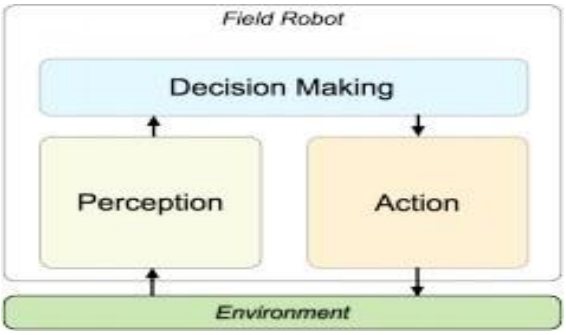


Fig 1. Measures applied in building agrobots[15]

IV. SOFTWARES THAT ARE USED FOR DEVELOPING AGROBOTS

- CARMEN: It is a Robot Navigation Toolkit. It is a modular software the main reason of making it modular is to divide the tasks which contains library for controlling the mobile robots. It has features like collection of data from sensors, algorithms for path mapping, 2d simulators.
- CLARAty It provides a software which can work as a laboratory to and can ease the process of testing and developing the robot. Provides a platform where on can develop local as well as remote acess robots.
- MRDS: It is an environment developed by where development and simulation of robots takes pace. It has its own language Visual Programming Language and also support other languages.
- Orca: Components of software is developed as building blocks and in later stage combined together to make a complex robot and is open-source.
- Orcos: It uses advanced version of C++ libraries for advanced machine and software control. Made to control robots and develop robotic operating system.
- Player: It a software which provides interface to support and control variety of robots. It is based on network-client interface system. Provided network between different robots with the help of TCP protocol. The client system collect the data through various samples.
- Robot Operating System (ROS): It a software which dispense a framework where one can write software for developing robots. It contains a strong library and provides various services. Examples are: inter-process communication, hardware abstraction.

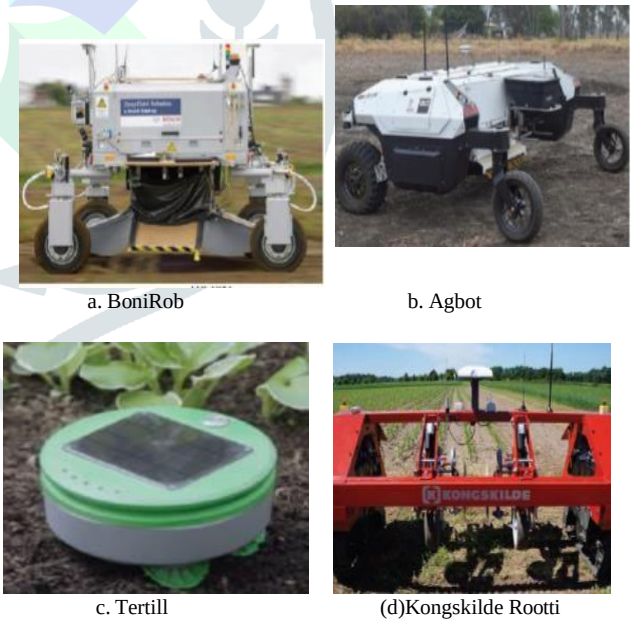
	Agricultural Applications	Multiple Platforms	Multiple Users	Open Source	Updated Recently
CARMEN	Yes	Yes	Yes	(Yes)	No
CLARAty	No	Yes	Yes	(Yes)	No
Agriture	No	No	No	No	No
Agroamara	Yes	No	No	No	No
AMOR	No	No	No	No	No
Mobotware	Yes	Yes	Yes	No	Yes
SAFAR	Yes	Yes	No	No	No
Stanley	No	No	No	No	No

Fig2. Comaprision table for softwares for building agrobots [15]

V. STUDY OF EXISTING AGROBOTS

4.1 Weed control and targeted spraying robots

The main reason to build agrobots is to reduce the involvement of humans in agriculture field. Introduction of robots for weed control is both effective for time and labor. (a)BoniRob this robot can create a detailed map of field and is effective for spraying weedicides for the row crops. (b)Agbot is another robot which is made to detect the weeds and is emancipated in application of fertilizers. It has algorithms for classification of different weeds and then manually or chemically removing it.(c) Tertill is an agricultural robot that uses solar energy for its operation and is made for weed cutting. (d)Kongskilde Rootti is a based on FoboMind and is capable of doing fully or semi-autonomous precision seedling system, weed control and also has furrow opening and cleaning.



