

# Agricultural Robots: The Applications of Robotics in Smart Agriculture: towards More Advanced Agro Informatics Practice

P. K. Paul<sup>1</sup>, R. R. Sinha<sup>2</sup>, P. S. Aithal<sup>3</sup>, Ricardo Saavedra<sup>4</sup>, Bashiru Aremu<sup>5</sup>, and S. Mewada<sup>6</sup>

<sup>1</sup>Executive Director, MCIS, Department of CIS, Information Scientist (Offg.), Raiganj University, India, Asia

<sup>2</sup>Pro Vice-Chancellor (Asian Region), Commonwealth Vocational University, Kingdom of Tonga, Oceania

<sup>3</sup>Vice-Chancellor, Srinivas University, Karnataka, India, Asia

<sup>4</sup>Director & Chair, International Inter-University Programs, Azteca University, México, North America

<sup>5</sup>Vice-Chancellor, Crown University, Intl. Chartered Inc. (CUICI) Argentina Campus, South America

<sup>6</sup>President, International Scientific Research Organization for Science, Engineering & Technology, India, Asia

Email: pkpaul.infotech@gmail.com

**Abstract-** Robotics is a machine which is supported by the Artificial Intelligence and Expert Systems. This is basically run with the programmable computer which is run and does the performance and activities automatically. The robotics systems can be done with the integrated systems built inside or it may be done by the external controlling mechanism. It is not mandatory that a robot always looks like a human being. It could be of any form and designing or shape, however, the things in robotics is that it is operated automatically. Robots are applicable in diverse areas and sectors and among these important are include healthcare, business, agriculture, transportation, manufacturing etc. As far as agriculture is concerned, Robotics is very much associated with the various pre and postproduction of agriculture and similar sectors. Initially in harvesting only the robotics were used but currently, there are more concerns where robotics can be applicable viz. drone for the weed controlling, plant seeding, environmental assessing and monitoring, soil mapping and analysis, etc. Initially, only basic Information Technology tools were common in agricultural practices but in recent past, many technologies are using in agriculture and among these important are Cloud Computing, Big Data, HCI, Usability Engineering, Robotics and AI, etc. According to the market analysis companies the growth of the robotics is very increasing and will touch the high very soon. This paper talks about the basics of robotics including a special focus on agriculture. Paper also highlighted the areas of applications with the concern of issues and challenges in brief.

**Keywords:** Agricultural Informatics, Robotics, AI, Artificial Intelligence, Agricultural Sciences, Development, Sustainable Growth in Agriculture.

## I. INTRODUCTION

The application of the Robotics and AI (also similar technologies) are called as Agricultural Robotics. It is increasing applications in diverse areas of agriculture and allied areas such as

1. Drone for the weed controlling
2. Plants seeding
3. Environmental assessing and monitoring
4. Fruit Picking
5. Automated Spraying (Man/ Driverless)
6. Sheep sharing Robots
7. In horticultural activities
8. Automated washing and castrating
9. Soli mapping and analysis, etc.

The uses and market of the Robotics in Agriculture and similar fields are growing rapidly and as per the Market Research Consultancy firm (Verified Market Research), this market may reach to \$11.58 billion by 2025. In Agricultural Robotics practices it is essential that the machine should learn and prepare before their task with the programs and using AI and emerging tools [1], [5], [21]. The machines should get knowledge of different factors by which they have to study or do the performance. Apart from the topics mentioned above, robotics is also very important in livestock management, postproduction, and local field-based transportation in some cases. Agricultural Robotics empowered many advantages and benefits in the concerned business and industry by increasing efficiency, enhanced productivity, minimizing production cost, minimizing manual labour and manpower involvement, etc. Even in such difficult operations, robots can be used effectively [2], [3], [10]. The many technologies involved with the Agricultural Robotic is, robotics; which is powered by the Artificial Intelligence (and within these technologies few important are Expert Systems, Deep Learning, Machine Learning); and few concerns of this technology is provided in next section [7], [14], [24]. Agriculture is emerging as high-tech industry and various companies and organizations are involving in this biggest industry in the world. Even with various new professions and professionals, new investors are also increasing with this field. The advancement of the production and farmers assistance is possible due to the IT and Computing application and the latest robotics and AI as well. Robotics and automation

technology are gearing the sector nicely by different means and stakeholders as well.

