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Collaborative Agricultural Robot

Fast-Forward the Agricultural Scenario of India

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***Abstract*— The recent commitment of the government supporting the idea that Agri-tech is a burgeoning market and exploring the use of robotics in this important sector would help in increasing the productivity and hence the economy is also enhanced. Agri-tech companies are already working closely with a few farmers in India, using technology, particularly robotics and AI, to help create new technologies and herald new innovations. This is a truly exciting time for the industry as there is a growing recognition that the significant challenges facing global agriculture represent unique opportunities for innovation, investment and commercial growth. This paper aims to provide an overview of the current impact and challenges facing Agri-tech, as well as associated ethical considerations. We hope the paper will provide the reader with an overview of the current trends, technological advances, as well as barriers that may impede the sector's full potential.**

***Index Terms*— Internet of Things; Real Time Kinematics; Crop Monitoring; perception**

I. Introduction

Despite many setbacks, Indian agricultural scenario has surely undergone many drastic changes and has achieved many milestones. The green revolution (1967-1978) transformed India from a food deficient stage to a surplus food market. In a span of 3 decades, India established itself as a net exporter of food grains Also in the Indian context, worth mentioning are the significant results achieved in the fields of dairying and oil seeds through our white and yellow revolutions.

As of now, in terms of agricultural output, India is ranked second in the world. India is also the largest producer in the world for milk, cashew nuts, coconuts, tea, ginger, turmeric and black pepper. India also boosts of the largest cattle population (193 million) in the whole world. India is home to 10 per cent of the world fruit production with first rank in the production of fruits like banana and sapote. With this India is rightly named as the Land of Agriculture and finds a very high portion of its economy.

Presently, Indian Agriculture is witnessing a phase of diversification. During recent years, much awareness has been generated on shifting to high-yielding varieties (HYV) of crops from conventional crops. This has enabled a successful transition in Indian Agriculture from its stagnation to a growth path. The competitive advantages that

Indian agriculture can surely boost of are the favorable agro-climatic zones which are suitable and make Indian land favorable for agriculture, huge irrigated lands and enough supply of skilled, educated, technical and scientific workforce suitable for this field.

II. Field Of Robotics

Those areas in which dirty, dull, and dangerous missions takes place where human worker have a threat to his life and most difficult jobs where human worker must apply terrible effort to accomplished it are replaced by the robots. Those fields in which high accuracy is required are also replacing the human workers. Following are the fields in which robots are introduced:-

In the Field Of Medicine: Robotically assisted surgery was developed to overcome both the limitation of minimally invasive surgery or to enhance the capabilities of surgeons performing open surgery.

Military Applications: Military robots are now used by the united states Army. They are remote control vehicles of unmanned which are used in military application.

Robots In The Mining: Robots are now doing jobs like lying explosives, going underground after blasting to stabilize a mine roof or mining in areas where it is impossible for humans to work of even survive.

Industrial Robots: The first industrial robot, manufactured by UNIMATE, was installed by General Motors in 1961. Thus, industrial robots have been used around for over four decades. Foundry robots is an example which are used in the industry to perform works at a very high temperature where human work is unimaginable. We have following types of robots for industry purpose material removal robot, material handling robot, painting/spraying robot, welding robot, assembling robot, dispensing robot, inspection robot.

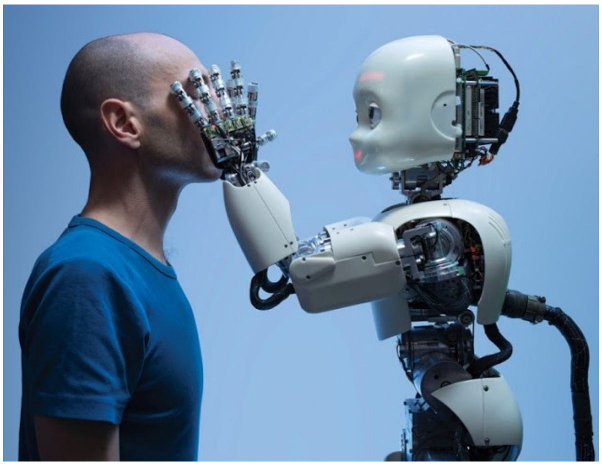

Fig. 1–Scope of Robotics

III. Collaborative Autonomous Agricultural Robot

A. Vision

Our vision is a new generation of smart, flexible, robust, compliant, interconnected robotic and autonomous systems working seamlessly alongside their human coworkers in farms and food factories. Teams of multi-modal, interoperable robotic systems will self-organise and coordinate their activities with the "human in the loop". Electric farm and factory robots with interchangeable tools, including low-tillage solutions, soft robotic grasping technologies and sensors, will support the sustainable intensification of agriculture, drive manufacturing productivity and underpin future food security.

