# ROBOTICS APPLICATION IN AGRICULTURE



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# ROBOTICS APPLICATION IN AGRICULTURE

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Agricultural robot technology is exploding as a result of decades of scientific and industrial study in the face of a growing demand for agricultural goods and a significant loss in agricultural resources and labor force. Given the complexity and uniqueness of agricultural robot technology development, summarizing its features and making credible judgements about its development trend is quite valuable. The types of agricultural robot systems are discussed in this paper. The development of key categories of monitoring robots for crop farming, livestock and poultry farming, and aquaculture are all discussed in depth, starting with the categorization of agricultural robot systems. Following that, a summary of the scientific research, core technology, and commercialization of several kinds of agricultural robots is given. The study focuses on the features of inter-discipline between agricultural robot technology and novel materials, and agronomy. The essential technologies of agricultural robot development are believed to be quick damage-free operation, autonomous navigation for complicated surroundings, target identification for complex backdrops, and unique design for agricultural robots, with a development route provided.

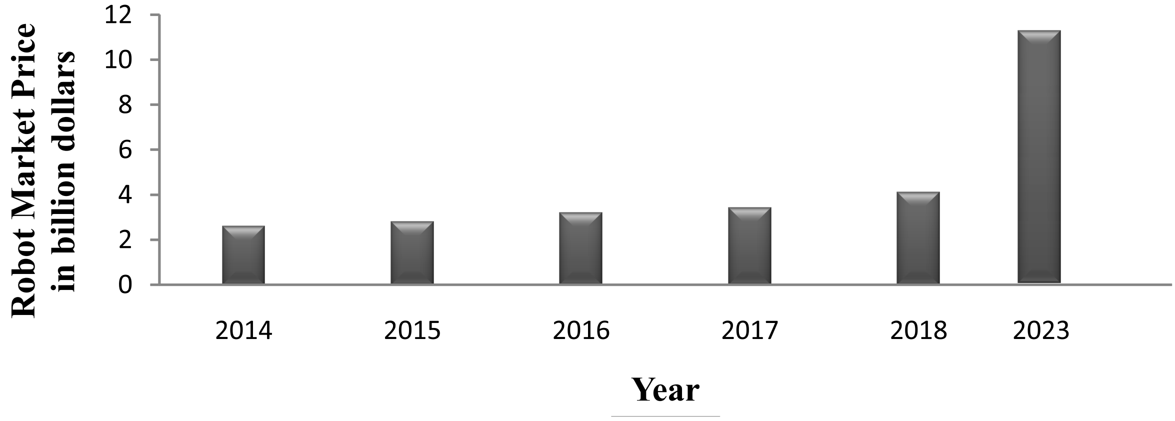
**Keywords:** Agricultural Robot, Agricultural Operations, Sensors, Status

## 1.Introduction

Today, with a global population of 7594 million, 430 000 people are still born every day (Jin et al., 2021). According to the World Health Organization, the world population is expected to reach 980 million in 2050 (World Population Prospects, 2017). At the same time, as people's living standards grow, so does demand for agricultural goods. As a result, the amount of arable land and other agricultural production resources available on the planet is diminishing. While climate change is having a negative impact on agricultural production, on the other hand the cultivable land is also decreasing continuously. Due to rapid population growth, food crisis is a big problem. To overcome this problem, there is a need for continuous increase in the production of food grains. Therefore, there is a need for continuous improvement in traditional farming methods so that agricultural production can be increased and the target of production of food grains can be achieved.

Currently there is a need of such techniques and methods in agriculture, which by producing more in less resources, provide not only food items but also nutritious food to the maximum population as per the requirement. This reduction in numerical workforce is not only seen in developing countries but it is also likely to decrease continuously in future in developed countries. The interest in agriculture of the younger generation is decreasing and they are adopting other fields except agriculture. Therefore, to attract the young generation towards agriculture, there is a need for high technologies like drones, sensor-based machines, and robotics.