a. BoniRob b. Agbot

c. Tertill (d)Kongskilde Rootti

Fig 3. Weed control and targeted spraying robots[14]

4.2 Field scouting and data collection robots

These robots have sensors attend to them to collection of data which is vey tedious task and has a lot of reliability issues. The devices used for data collection must provide veracious

information. If these robots are accurately assembled than will prove its worth in terms of flexibility and multipurpose use and thus will proved to be very cost effective. The devises needed to be equipped with advanced imaging sensors which work with 3d point clouds and also with GPS navigation system.

(a) Trimbot is an autonomous navigation and monitoring robot which is specifically used in rose plantation area. Being equipped with robotic arm these robots are designed for rose cutting and trimming of rose bushes. (b)Wall-Ye is an agrobot specially built for vineyards. It is designed for mapping the grapes through camera and sensors, pruning and harvesting the grapes. (c)Ladybird is used for multiple purposes and is also an autonomous robot used for monitoring, have sensors or mapping objects detected during surveillance and uses advanced classification algorithm for distinguishing between different varieties of vegetables. (d) MARS (Mobile Agricultural Robot Swarm)It consists of swarm of few small and sleek robots. The main idea of designing such robots is to minimize soil compaction and also to reduce energy consumption. These robots can be customized for farm specific use.

(a) Trimbot

(b)Wall-Ye

(c)Ladybird

(d) MARS

Fig 4. Field scouting and data collection robots[14]

4.3 Harvesting robots

Harvesting is an intensive, time-consuming and expensive process of farming. Harvesting is one of the most censorious phases of agriculture, and it poses different challenges. Besides that agricultural harvesting process largely depends on labor availability. So there's a big demand at the process to move to using some autonomous machines. Few of the robots harvested are:

a. Harvey

b. CROPS

c. SWEEPER

d. Energid citrus picking system

Fig 5. Harvesting robots[14]

Most of these robots are emanate on the principle of detect and move. These robots are equipped with high quality of sensors, camera and a robotic arm. The robots detect fruits through camera and sensors. The next step is to move the robotic arm to the fruit so as to pluck it. The algorithms are designed so scan the shortest path between the fruit and robotic arm considering the fact that the branches should be always at the back of the fruit.

VI. DIGITAL FARMING WITH THE HELP OF AGOBOTS

Agriculture sector is facing colossal problem of declining profit. If we take example of country like India whose 60% population is engaged in agriculture yet share only 18% share in GDP. With the help of digital framing and introduction of robots in agriculture there a very good chance of reduction of labor cost and earning more profit.

Digital farming comes with the concept of collecting real-time data of field with the help of integrated technologies than transferring this data to control and processing unit and then advising the farmers to take necessary steps. There are various aspects of digital farming including thermal imaging to check crop and soil health. Digital farming also includes the use of emerging technologies like Big data, cloud computing, data science, Internet of Things, GPS, virtual farms, UAVs, mobile devices and robotics.[14]

Introduction computer to robot communication system involves collection of data than sending it to cloud system and then give the processed results. The cloud based results are more reliable as they include analysis considering both historical and real-time data. With the help of UAV digital framing involves reconstruction od a 3D orchard, using this concept people can connect their farms and provides better data collection and make better decree and predictions.

If we compare this with the traditional methods which used heavy machinery like tractors which caused soil compaction and thus reduces the nutritional values of the soil and takes years to recoup its fertility.

One solution to the above problem proposed by the researchers is using multiple small robots. These robots are devised using high level machine learning and genetic algorithms along with the concepts of artificial intelligence. One such example is construction of nutrient map by a group of robots who collect soil at different field location. But in making multirobot coordination system the primary goal is to find out the design algorithms for obstracle detection, navigation using GPS and coordination between them. These can collect information like: temperature, luminous intensity, presence of carbon dioxide and other harmful gases.