Fig. 2-Robot on Agricultural field

To deliver this vision the research and innovation needs include the development of robust robotic platforms, suited to agricultural environments, and improved capabilities for sensing and perception, planning and coordination, manipulation and grasping, learning and adaptation, interoperability between robots and existing machinery, and human-robot collaboration, including the key issues of safety and user acceptance. Technology adoption is likely to occur in measured steps. Most farmers and food producers will need technologies that can be introduced gradually, alongside and within their existing production systems. Thus, for the foreseeable future, humans and robots will frequently operate collaboratively to perform tasks, and that collaboration must be safe. There will be a transition period in which humans and robots work together as first simple and then more complex parts of work are conducted by robots, driving productivity and enabling human jobs to move up the value chain.

B. Technology

The advent of autonomous system architectures gives us the opportunity to develop a new range of flexible agricultural equipment based on small, smart machines that reduces waste, improves economic viability, reduces environmental impact and increases food sustainability. There is also considerable potential for robotics technologies to increase the window of opportunity for intervention, for example, being able to travel on wet soils, work at night, etc. Sensory data collected by robotic platforms in the field can further provide a wealth of information about soil, seeds, livestock, crops, costs, farm equipment and the use of water and fertiliser. Low-cost Internet of Things (IoT) technologies and advanced analytics are already beginning to help farmers analyse data on weather, temperature, moisture, prices, etc., and provide insights into how to optimise yield, improve planning, make smarter decisions about the level of resources needed, and determine when and where to distribute those resources to minimise waste and increase yields [1]. Future telecommunications availability is likely to enhance IoT capacity, with Agri-tech test beds already under development.

Fig 3- Environment mapping

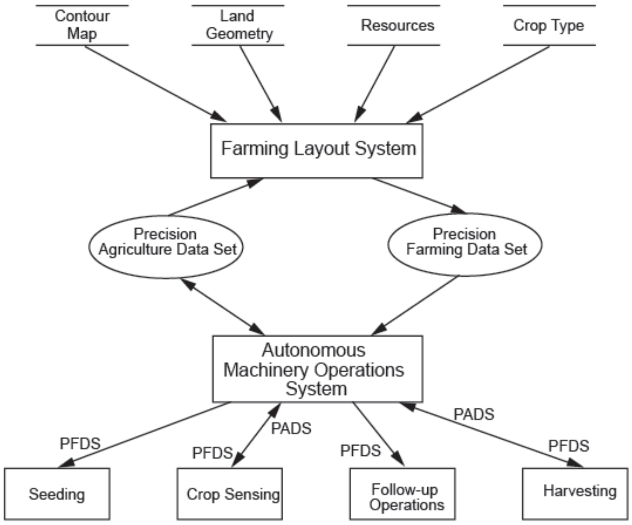

Fig. 4- Autonomous Machinery operating system

Our long-term technology vision encompasses a new generation of smart, flexible, robust, compliant, interconnected robotic systems working seamlessly alongside their human co-workers in farms and food factories. Teams of multi-modal, interoperable robotic systems will self-organize and coordinate their activities alongside and within existing Agri-Food systems. Electric farm and factory robots with interchangeable tools, including low-tillage solutions, novel soft robotic grasping technologies and sensors, will support the sustainable intensification of agriculture and drive manufacturing productivity throughout the food chain. Future Agri-robotic systems will deploy artificial intelligence and machine learning techniques to increase their own productivity. Meanwhile, investigation of alternative systems for food production, including innovations from areas such as vertical farming, will further help to address the sustainable intensification of agriculture, while protecting the environment, food quality and health. A vital aspect of making this transition effective is the clear demonstration of economic benefits, which has always been the primary driver of change to the agricultural community. While some emerging robotic technologies are already achieving or approaching the robustness and cost-effectiveness required for real-world deployment, other technologies are not yet at that stage. For example, soft fruit picking still requires fundamental research in sensing, manipulation and soft robotics.

A wide range of technologies will enable the transition of agricultural robotics into the field. Some technologies will need to be developed specifically for agriculture, while other technologies already developed for other areas could be adapted to the agricultural domain, for example, autonomous vehicles, artificial intelligence and machine vision.

C. Locomotion

Agricultural robots need to move in challenging dynamic and semi-structured environments. Ground robots needs to travel on uneven, inhomogeneous, muddy soil, while aerial vehicles need to operate for long periods of time, in different weather conditions. Current Agri-robots are mainly designed by borrowing technology from other sectors (e.g. drones) or as an add-on to existing platforms (e.g. autonomous tractors). As such, they may be not fully optimised for their tasks, or may retain some of the limitations of existing platforms. UAVs can fly using multiple rotors or a fixed wing platform (with precision of location in the former and extended flight time in the latter), whereas ground platforms need to be able to locomote on rails and concrete floor in greenhouses, on gravel or grass in polytunnels, and in extremely muddy and difficult terrain in open fields.[2] We will therefore see a wide variety of robots being developed with different means to locomote.

