaging neighbouring crops.

Robotics in Agrciturle : Advantages and Disadvantages

Advantages

a. It possesses vision systems and an intelligent hoe that enable it identify the rows of crops and steer accurately between them hence considerably reducing the need for herbicides.
b. Robots gantry can operate as both fertilizer or liquid sprays, and importantly an automatic self-control system that responds to the weather change conditions.
c. They can be small in size and hence enable it to accumulate data close to crops and perform mechanical weeding, mowing, spray pesticide and fertilizer.
d. Robotics cameras and sensors can detect weeds, identify pest, diseases or parasites and other forms of stress. The sensors are usually selective and used to spray only on the area affected.
e. Robots provide opportunity of replacing human operators aside providing effective solutions with good investment return.
f. The Robot does not get sick or tired and does not need time off.

g. It can operate with closer tolerances (so every round is at full field capacity) with fewer errors and at higher speeds.

(Shwetal & Bhophe, 2015)

Disadvantages

a. It promotesunemployment.
b. Liability.
c. Limited access to the technology.
d. A periodic human presence in the field.
e. Energy cost and maintenance
f. In future it could change emotional appeal to agriculture.
g. Not currently scale neutral.
h. High cost of research and development.
i. Lack of access for poor farmers.

(Shwetal & Bhophe, 2015)

Operation cost

The costs of operating new technologies were calculated by using conventional methods for estimating depreciation, interest and maintenance of machinery (Sørensen, Madsen, & Jacobsen, 2005). The costs are usually distributed over a prearranged period over the number of hectares being treated by the machines. The machinery costs included interest, depreciation, maintenance, fuel consumption and subsequently necessary manual labour input. Repair and maintenance costs per hour included costs for labour and materials. However these were based on normative data for maintenance costs derived as a fraction of the initial investment and depending on the yearly use of the machine (Laursen, 1993). In this way, the variation in respect of the function of machinery size was reduced. This is a general method used for both farm implements and tractive machinery. The average fuel requirement or consumption per hour was estimated as a function of machinery size.

Significance of robotics in agriculture

The use of farm machines in agriculture holds a key for increase human productivity and sustainability in crops management and is a whole new big sector of employment. In Malaysia agricultural sector is among the main economy contributors therefore provision of technologies for farm mechanization is necessary as our population increases with limited natural resources (MARDI, 2014). Fascinating new jobs and employment are being created in new technologies in agriculture thereby attracting young people back to the farm.

Recently advancement in science and technology has been largely applied in agriculture in order to improve the farm produce quality and sustainability. (Bayar *et al*., 2015) proposed a novel control method for an autonomous agriculture that operates in orchards and does not require GPS signals for path tracking, but rely only on data from planer laser scanner and wheel steering encoders, thereby making it suitable for real agricultural application. Hence, agro-robots can be a good alternative for organic farm weed management since the use of chemical pesticides is restricted. Weed control within crop rows is one of main problems in organic farming' (Van der Weide *et al*., 2008).

Future robotics in agriculture

In the future, the number of robotics used in agricultural field is expected to increase considerably as autonomous robots (using solar energy power) is able to work for many hours withput pause. (Karthik & Chandra, 2014). A photoelectric and a capacitive sensor were tested for localizing cutting along the row and proved to be suitable to be included in intra-row weeding machine (Assirelli *et al*., 2015).

Flying micro robots are the products of reverse-engineering mechanics of insects which are specially designed to scout battle fields, search for victims trapped in rubble and record images in agricultural fields. A micro robot consists of propeller which has the ability to fly and land precisely on its target, and it is expected to be used in agriculture for the control of insects and weeds.

Figure 3: Micro-flying robot (Karthik & Chandra, 2014).

Conclusion

A good number of research has been conducted on rebotic applications technologies in pest detection, identification and management control. Eradicating weeds in organic farming is very difficult and requires great labour due to non-use of synthetic chemicals. Monitoring and control are very important components in pest control and a pest insect traps equipped with low power image sensor designed to perform remote automatic pest monitorization would curtail the menace of insect pest infestations. Accurate methods of robotics automatic detection and identification of pest will no doubt minimize incessant application of herbicides and weedicides and improve the quality and precisions of the modern agricultural technology towards crop production, protection, health, and sustainable agriculture.

Recommendation

There is a need to carry out feasibility study to evaluate substantial utilization and efficacy of innovations in robotic technology in agricultural system with the aim to identify potential benefits and economic significance. Provision of long term national policy that would give a sense of direction on robotics towards agriculture is worthy.

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