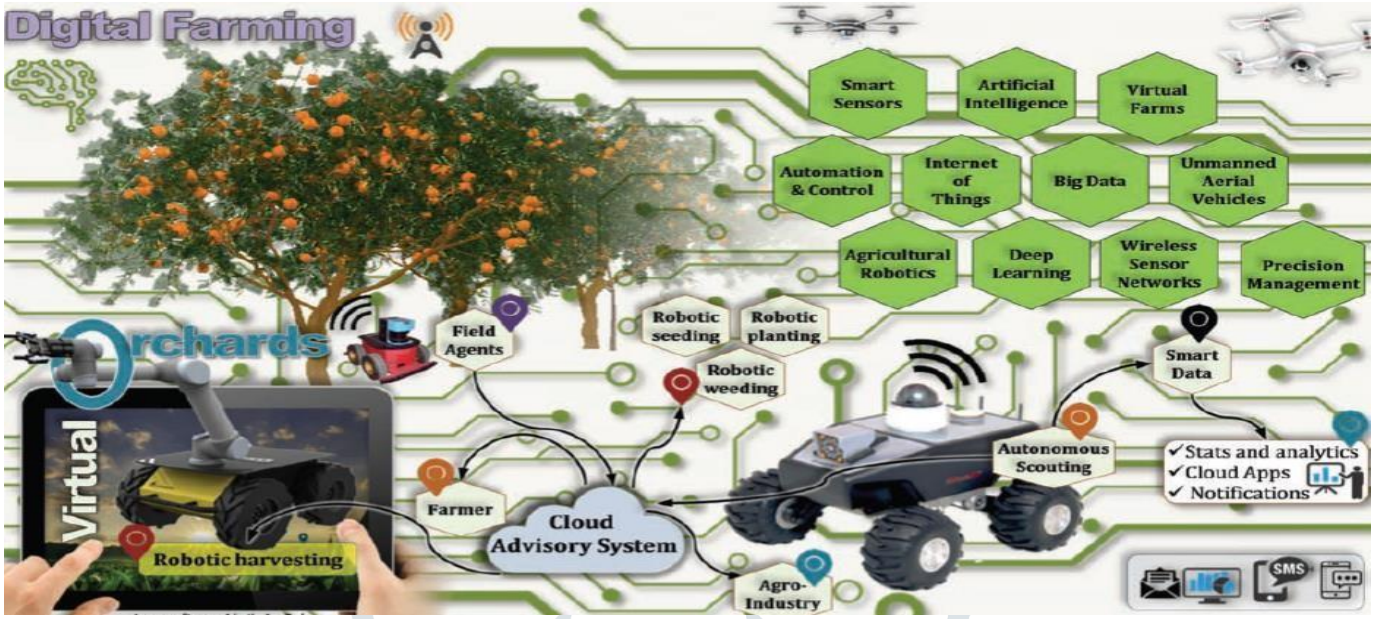


Fig 6. A conceptual illustration of digital farming and virtual orchards with emphasize on the role of agricultural robotics[14]

VII. CHALLANGES IN IMPLEMENTING AGROBOTS

After several years of research now scientists have been able to develop advanced and efficient sensors for collecting information. But data collection is not always ample, it only helps in making better analysis and decision making. Which only reduces our decision making time but can only provide profit if it is supported by efficient management technologies.

One another challenge of using networking in this process is the threat of network being compromised. If the network is being compromised it will cause catastrophic loss for farmers as will create ambiguity in data collected by the farmer. When algorithms are applied on these ambiguous data will abviously produce wrong decisions and predictions and thus will cause a great loss to the farmer.

The next problem in implementing is huge investment these technologies are very beneficial but often benefits come with a cost. Installing robotics equipment in fields comes with a heavy on time investments because the designing of such efficient robots requires a obligatory skill and expertise and also the software used in these robots are very expensive.

Sometimes the system may confuse about the output and may give a wrong output. One of such example is analysis of color of leaf and detecting the disease in plant. The color of leaf may turn yellow due to normal leaf shedding process by a healthy plant or due to lack of nitrogen content in soil or because of lack of moisture. This situation requires machine to interact with human to produce a correct output. But interaction with the humans is not desirable for developing fully automated system.