Moreover, India is a country of small and medium farmers, whose number is more than 86%, so machines should be made keeping in mind the small and medium farmers. In this episode, with the technological development, robot-based machines can prove to be very useful to make agricultural work easier.Agricultural robot technology is an unavoidable requirement of the 1.0 to 4.0 eras, and its fundamental task is not only to solve the problem of less labor, precision, safety, comfort, and green operationbut also to fill the blank fields where traditional agricultural machinery are unable to do operation.




Source: https://www.mordorintelligence.com/

**Figure 1 Valueof agricultural robot market in the world**

Agricultural robotic systems are now being developed to operate in the field and assist farmers with tiresome jobs, pushing agricultural systems to the new idea of Agriculture 5.0.The value of agricultural robot market in the world is moving towards a steady growth as shown in **Fig.1**. The market value in the year 2014 was US$ 2.6 billion which increased to US$ 3.42 billion in the year 2017 and it is estimated that the market value will reach US$ 10 billion in the year 2023. According to the International Federation of Robotics, the market is mainly occupied by China, Republic of Korea, Japan, USA and Germany, which together account for 74% of their total supply.

## 2 Development of agricultural robot systems

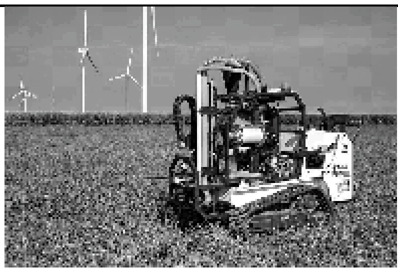
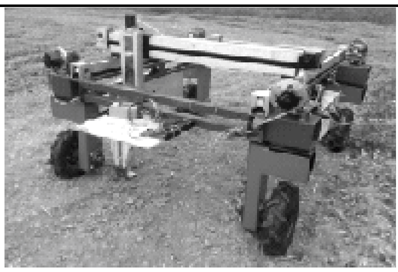
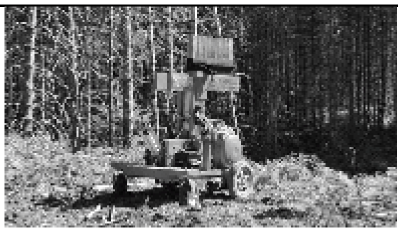
Agricultural robots are now classified using a variety of domain definitions and classification methods. Agricultural robot technology has been investigated and utilized widely in planting, livestock and poultry farming, and aquaculture, as indicated in Table 1. Agricultural robots for phenotyping(Palli et al., 2019; Hang et al., 2017), monitoring, mapping, crop management, environmental control, and other tasks are available in crop farming. Agricultural robots may also undertake phenotyping, monitoring, management, environmental control, and other tasks in cattle and poultry farms and aquaculture. Agricultural robot research and development has covered open field production, semi-closed greenhouse production, and fully enclosed plant factory production, as well as every task of tillaging, grafting (Xie et al., 2020; Jiang et al., 2020), planting, fertilizing, pollination, spraying, harvesting, grading, and so on for crop farming. There are three types of robotic solutions: airborne, earthbound, and aquiclude solutions (Treiber et al., 2019). Agricultural robots may be split into two types based on their operation implementation mode and technological level: non-selective working robots and selective working robots. Working robots that aren't selective don't know who they're working on. Selected working robots, on the other hand, must be able to carry out selective operations on individual agricultural targets by using machine vision or other sensing technologies to identify, position, and diagnose them.