Compared to tractors, these robots are extremely lightweight, but as robots (or autonomous tractors) are to perform more energy demanding task, the robots will also increase in size and weight. Most agricultural robots today run on batteries and electrical motors.

Fig.5- Flexible legs of robot for easy locomotion

Fig.6- Locomotion of tractor

Future developments will depend on how the battery technology evolves, but we will probably see both electric and combustion engines in the field for the foreseeable future.

D. Manipulator

Manipulators will be needed for a range of tasks in future agriculture, replacing dexterous human labour, reducing costs and increasing quality, or performing operations more selectively than current larger machinery like slaughter harvesters. Work in this direction is ongoing, with soft grippers used for experimental work on selectively harvesting mushrooms, sweet peppers, tomatoes, raspberries and strawberries. In the open field, and for protected crops, there are complementary tasks to harvesting where manipulators can also play an important role. This includes mechanical weeding, precision spraying, and other forms of inspection and treatment. Manipulators will also be needed for the increased automation seen in food handling applications, such as large automated warehouses.

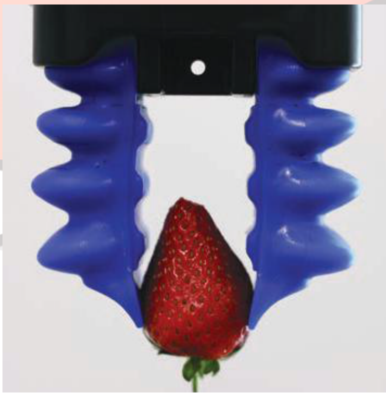

Fig.7- Soft manipulator

E. Localization and Mapping

The use of GPS navigation in agriculture has become almost ubiquitous with the deployment of RTK (Real Time Kinematics) allowing accuracy of centimeters for the automated positioning of large farm machinery such as tractors and combined harvesters. Sensor information is also required in detecting objects and risks in field in order to ensure safe operation of robotic vehicles. To minimize damage to crops, the accuracy of relative positioning and navigation is more important than that of absolute navigation and position as provided by RTK GPS in many applications. Multi-modal systems based on a combination of GPS, INS, LiDAR, vision, etc have further potential for providing accurate and robust solutions, without requiring in-field infrastructure. Robotic sensing platforms offer the potential for broad area analysis of insect pest or pollinator movement and their speciation, utilising 3D microphones alone or in combination with light backscatter measurements to enable daylight measurements of characteristic flight trajectories. Thematic maps can be built up for diseases, pests or weeds, which enable variable rate treatments, a key concept in precision agriculture.

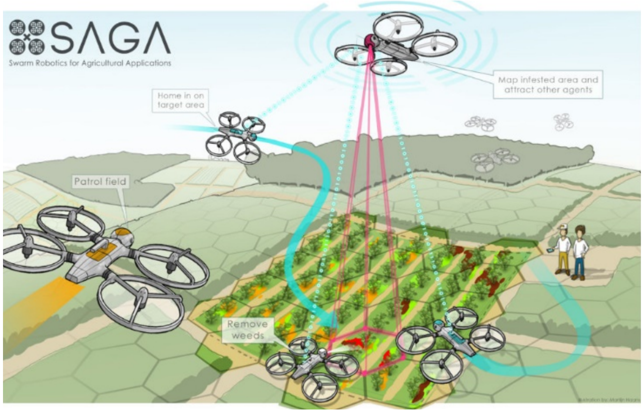

Fig. 8-Swarm Robotics for Agricultural Application

F. Crop Monitoring

The use of both land-based and aerial platforms can allow the third dimension to be accurately added to the management of crops using data fusion and SLAM techniques. This can be combined with virtual reality or augmented reality (VR/AR) systems to provide monitoring and intervention possibilities to an individual plant scale. Long-term data collection will further enable the modelling of crops over time, for example, tracking the development of the crop canopy, and thus improved prediction of future growth patterns. For example, through applying a focused beam of light at specific areas of crop tissue, and then modulating the spectrum and intensity, it is possible to drive photo-chemistries within specific parts of plants, e.g. stems, young leaves, senesced older leaves, etc., which can then be sensed via multispectral imaging.