The other problem with its implementation in developing countries like India is connectivity as the agricultural fields are located in the village areas of the country. The village areas have very poor wireless connection. The main problem with the wireless connectivity signals. We cannot think of robotics system like MARS to be implemented in such interior village areas of a country.

The other challenge is withstanding the wrath of nature some robots might work appropriately in test conditions in laboratories but the things may not work when it comes to a real-time situation. Some of the sensors may even get damaged due to heat or not work appropriately work in excessive cold weather. Withstanding in rain is another a tough task. Robots designed need to be waterproof and be light so that it can be taken out of the field during rain from the marshy soil or need to be implemented with the wheels that could drive robots out of the marshy area.

Maintenance is also a big challenge for the robots because in country like India most of the farmers lack technical knowledge required for the maintenance of the robots. They need either to depend on authorized company for its maintenance or need to hire some technical expert for its maintenance. This will again add up to the cost of total agricultural production.

There has been oodles of research taking place about developing advanced agricultural robots in past few years. The introduction of robots in agriculture has greatly reduced the dependence of framers on labors and helped to overcome the labor shortage problem. With more advanced tools it

provides correct decision steps like accurate detection of diseases or find the requirement of fertilizers in plant, detection and removal of weeds. Robots also involve human interaction to come-up with a fully correct outcome. Example of such system is; if a fruit is missed by a robot than human can detect and direct the machine to pluck it.

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REFERENCES

[1] Bosilj, P., Duckett, T., & Cielniak, G. (2018). Analysis of Morphology-Based Features for Classification of Crop and Weeds in Precision Agriculture. *IEEE Robotics and Automation Letters*, *3*(4), 2950–2956. https://doi.org/10.1109/LRA.2018.2848305

[2] Ramin Shamshiri, R., Weltzien, C., A. Hameed, I., J. Yule, I., E. Grift, T., K. Balasundram, S., … Chowdhary, G. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal of Agricultural and Biological Engineering*, *11*(4), 1–11. https://doi.org/10.25165/j.ijabe.20181104.4278

[3] Behmanesh, M., Hong, T. S., Kassim, M. S. M., Azim, A., & Dashtizadeh, Z. (2017). A brief survey on agricultural robots. *International Journal of Mechanical Engineering and Robotics Research*, *6*(3), 178–182. https://doi.org/10.18178/ijmerr.6.3.178-182

[5] Velayudhan, T. . M., & Yameni, M. . (2012). Design and Static Analysis of Airlesstyre to Reduce Deformation. *IOP Conference Series.: Material Science and Engineering 197 012057*, *36*, 10–12. https://doi.org/10.1088/1757-899X

[6] Li, X. F., Du, Z. H., Yang, C., Lim, C. C., & Ngai, T. F. (2005). Speculative parallel threading architecture and compilation. *Proceedings of the International Conference on Parallel Processing Workshops*, *2005*(January), 285–294. https://doi.org/10.1109/ICPPW.2005.81

[7] Ramin Shamshiri, R., Weltzien, C., A. Hameed, I., J. Yule, I., E. Grift, T., K. Balasundram, S., … Chowdhary, G. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal of Agricultural and Biological Engineering*, *11*(4), 1–11. https://doi.org/10.25165/j.ijabe.20181104.4278

[8] Jensen, K., Larsen, M., Nielsen, S. H., Larsen, L. B., Olsen, K. S., & Jørgensen, R. N. (2014). Towards an open software platform for field robots in precision agriculture. *Robotics*, *3*(2), 207–234. https://doi.org/10.3390/robotics3020207

[9] Zhuang, J., Xu, S., Li, Z., Chen, W., & Wang, D. (2015). Application of intelligence information fusion technology in agriculture monitoring and early-warning research. *Proceedings - 2015 International Conference on Control, Automation and Robotics, ICCAR 2015*, 114–117. https://doi.org/10.1109/ICCAR.2015.7166013

[10]Bosilj, P., Duckett, T., & Cielniak, G. (2018). Analysis of Morphology-Based Features for Classification of Crop and Weeds in Precision Agriculture. *IEEE Robotics and Automation Letters*, *3*(4), 2950–2956. https://doi.org/10.1109/LRA.2018.2848305