## II. OBJECTIVES

The present work is theoretical and conceptual in nature and deals with following aim, objective, and agendas—

1. To learn about the basics of Information Technology and its basic uses in agriculture and allied areas.
2. To know about the Agricultural Informatics with its emerging technologies and role in making smart agriculture.
3. To get the knowledge on Artificial Intelligence including its evolution, features, and functions.
4. To get about the Artificial Intelligence applications in the field of agriculture including its role in enhancing smarter agriculture.
5. To get a picture of issues and current challenges of Artificial Intelligence applications in the field of agriculture.
6. To proposed and suggest in modernizing Artificial Intelligence applications in the field of agriculture

## III. METHODS

The present work entitled ‘Agricultural Robots: The Applications of Robotics in Smart Agriculture—*Towards More Advanced Agro Informatics Practice*’ as theoretical in nature. Moreover, the work also deals with secondary sources initially and various kinds of published secondary works have been consulted viz. Artificial Intelligence, Robotics, DL & ML, Agricultural Sciences, Agro Informatics. The primary sources have also been gathered, analyzed, and reported in this work and in this context to get a current picture of AI based Agro Industries and the company’s current offering and services also been mapped. And these websites of the concerned organization have been checked and analyzed. Moreover, the Government and different agencies report also been analyzed and incorporated here.

### A. Artificial Intelligence

is a kind of simulation of human intelligence and that is enacted in the machines. In such machines, programs are basically acting like humans and mimic their actions nicely. It is also applicable in the machine which basically exhibits traits connected with a human brain viz. learning including problem-solving,etc moreover it is holding the nature of the ability to rationalize as well as take actions for achieving a specific and predefined goal. Artificial Intelligence and robotics are not the same. These two are connected, though people have misconceptions that both are the same [15], [16], [23]. Artificial intelligence is a kind of human intelligence offering devices or systems that can look like a man or maybe a simple device only. Hereafter the mimic machine basically executes tasks or work. Artificial Intelligence basically aimed with the following:

1. Learning
2. Reasoning, and
3. Perception.

Initially, the machines which are able in calculating viz. basic functions or recognize text through optical character recognition are considered as AI. But with the development, the scenario becomes changed and continuously changing [11], [13], [20]. Artificial Intelligence is using the cross-disciplinary subjects for its real development and these include:

1. Mathematics,
2. Computer Science,
3. Linguistics,
4. Mechanical EngineeringPsychology and more.

### B. Agricultural Informatics Vis-À-Vis Smart Agriculture

Agricultural Informatics is the application of Information Science and Technology in the Agriculture and allied areas/ sectors. In general, it is also called as IT in Agriculture. The field of Agricultural Informatics is interdisciplinary in nature and applicable in diverse areas. This becomes a field of study in many countries with different level of programs. Agricultural Informatics uses different components of Information Technology viz. Database Technology, Software Technology, Multimedia Technology, Web Technology, Networking Technology, etc. The Agricultural Informatics is not only the use of IT but additionally documentation and basics of Information Management [8], [17], [27]. In the recent past, various emerging technologies viz. Cloud Computing, Big Data, HCI, Usability Engineering, Robotics and AI,etc are growing rapidly. These technologies are playing a pivotal role in developing Smarter Agricultural practice as well. The applications of Robotics, AI and Machine Learning are tremendous in recent past. Agricultural robots are helping in enhancing the productivity of the yields for the farmers in using drones, harvesting machines, autonomous tractors, agro based robotic arms,etc are rising rapidly and this will help in proving the food requirement of the growing populations.

It is expected that the population will rise 9.7 billion in 2050(from the current 7.3 billion); according to the United Nations. Hence in this regard, more food is needed and thus farmers gave to think beyond the traditional systems to provide such demand in the future. Hence in this context Agricultural Informatics and allied branches viz. –

1. Agricultural Information Systems
2. Agricultural Information Technology
3. Agricultural Computing
4. Agricultural ICT,etc will play a great role.