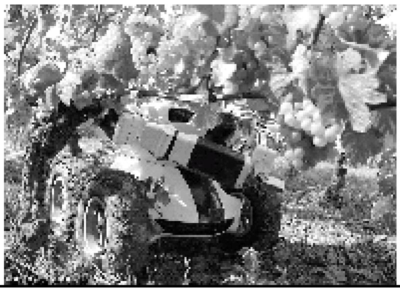
**Table 1 Classification of agricultural robot systems (Jin et al., 2021)**

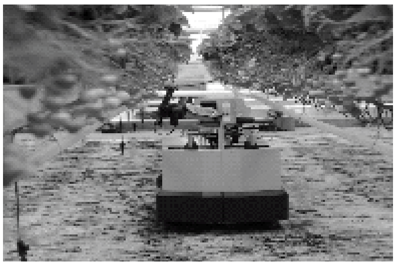
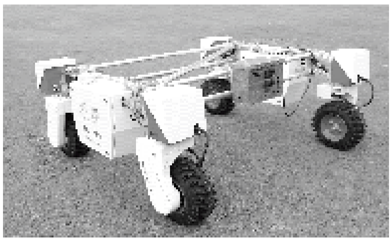
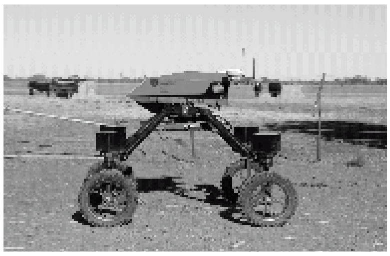
| Aspect | Type |
|---|---|
| Type of industry | Crop farming, livestock and poultry farming, aquaculture |
| Function | Phenotyping, monitoring, mapping, health protection, etc. |
| Intelligent level | Remote-control, man-robot collaboration, full autonomous |
| Working mode | Selective, non-selective |
| Mobility | Stationary, mobile |
| Space | Aerial, ground, aquiclude |

Robots are small as well as suitable for performing frequent, risky tasks which can reduce the dependence of farmers on agricultural labor. The use of robots is also a beneficial solution in such agricultural work which is likely to have a bad effect on health. Robots can be brought in sowing, weeding, hoeing, spraying of fertilizers and pesticides etc. Different applications of robot in agriculture are given in Table 2. Robots are being used successfully in many countries to do agricultural tasks easily which are being used for plucking fruits, removing weeds, etc.

**Table.2 Different applications of robots in Agriculture**

| S. No. | Operation / Task | Description | Appearance example |
|---|---|---|---|
| 1 | Soil sampling | "Smartcore" an automated robot collecting soil samples |  |
| 2 | Seeding | Robot developed by Indian Agricultural Research Institute |  |
| 3 | Transplanting | A tree planting robot named "TreeRover" |  |

| S. No. | Operation / Task | Description | Appearance example |
|---|---|---|---|
| 4 | Weeding | Robot named "Evo" doing weeding work in the fields |  |
| 5 | Weeding | Robot named "Ted" working in the vineyard |  |
| 6 | Weeding | "PUM-Agri" a Universal Mobile Platform for Agriculture |  |
| 7 | Weeding | "Duck" robot developed in Japan working in paddy field |  |
| 8 | Prooning | Robot working in vineyard |  |

| S. No. | Operation / Task | Description | Appearance example |
|---|---|---|---|
| 9 | Harvesting | Strawberry plucking robot developed by Octaneon |  |
| 10 | Mowing | iRobot Automatic Mower |  |
| 11 | Phenotyping | Robot named "Ira" collecting phenotype information at the farm |  |
| 12 | Multipurpose prime mover | "PUM-Agri" a Universal Mobile Platform for Agriculture |  |
| 13 | Poultry | Robot named "Swagbot" developed to look after cattle in cattle-farm |  |

Like automatic vehicles, small sized robots can be used to move between rows of plants in the fields for various types of tasks like weeding, hoeing, spraying fertilizers and pesticides, cutting crops, plucking fruits, sowing seeds etc.Similar to other industries, agriculture is also going to become a high-tech industry full of adventure in which youth and people of other professions are taking interest. New companies and investors are also eager to work in this area and many have even started working. Companies are engaged in developing robots and drones. Agricultural robots are helping in increasing agricultural production in different ways. Various types of robots have been used in agriculture, some of which are as follows-