[11]UK RAS Network. (2018). The Future of Robotic Agriculture. *UK-RAS White Papers*. Retrieved from www.ukras.org

[12]Benjamin, M. R., Leonard, J. J., Schmidt, H., & Newman, P. M. (2012). Nested Autonomy for Unmanned Marine Vehicles with MOOS-IvP. *Journal of Field Robotics*, *29*(4), 554–575. https://doi.org/10.1002/rob

[13]Amrita Sneha, A., Abirami, E., Ankita, A., Praveena, R., & Srimeena, R. (2015). Agricultural Robot for automatic ploughing and seeding. *Proceedings - 2015 IEEE International Conference on Technological Innovations in ICT for Agriculture and Rural Development, TIAR 2015*, (Tiar), 17–23. https://doi.org/10.1109/TIAR.2015.7358525

[14] Behmanesh, M., Hong, T. S., Kassim, M. S. M., Azim, A., & Dashtizadeh, Z. (2017). A brief survey on agricultural robots. *International Journal of Mechanical Engineering and Robotics Research*, *6*(3), 178–182. https://doi.org/10.18178/ijmerr.6.3.178-182

[15] Bosilj, P., Duckett, T., & Cielniak, G. (2018). Analysis of Morphology-Based Features for Classification of Crop and Weeds in Precision Agriculture. *IEEE Robotics and Automation Letters*, *3*(4), 2950–2956. https://doi.org/10.1109/LRA.2018.2848305

[16]Jensen, K., Larsen, M., Nielsen, S. H., Larsen, L. B., Olsen, K. S., & Jørgensen, R. N. (2014). Towards an open software platform for field robots in precision agriculture. *Robotics*, *3*(2), 207–234. https://doi.org/10.3390/robotics3020207

[16] Alencastre-Miranda, M., Davidson, J. R., Johnson, R. M., Waguespack, H., & Krebs, H. I. (2018). Robotics for Sugarcane Cultivation: Analysis of Billet Quality using Computer Vision. *IEEE Robotics and Automation Letters*, *3*(4), 3828–3835. https://doi.org/10.1109/LRA.2018.2856999

[17] Billingsley, J., Visala, A., & Dunn, M. (2008). Robotics in Agriculture and Forestry. *Springer Handbook of Robotics*, 1065–1077. https://doi.org/10.1007/978-3-540-30301-5_47

Taylor, R. H., Menciassi, A., Fichtinger, G., & Dario, P. (2008). Medical Robotics and Computer-Integrated Surgery (From Springer Handbook for Robotics). *Robotics*, (August 2014), 1199–1222. https://doi.org/10.1007/978-3-540-30301-5

[18]Koli, M., Kori, U., Abdulrahman, & Ahmadakbar. (2017). Seed Sowing Robot. *International Journal of Computer Science Trends and Technology (UCST)*, *5*(2), 131–143.

[19]Tokekar, P., Hook, J. Vander, Mulla, D., & Isler, V. (2016). Sensor Planning for a Symbiotic UAV and UGV System for Precision Agriculture. *IEEE Transactions on Robotics*, *32*(6), 1498–1511. https://doi.org/10.1109/TRO.2016.2603528

[20] Velayudhan, T. . M., & Yameni, M. . (2012). Design and Static Analysis of Airlesstyre to Reduce Deformation. *IOP Conference Series.: Material Science and Engineering 197 012057*, *36*, 10–12. https://doi.org/10.1088/1757-899X

[21] Auat Cheein, F. A., & Carelli, R. (2013). Agricultural robotics: Unmanned robotic service units in agricultural tasks. *IEEE Industrial Electronics Magazine*, *7*(3), 48–58. https://doi.org/10.1109/MIE.2013.2252957

[22] Yang, C., Everitt, J. H., Du, Q., Luo, B., & Chanussot, J. (2013). Using high-resolution airborne and satellite imagery to assess crop growth and yield variability for precision agriculture. *Proceedings of the IEEE*, *101*(3), 582–592. https://doi.org/10.1109/JPROC.2012.2196249

[23] Ball, B. D., Ross, P., English, A., Milani, P., & Richards, D. (2017). *Vision-Based Robotics for Broad-Acre Agriculture* ©. (April)