Especially the technologies viz. Robotics and AI are important to build more intelligent and smarter agriculture and cultivation practices [6], [9], [22].

### C. Agricultural Robot Applications

Agricultural robots with multi-tasking facilities it normally holds the feature of running or doing the task automatics way or do it as automate slow or perform it as repetitive. Hence this way, farmers may have more concentration on the field and more agro production. The basic work performance of the Agricultural robots is depicted in Fig: 1.

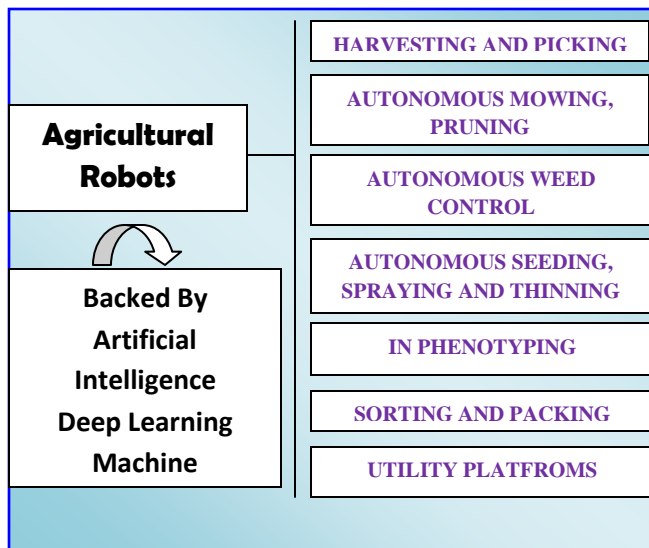


Fig.1 Uses of Agricultural Robots and Basic Applications with Back Up Technology

Robotic applications in agriculture are mostly practiced in harvesting and picking. It offers more accuracy as well as speed. Hence it helps in improving not only in the size of yields but also helps in reducing from the waste from crops. In Agricultural robots, the vision systems are able to find a location and able to get the product irrespective of the situation including dust, temperature, movement of the wind [18], [26], [32]. Though harvesting and picking robots are becoming important Robotic applications in agriculture but there are other sectors in which it is applicable and ultimately helps in agricultural industry development using the automation. The demand for food is the main reason for the uses of robot in agriculture. Robotics is very much associated with the various pre and post production of agriculture and similar sectors. Agricultural Robotics is helpful in following activities (but not limited to):

1. Increasing the efficiency
2. Enhanced productivity
3. Minimizing production cost
4. Minimizing manual labour
5. Industrial promotion and development
6. Helps in harvesting
7. Manpower involvement, etc.

### D. Agricultural Robots & Field Specific Applications

The role of the Agricultural robots is enhancing rapidly and there are many sectors in which robots and artificial

intelligence-based systems can be used for. The robot and AI based tool ultimately helps in food crises and future food demand. The global growing population is the important concern, and, in this context, Agricultural robots is applicable; directly and indirectly. It is a fact till only in developed countries Agricultural robots are used in some context; however, there are huge potentialities in other developing countries in coming days due to its variety of jobs. It is expected according to the market researchers that, Agricultural robots and allied technologies will grow its business at \$ 35 billion within 2025.

Due to the problem of traditional farming and efficiencies provided by the Agricultural robots this is expected. There are plenty of works in which Agricultural robots are applicable and few of them are depicted as under (also refer Fig: 2 to find sample machines and devices, source: official website built-in):

### E. In Planting

Agricultural robots are nicely useful in the planning and nurseries are where seeds are grown into young plants. There are a few factors which help in promoting the planting of different vegetables, crops and plants. Nursery Plants are the prime example of Agricultural robots uses.