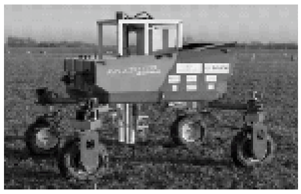
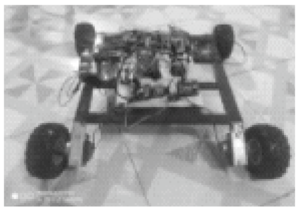
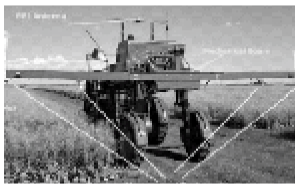
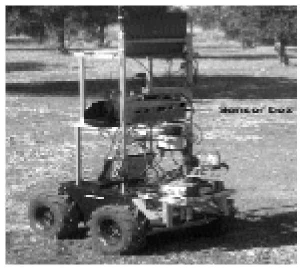
- Soil Testing
- Robot for sowing seeds and for planting seedlings
- Robots for weed control and weeding
- Robots for harvesting and sorting plants and vines
- Fruit picking robot
- Automated robots to harvest grass
- Robots to take care of cattle and pasture

**1. Soil testingrobot**

Due to continuous growing of crops, there is a shortage of nutrients in the soil and to meet these nutrients, the farmer applies different types of fertilizers in the fields. However, nutrient levels in the field may vary from place to place and this affects the germination and growth of seeds, resulting in variation in production in different parts of the same field. That is why farmers need to keep testing the soil of their fields continuously so that the status and level of nutrients present in it can be known. It is a laborious task for the farmers to collect more number of samples from the field to know the variability of nutrients. At the same time, it is also a difficult task to keep accurate information about the place of the samples taken by them. In traditional soil sample collection, changes in depth and sampling location can lead to sampling errors of up to 20%. Errors in sampling may result in farmers having to spend more on fertilizers than necessary or there may be shortage of fertilizers in some areas.

Scholz et al. (2014) developed an automatic soil penetrometer that was integrated into an autonomous mobile robot named Bonirob. Field measurements were taken with the robot in two modes: "manual mode," in which the user controls the system via a remote-control panel, and "automatic mode," in which the robot acts completely automatically. The European Union Vine Robot project, which includes eight partner groups from wine-producing countries such as France, Italy, Germany, and Spain, has created an autonomous robot that will measure vineyard parameters (vegetative growth, grape yield, grape composition, and soil moisture) on-the-go in a non-invasive way to aid winemaking decisions (Saiz et al., 2017; Xu et al., 2021). Examples of different soil monitoring robots are given in Table 3.

**Table.3Soil monitoring robots in agriculture**

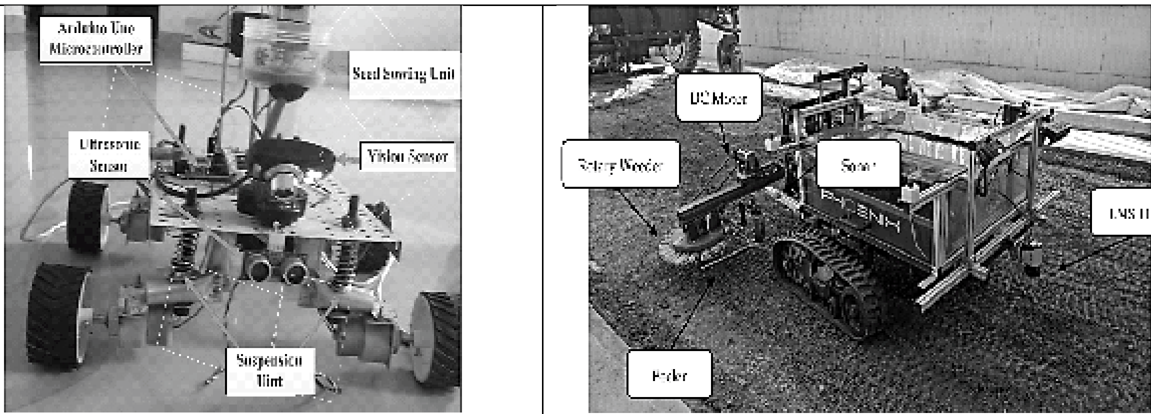
| Sl. No. | Task | Monitoring sensor | Appearance | Reference |
|---|---|---|---|---|
| 1 | Soil monitoring | Penetrometer app |  | Scholz et al., 2014 |
| 2 | Soil and crop growth monitoring | Fluorescence, infrared thermography |  | Saiz et al., 2017 |
| 3 | Soil and climate monitoring | Soil moisture level sensor, weather station |  | Xu et al., 2021 |
| 4 | Crop growth monitoring | ultrasonic sensors, crop circle sensors, infrared thermometer, RGB camera |  | Bayati and Fotouhi, 2018 |
| 5 | Soil monitoring | visual cameras, VIS – NIR sensor, thermal camera, IMU |  | Annalisa at al., 2018 |