G. Robotic Vision

Machine vision approaches offer significant opportunities

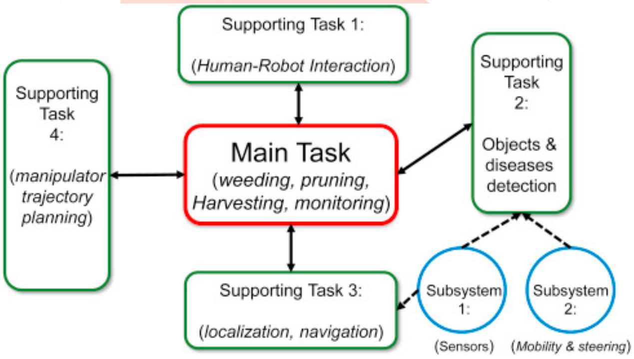

Fig.9-Robot tasks in Agriculture

for enabling autonomy of robotic systems in food production. Vision-based tasks for crop monitoring include phenotyping[3], classifying when individual plants are ready for harvest, and quality analysis , e.g. detecting the onset of diseases, all with high throughput data. Vision systems are also required for detection, segmentation, classification and tracking of objects such as fruits, plants, livestock, people, etc., and semantic segmentation of crops versus weeds[4], etc. to enable scene analysis (understanding "what" is "where" and "when") and safe operation of robotic systems in the field. Robotic vision in agriculture requires robustness to changes in illumination, weather conditions, image background and object appearance, e.g. as plants grow, while ensuring sufficient accuracy and real-time performance to support on-board decision making and vision guided control of robotic systems.

Fig.10- Crop Monitoring system

H. Planning and Coordination

The true potential of robotics in agriculture will be harnessed when different types of robots and autonomous systems are brought together in a systemic approach. Planning, scheduling and coordination are fundamental to the control of multi-robot systems on the farm, and more generally for increasing the level of automation in agriculture and farming. For example, intelligent irrigation systems can respond to the change of weather conditions and crop growth status to automatically optimise the irrigation strategy so as to reduce the use of fresh water without loss of yields. The optimised strategy (e.g. when, where and the amount of water) is then implemented by computer-controlled irrigation equipment.

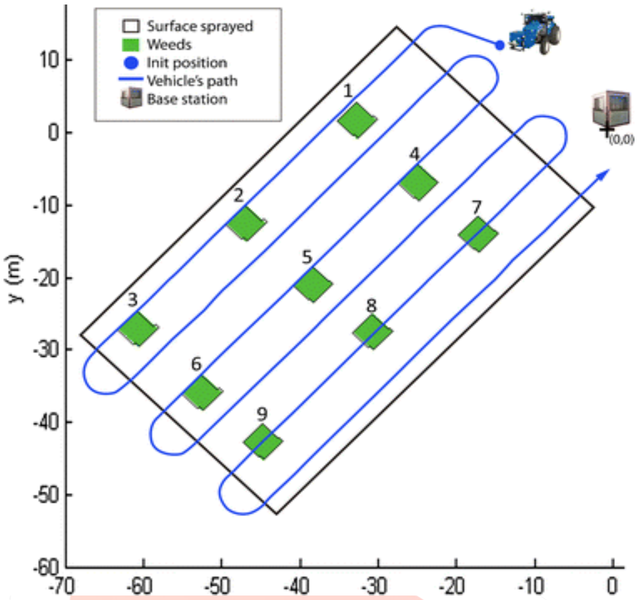

Fig.11- Robot path and function planning

IV. CHALLENGES

Establishment and Seeding

Ploughing is one of the most important primary cultivation processes, and involves the inversion or mixing of topsoil to prepare a suitable seed bed. Currently modern agriculture uses a huge amount of energy in ploughing: it is estimated that 80%-90% of the energy in traditional cultivation is used to repair the damage done by large tractors. Seed placement and mapping could be further automated to optimise the density and seeding pattern with respect to the requirements for air, light, nutrients and ground moisture of the individual crop plants. Robotics will also have an important role to play in managing the inputs to primary production, including both monitoring and interventions, particularly for soil and water [5] [6].

Crop Care

One of the main operations in crop management is scouting to collect timely and accurate information. Autonomous robots carrying a range of sensors to assess crop health and status could thus assist in cost-effective data collection. Both aerial and ground-based platforms, or their combination [7], could be utilised. Fusing data collected by different devices or obtained from sources with a wide range of temporal and spatial resolutions and automatically.

Selective Harvesting

Selective harvesting involves harvesting only those parts of the crop that meet certain quality or quantity thresholds [8]. Two criteria are needed: the ability to sense the required quality factor before harvest (in-field grading) and the ability to harvest the product of interest without damaging the remaining crop. Selective harvesting presents several challenges for current robotic technology, perhaps the foremost of which is how to perform autonomous sensorimotor coordination with noisy and incomplete sensory data in the complex agricultural environment.

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