### F. In Seeding of the Corps

Agricultural robots are useful in the seeding of the corps over traditional methods for sowing seeds. With the Agricultural robot applications, many seeds around the field can be its right place by the tractor throughout. It is an efficient method and increasing worldwide. In this strategy, robotics, and geo-mapping; both play a well deal. The map in useful to know the soil condition including the quality and quantity and tractors then place the seeds to the field based on soil condition [4], [12], [25]

### G. In Monitoring and Managing Corps

Monitoring is treated as an important job of the agricultural sectors and production and this can be simpler by the uses of Agricultural robots. Here sensor and geo-mapping technologies help to get a good amount and quality of the crops. Here both field-based robots and drones provide can collect the data autonomously and based on this, farmers can decide upon [19], [23], [29].

Here basically robotic hardware including the analysis software is integrated and drone do the task above the field. With the designed systems the data can be collected by the tablet or smartphone in real time.

More specifically these can be done with detailed closer monitoring of the crops, plants, etc and few machines even also able in weeding and fertilizing as well.

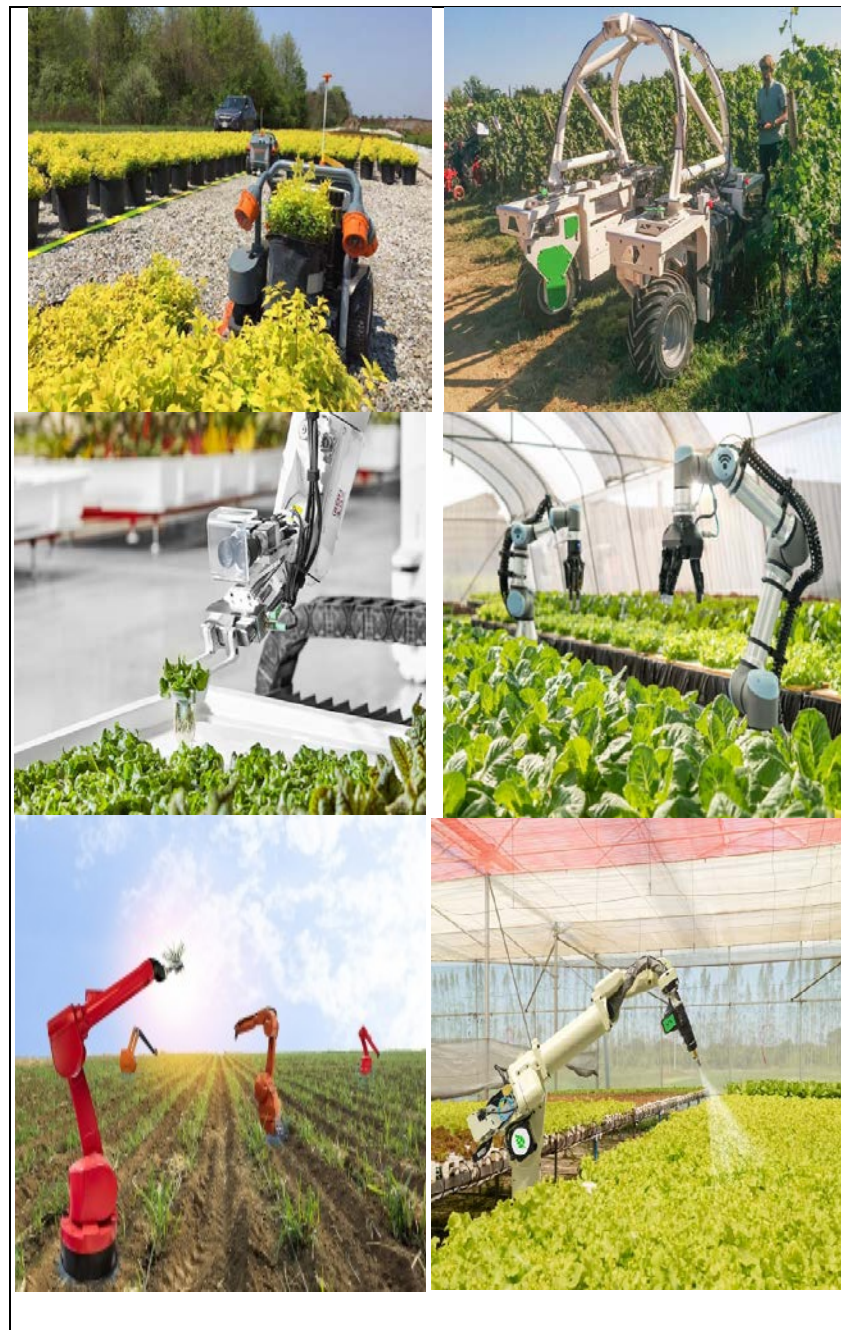


Fig. 2 Samples of Few Intelligent Agro Machines and Robots

### ***H. In Fertilization and Irrigation Activities***

Agricultural robots are perfectly useful in the activities of the irrigation and fertilization to the field and this will be helpful in the production of vegetables, crops, plants, etc. The Agricultural robots can reduce wasted water and, in this context, the ground robots help in crop and pour water directly. Agricultural robots can move anywhere in the field which is not possible by the traditional Agricultural systems [17], [28], [30]. Even some machines are so perfect at their roles that they collect the plants first and then the corps, as plants grow much and ata higher speed than that of crops.

The irrigation is also become possible based on soil conditions and analysis of the water level and need.

### ***I. Weeding ofthe Corps and Spraying***

Agricultural robots are applicable in the spraying with pesticides in the fields.As weeding of corps is a little difficult task the robotis a much efficient method.The micro-spraying is also increasing rapidly and responsible for reducing herbicide used in crop growing. Using computer vision technology this is can be possible and used. Computer vision in some agricultural robots is used to detect plants as it is pushed by a tractor.