**2. Robot for seed sowing and transplanting**

Quality seeds are expensive and are directly responsible for the yield. If improved quality seeds are used, then 20-25 percent more production can be obtained. Along with this, seeds need to be sown at proper distance and depth and robots can be a better option for this task. In small sized fields, where it is not possible to operate large sized machines, small sized robots can be used for the work of sowing seeds and transplanting plants. Vegetable seeds can also be sown by using a dibbler with a robot. Robotic seed sowing systems have been developed using sensing device, Ultrasonic sensor, IR sensor, actuator, seed handling unit, microprocessor, stepper motors, servomotors,communication, and data processing unit(Kumar & Ashok, 2020; Jayakrishna et al., 2018; Nagdeve et al., 2020; Naik et al., 2016; Santhi et al., 2018).

The Indian Institute of Agricultural Research has worked on the development of a precision planter for bold seed. The robotic planter is based on Cartesian coordinate movement for precise

planting. The length of the planter is 1.75 m, width is 2.10 m and height is 1.25 m. The total weight of the planter is 460 kg. It uses four 70Ah batteries and can last up to 4 hours on a single charge. The robot can connect via wireless network to which instructions can be sent via mobile. Robot sows 1.5 m x 1.0 m area in batch process and then proceeds to next batch. It repeats the work cycle as per the command given to the robot. Sowing of paddy and maize seeds was done by robot (Annual report IARI, 2018).
A sensor and vision-based agricultural robot for seed planting was developed by Santhi et al. (2018) (Fig.2 (a)). This prototype can explore any agricultural field while also doing seed planting operations. The navigation and localization tasks are completed using onboard sensors, a vision system, and vision-based techniques. The global and local maps created by the Global Positioning System (GPS) and on-board vision system linked with a personal computer establish the robot's self-awareness of its location.




| (a) | (b) |
|---|---|

Figure 2 (a) Vision and sensor based autonomous seed sowing robot (Santhi et al., 2018), (b) Autonomous robot called “phoenix” with attached rotary weeder implement and sensors (Reiser et al., 2019)

**3. Robots for weed control and weeding**

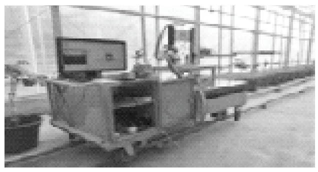
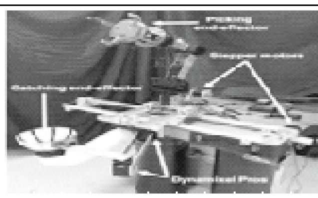
To get more yield, weeding is one of the important tasks, which takes both time and energy. Weed control can be controlled by two methods. The first is mechanical control, in which the weeds are thrown away by mechanical means and the second is the spraying of weedicide chemicals. Spraying of chemicals is easier than mechanical work. However, spraying chemicals is easy on the one hand, on the other hand it is going to harm the body, soil and environment.