### ***J. In Harvesting***

Harvesting of the items viz the crops, plants are an important activity of agriculture or cultivation and it can be done automated and intelligent combine harvester. It could be looks like a tractor. Though, the soft fruits manual harvesting may be required in some context. The automated harvesting is also increasing in some of the diverse areas viz. apple harvesting, grape picking and sweet pepper picking.

### ***K. In Harvesting***

Harvesting of the items viz the crops, plants are an important activity of agriculture or cultivation and it can be done automated and intelligent combine harvester. It could be looks like a tractor. Though, the soft fruits manual harvesting may be required in some context. The automated harvesting is also increasing in some of the diverse areas viz. apple harvesting, grape picking, and sweet pepper picking.

### ***L. Thinning and Pruning the Fields***

Thinning basically deals with reducing the density of plants. So that more plants can grow whereas Pruning is dedicated to the cutting back parts of plants more growth and in this context the agro robots are useful. Many thinning robots are used in computer vision and in this regard many companies are growing viz. LettuceBot. Pruning is another area of use of agricultural robots as pruning is a complex task and more perfect in the wine industry.

### ***M. In Uses of Intelligent Tractors and Transportation***

Intelligent tractors and transportation are the prime examples of the Agricultural robots, which is responsible for the various activities of fields including pre-production, during cultivation and mainly after the growth of the corn, vegetables, and plants as well. This is not only suitable for reducing manual manpower but also in some difficult situations where the uses of manual drivers become difficult. According to a report it is noted that more than 300 thousand tractors were sold just in the year 2016 and this trend is growing internationally.

### ***N. Shepherding and Herding***

As mentioned previously that Agricultural robots are useful in shepherding and herding. This is common in animal's applications such as sheep and cattle farming. Even in some cases, farmers are using drones to see or track of their animals. In New Zealand and Ireland, this trend is growing due to their huge business in this context. Moreover, the remote-controlled, cattle-herding drones will become more popular in the coming days according the market experts [7], [31].

### ***O. In Process of Milking***

The applications of robotics can also be seen in the case of the milking process and nicely applicable in the dairy farms. The UR5 is useful in spray disinfectant on the cow's udders in preparation for milking and this trend is growing rapidly in developed countries and the nations which are the leaders in milk production.

### ***P. Robotics for Agriculture: Concern in Development***

Agricultural robots are increasing day by day. However, the root of this was during the 1920s. This was regarding the designing and development of automatic vehicle guidance into agriculture beginning to take shape. Though later during the 1950s and 60s different automated vehicles become started their operation in agricultural sectors. The development was not so perfect as cable systems need to connect in these systems. During the 1980s the applications of various AI based tools were increased including the development of the computer and IT in agro fields, including machine vision. Initially, the harvesting of oranges considered as an important development in harvesting automatically (in the US and France became popular). Initially only the agricultural firms and in scientific use the AI and Robotics were common and gradually it becomes a tool for the industrial and outer markets. The aspects and issues of manpower and gradual popularity were the main reason for the increasing AI and Robotics applications in the agricultural sectors. In this context, the USA and Japan played a lead role. In the recent past many other countries viz. Germany, Ireland, South Korea, China, India, and even a few countries from Africa as well doing their operation with Agricultural robots and other areas of Agricultural Informatics in their operation [18], [30].

### ***Q. Future Potentials and Context***

Agricultural robots and their uses are rising internationally. Various research work has started in different research organizations, research centers, and universities, etc. The uses of autonomous agricultural vehicles have most recently emerged rapidly and in the coming days, it is to be part of other undeveloped countries due to the initiatives taken by the government of various countries. There are certain issues in cultivating some of the fruits and crops using machines and devices and in this regard research and development activities are going on. Collection of data is an important issue and thus Agricultural robots are using to gather data. Further, various other technologies also employing in different agro related activities and among such few important are include:

1. Cloud Computing and Virtualization
2. Big Data and Analytics
3. HCI and HCC
4. Usability Engineering and UXD

#### IV. ISSUES AND SUGGESTION

Agricultural robots are having a different kind of nature and characteristics and growing its importance worldwide; however, there are few concerns, issues and these can be solved using proper steps such as (also refer Fig: 3)—

1. Agricultural robots are costly; including initial cost and operating such machines become costly. Hence proper support is needed in the developing countries by the concerned countries, departments, agro firms, NGOs, and Charitable Trust, etc.
2. Agricultural robots are not suitable in some of the fruits and products and for this more research and development can be offered.
3. Agricultural robots need proper manpower in its development, development and upgrading and thus proper formal educated manpower is required for more development in the coming days.
4. As it involves various kinds of machines and operations thus farmers should be properly trained on such machines and thus proper workshop, training may be organized on this area for the cultivators and agro industry professionals.
5. Agricultural robots need proper maintenance time to time for their effective uses and better productivity.

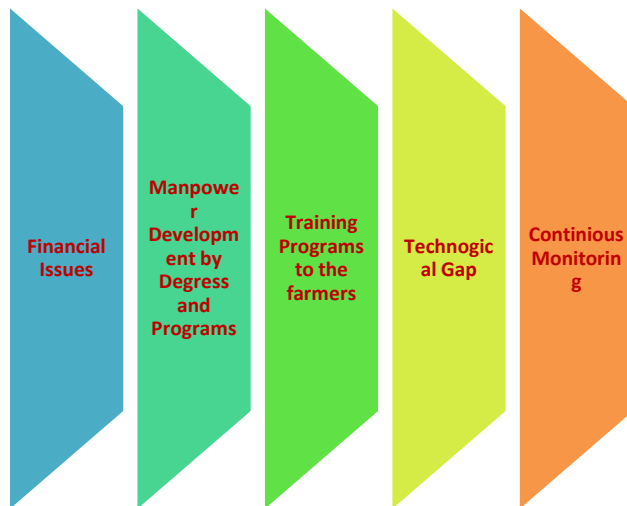


Fig.3 Major issues and concern on Agricultural Robots and technologies

#### V. CONCLUSION

The uses of Agricultural robots are noticeable in some of the developing countries as well. Due to wider benefits including the wider scale business and operation, this becomes possible. Infarming is the milk bot, this is also widely used. Apart from agriculture, the uses of Agricultural robots are noticeable in allied fields viz. in Horticulture and Environmental monitoring and management. RV 100 can be considered as an important tool in this regard for transpiration of the products inside and outside as well. Initially, only in a few activities

Agricultural robots were used and gradually it is started operation in diverse areas and sectors of agro operation. This is due to the sophisticated development of Research and Development, Intelligent devices and machines, emerging Information Technologies, etc. The manpower development is an important issue, and, in this regard, academic programs need to introduce Agricultural robots and allied areas. Even in running Agricultural Informatics, the Agricultural robots may be started as a specialization. Handling and solving the issues can lead to more development in respect of agricultural development no doubt.