For the management of weeds, the use of robots can be used for spraying both mechanical and weedicide chemicals. Where on the one hand the mechanical robot picks up the weeds from the field selectively and on the other hand can spray the weedicide chemicals with accuracy. Mechanical robots work with very slow speed. The robot needs energy to work continuously which can be met by the use of solar energy so that it can work continuously.Like soil testing and plantation robot, these robots also use RTK GPS to move. Simultaneously, these robots use vision-based technology in which the camera is used to make a three-dimensional map and this technology is used to identify plants and their rows.Automation allows for the identification and differentiation of crops from weeds, as well as the removal of weeds using a carefully controlled device (Tillett et al. 2008; Astrand et al., 2002; Cloutier et al., 2007; Griepentrog et al., 2006).To minimize overall weight, the hydraulic motor of the traditional tool was replaced with an electric motor, and several mechanical elements were refabricated by Reiser et al. (2019) as shown in Fig.2(b). Linear electric motors were used to change the side shift, the height, and the tilt. Two distinct approaches for determining trunk locations were tested: a traditional electromechanical sensor (feeler) and a sonar sensor. The robot can work autonomouslyusing row following technique with the help of two-dimensional laser scanner data.

## 4. Robots for harvesting and sorting plants and vines

Robotic multi-arm harvesting has gotten a lot of attention, and it's thought to be able to significantly boost harvesting efficiency (Silwal et al., 2017 and Li et al., 2021). In general, there are two types of robotic multi-arm harvesting: parallel operation and collaboration (Table 4).Multi-arm robots for kiwifruit, tomato, and grape harvesting, as well as other high-density fruit, have been developed by Williams et al. (2020), Zhang et al. (2018), Mu et al. (2020), Chen et al. (2015), Ling et al. (2019), and Liu et al. (2019).

**Table 4 Different types of harvesting robots**

| Object | Category | Detection sensor | Appearance | Reference |
|---|---|---|---|---|
| Kiwifruit | Parallel | A pair of colour cameras |  | Williams et al. (2020) |
| Tomato | Parallel | Xtion (head), Carmine (arm) RGBD sensors |  | Peng et al. (2021) |
| Tomato | Cooperation | Bumblebee2 stereo camera |  | Zhao et al. (2016); Ling et al. (2019) |
| Apple | Cooperation | 3 finger piking, catching |  | Davidson et al. (2017) |

Peng et al. (2021) and Chen et al. (2015) created distinct humanoid dual-arm harvesting robots to meet the new need of the new urban production–leisure integrated industry, which use on-head RGB-D cameras and in-hand RGB-D cameras in a simultaneous operating mode. With many arms and end-effectors working at the same time, it is thought that a substantially greater combined harvesting rate may be achieved(Silwal et al., 2017;Strisciuglio et al., 2018). Harvest zones and harvest order planning, on the other hand, are critical and significant problems in achieving efficiency multiplication (Zhang et al., 2018; Chen et al., 2015; Zion et al., 2014;Mann et al., 2016).

Fruits are among the most important agricultural products in terms of both their economic value and their nutritional and health advantages. A fruit's biological properties are influenced by its location, growing environment, geometric form, size, colour, and hardness, among other variables. Fruit harvesting is a time-consuming and labor-intensive mechanical and repetitive operation. Fruits have biological properties that are determined by the environment in which they develop, as well as their geographical location, geometric form, size, colour, and hardness. Fruit harvesting is a time-consuming and labor-intensive mechanical and repetitive operation. These factors have sparked interest in fruit picking robots (Ceres et al., 1998; Van Henten, 2006; Van Henten et al., 2009; Zou et al., 2012, 2016; Hiroaki et al., 2017) .