#### REFERENCES

- [1] T.Ahmad, S.Ahmad and M. Jamshed, "A knowledge based Indian agriculture: With cloud ERP arrangement". In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)*, 333-340, October, 2015.
- [2] K.R. Aravind, P. Raja and M. Pérez Ruiz, M, "Task-based agricultural mobile robots in arable farming: A review", *Spanish Journal of Agricultural Research*, Vol.15, No.1, pp.1-16, 2016.
- [3] B.A. Aubert, A.Schroeder and J. Grimaudo, "IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology." *Decision support systems*, Vol.54, No.1, pp.510-520, 2012.
- [4] S.M. Babu, A.J. Lakshmi and B.T. Rao, "A study on cloud based Internet of Things: CloudIoT". In *2015 global conference on communication technologies (GCCT)* (60-65). IEEE, April, 2015
- [5] S. Balamurugan, N. Divyabharathi, K. Jayashruthi, M. Bowiya, R.P. Shermey and R. Shanker, "Internet of agriculture: Applying IoT to improve food and farming technology", *International Research Journal of Engineering and Technology (IRJET)*, Vol.3, No.10, pp.713-719, 2016.
- [6] C. Bauckhage and K. Kersting, "Data mining and pattern recognition in agriculture," *KI-Künstliche Intelligenz*, Vol.27, No.4, pp. 313-324, 2013.
- [7] A. Bechar and Y. Edan, "Human-robot collaboration for improved target recognition of agricultural robots". *Industrial Robot: An International Journal*, Vol.30, No.5, pp.432-436.
- [8] A. Bechar and C.Vigneault, "Agricultural robots for field operations: Concepts and components,". *Biosystems Engineering*, Vol.149, pp. 94-111, 2016.
- [9] H. Channe, S. Kothari and D. Kadam, Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *Int. J. Computer Technology & Applications*, Vol.6, No.3, pp.374-382, 2015.
- [10] Y. Edan, "Design of an autonomous agricultural robot". *Applied Intelligence*, Vol.5, No.1, pp.41-50, 1995.
- [11] S.S. Gill, I. Chana and R. Buyya, "IoT based agriculture as a cloud and big data service: the beginning of digital India." *Journal of Organizational and End User Computing (JOEUC)*, Vol.29, No.4, pp.1-23, 2017.
- [12] R. Gómez-Chabla, K. Real-Avilés, C. Morán, P. Grijalva and T. Recalde, "IoT Applications in Agriculture: A Systematic Literature Review". In *2nd International Conference on ICTs in Agronomy and Environment*, pp.68-76, 2019.
- [13] M.S. Goraya and Kaur, "H. Cloud computing in agriculture". *HCTL Open International Journal of Technology Innovations and Research (IJTIR)*, Vol.16, pp.2321-1814, 2015.
- [14] E. Guardo, A. Di Stefano, A. La Corte, M. Sapienza, and M. Scatà, "A fog computing-based iot framework for precision agriculture", *Journal of Internet Technology*, Vol.19, No.5, pp.1401-1411, 2018
- [15] I.A. Hameed, D. Bochtis, and C.A. Sørensen, "An optimized field coverage planning approach for navigation of agricultural robots in fields involving obstacle areas". *International journal of advanced robotic systems*, Vol.10, No.5, pp.231, 2013.
- [16] S.S.Kamble, A. Gunasekaran, and S.A. Gawankar, "Achieving sustainable performance in a data-driven agriculture supply chain: A