Several agricultural harvesting robots based on machine vision have been developed (Bulanon et al., 2002, 2004; Hayashi et al., 2002; Van Henten et al., 2003; Grift et al., 2008; Scarfe et al., 2009; Yin H. et al., 2009; Bechar, 2010) Hands-free navigation and fruit localization are two major problems for robotic subsystems (Jiménez et al., 2000b; Li et al., 2009; Kapach et al., 2012; Wang, 2018; Blok et al., 2019).

**Fig.3 lists some representative forms of picking robots.**


**Figure 3** Representative forms of picking robots in the references. (A) Autonomous coconut-harvesting-robot (Wibowo et al., 2016); (B) Strawberry harvesting robot (Qingchun et al., 2012); (C) Apple harvesting robot (Zhao et al., 2011); (D) Sweet-pepper harvesting robot (Barth et al., 2019); (E) Another sweet-pepper harvesting robot (Hemming et al., 2014); (F) Another apple harvesting robot (Si et al., 2015)

## 5. Robots for Automatic Grass Harvesting

any companies are engaged in developing automatic lawn mowers according to the market demand for the maintenance of fields in the grass. Landscaping companies have to hire laborers to maintain the lawns and it costs about 40-60 percent of the maintenance. That's why the demand for automated robots by landscaping companies has increased. Engine-powered lawn mowers are a menace that injure or paralyze more than 6000 people in the United States each year. That's why lawn mowers have great potential for improvement. However, keeping in mind tight profit margins, labor shortage and environmental concerns, efforts are being made by many startups to innovate in the market. The grasslands are flat as compared to the fields and the task is easier for the automated robots. Grass cutting is the most fundamental but tedious task (Huang et al., 2020; Wang et al., 2018). Remote-controlled and autonomous robotic lawn mowers guided by global navigation satellite systems are welcomed (Ibrahim et al., 2020; Chung et al., 2020) More and more robotic lawn mowings are incorporated with GPS, cameras, ultrasonic sensors to have performances of detection and avoidance of obstacles (Daniyan et al., 2020) (**Fig.5**)

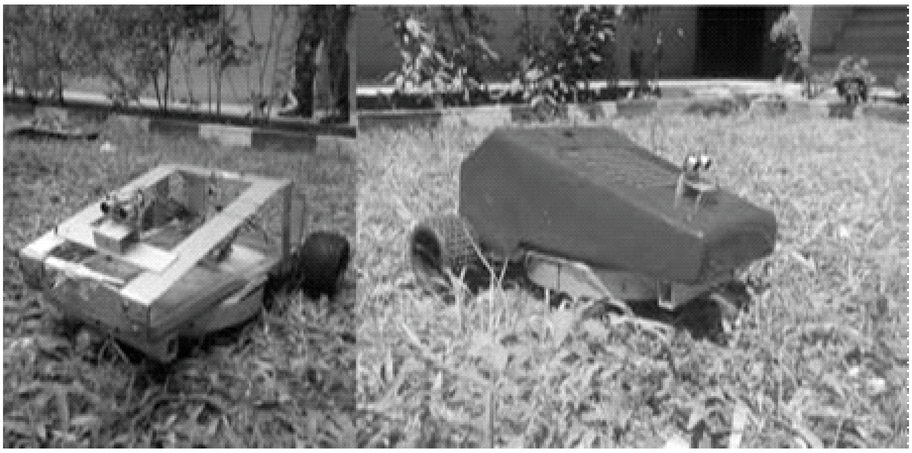
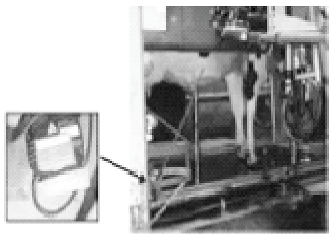
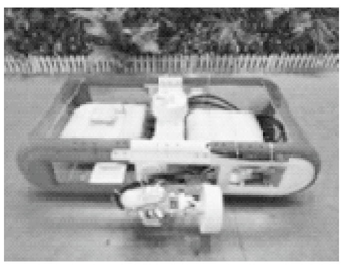
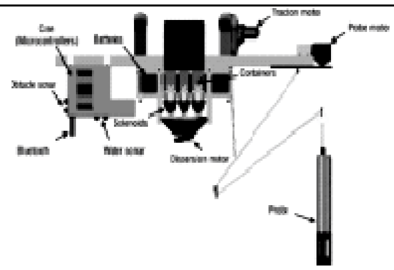


**Figure5.automatic lawn mowing robots**

**6. Robots to take care of livestock and poultry farming and aquaculture**

A field robot is used to monitor livestock and make sure they are healthy and have enough pasture area to graze. The development of a robot called Swagbot was used to look after and guide the cattle. The robot can automatically move along farm roads and collect grass and soil samples. It can spread the grass at certain places in the field, which is very laborious work for the farmer. Soil samples made by robots can be sent to the laboratory for testing and can be used to map and analyze soil fertility for better pastures. This robot is being developed under the Australian Center for Field Robotics (ACFR) in collaboration with the public company Meat and Livestock Australia. Many other organizations are also working to develop other similar robots in Australia. Daily monitoring of poultry houses is necessary to guarantee animal health and effective house operation (Usher et al., 2017). Maintaining optimum health and welfare standards for cattle has long been a primary concern of farmers, and more lately, consumers(Usher et al., 2017). Today, an increasing number of people are working on the development of robotic monitoring systems for livestock and poultry husbandry (Table 3). Farmers and researchers alike are increasingly concerned about the air quality within livestock buildings(EsnaolaGonzalez et al., 2020). Not only will suboptimal air quality have an effect on farm animal production, as well as the health and well-being of livestock and employees, but it will also have an effect on the livestock and poultry industries' healthy and sustainable development (Qi et al., 2016). Due to the heterogeneity of the distribution of indoor environmental factors in livestock and poultry buildings, they required to be monitored regularly, flexibly, and freely(Qi et al., 2016). As a result, robotic monitoring is widely used. Qi et al. (2016)built the robot by retrofitting an off-the-shelf vehicle with a 9-DOF MEMS IMU sensor and mounting measurement instruments (temperature, relative humidity, and dust sensors). In cattle and poultry production, epidemics and outbreaks of numerous illnesses will result in enormous losses. To combat these illnesses, farm scientific technology for health monitoring must be used to lower production costs (Mayer et al, 2004).

**Table 5 Robots for livestock and poultry farming and aquaculture monitoring**

| Function | Monitoring sensor | Appearance | Reference |
|---|---|---|---|
| Air quality monitoring | Temperature sensor, relative humidity sensor, dust sensor |  | Qi et al. (2016) |
| Health monitoring | 6 strain gages, laser distance sensor |  | Pastell et al. (2006) |
| Water quality monitoring | Temperature sensor, pH sensor, dissolved oxygen sensor |  | Huang et al. (2020) |
| Feeding and water monitoring | Physicochemical sensors |   | Borstel et al. (2013) |

## Conclusion

The development of agricultural robots continues to suit the needs of traditional farming practices. Agricultural robots are designed to facilitate not only soil testing but also sowing and planting, weed control and weeding, vine harvesting and pruning, fruit plucking, hay harvesting, phenotype information gathering, cattle and pasture care, etc. Agricultural robots are being used the most for weeding, hoeing and harvesting of fruits and are proving to be more efficient than humans. Along with this, robotic multi-use platforms have also been developed which are being used for various agricultural works. GPS technology and various sensors are being used for navigation in almost all types of robots. Simultaneously, the use of artificial intelligence is increasing continuously. Robotic sector in agriculture is an emerging market in which there is immense potential for jobs and employment, as well as robots will definitely prove helpful in attracting the younger generation to agriculture and increasing agricultural production.

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