- review for research and applications,” *International Journal of Production Economics*, Vol.219, pp.179-194, 2020.
- [17] R.Kajol and K.K. Akshay, “Automated Agricultural Field Analysis and Monitoring System Using IOT,” *International Journal of Information Engineering and Electronic Business*, Vol.11, No.2, 2018.
- [18] A. Na and Isaac, “W, Developing a human-centric agricultural model in the IoT environment.” In *2016 International Conference on Internet of Things and Applications (IOTA)*, pp.92-297, IEEE, 2016.
- [19] B. Ozdogan, A. Gacar, A and H. Aktas, “ Digital agriculture practices in the context of agriculture 4.0,” *Journal of Economics Finance and Accounting*, Vol.4, No.2, pp.186-193, 2017.
- [20] Paul, Prantosh Kumar Minakshi Ghosha and Dipak Chatterjee, “Information Systems & Networks (ISN): Emphasizing Agricultural Information Networks with a case Study of AGRIS,” *Scholars Journal of Agriculture and Veterinary Sciences*, Vol.1, No.1, pp.38-41, 2014
- [21] Paul and Prantosh Kumar, “Information and Knowledge Requirement for Farming and Agriculture Domain,” *International Journal of Soft Computing Bio Informatics*, Vol.4, No.2, pp.80-84, 2013.
- [22] Paul and Prantosh Kumar *etal*, “Agricultural Problems in India requiring solution through Agricultural Information Systems: Problems and Prospects in Developing Countries,” *International Journal of Information Science and Computing*, Vol.2, No.1, pp. 33-40.
- [23] Paul and Prantosh Kumar *etal*. “Cloud Computing and Virtualization in Agricultural Space: A Knowledge Survey,” *Palgo Journal of Agriculture*, Vol.4, No.2, pp.202-206, 2016.
- [24] Paul and Prantosh Kumar *etal*, “Information and Communication Technology and Information: their role in Tea Cultivation and Marketing in the context of Developing Countries—A Theoretical Approach,” *Current Trends in Biotechnology and Chemical Research*, Vol.5, No.2, pp.55-161, 2015
- [25] S.M. Pedersen, S. Fountas, H. Have and B.S. Blackmore, . “Agricultural robots—system analysis and economic feasibility,” *Precision agriculture*, Vol.7, No.4, pp.295-308, 2006.
- [26] N.V.Reddy, A.V.V.Reddy, S. Pranavadithya and J.J. Kumar, “A critical review on agricultural robots,” *International Journal of Mechanical Engineering and Technology*, Vol.7, No. 4, pp.183-188, 2016.
- [27] T. Rezník, K.Charvát, V. Lukas, K. Charvát Jr, S. Horáková and M. Kepka, “Open data model for (precision) agriculture applications and agricultural pollution monitoring”, In *EnviroInfo and ICT for Sustainability 2015*. Atlantis Press, 2015.
- [28] S.Sakai, M. Iida, K. Osuka and M. Umeda, “Design and control of a heavy material handling manipulator for agricultural robots,” *Autonomous Robots*, Vol.25, No.3, pp.189-204.
- [29] H.G.Tanner, K.J. Kyriakopoulos, and N.I. Krikelis, “Advanced agricultural robots: kinematics and dynamics of multiple mobile manipulators handling non-rigid material”. *Computers and electronics in agriculture*, Vol.31, No.1, pp.91-105, 2001.
- [30] F. TongKe, “Smart agriculture based on cloud computing and IOT,” *Journal of Convergence Information Technology*, Vol. 8, No. 2, pp.210-216, 2013.
- [31] S. Vougioukas, S. Fountas, S.Blackmore, and L.Tang, , “Combining reactive and deterministic behaviours for mobile agricultural robots,” *Operational Research*, Vol.5, No.1, pp.153-163, 2005.
- [32] S. Yaghoubi, N.A. Akbarzadeh, S.S. Bazargani, S.S. Bazargani, M. Bamizan and M.I Asl, “ Autonomous robots for agricultural tasks and farm assignment and future trends in agro robots,” *International Journal of Mechanical and Mechatronics Engineering*, Vol.13, No.3, pp. 1-6, 2013.