



Robotics, Artificial Intelligence and IoT Enabled Technologies can Change the Agricultural Scenario in Developing Nations

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Received: December 26, 2024

Published: February 01, 2025

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Technology advancements, urbanization, contemporary farming methods, and climate change are all transforming agriculture in developing nations. With the adoption of cutting-edge technologies like sensors, actuators, controllers, Internet of Things (IoT), artificial intelligence (AI), and robotics, agriculture can become more productive, economically rewarding, socially acceptable, and environmentally sustainable. In many developing countries during the past ten years, research in the fields of precision agriculture, digital farming, precision irrigation, user-friendly mobile applications, etc. have accelerated. These technologies simplify the majority of repetitive and labor-intensive tasks, including sowing/planting, irrigation, weeding, crop scouting, and grading/sorting. Other linked industries, such as livestock management, animal health monitoring, feeding and processing, on-farm storage, and product quality evaluation, including monitoring at the farm gate for initial storage, also benefit from similar technologies (Subeesh and Mehta, 2021, Khadatkar, et al., 2022). Precision farm management tools (GPS/GNSS, DSS, VRT), end-user applications (apps, mobiles, machines, Agri-bots), and data solutions (data IoT, information, tech-empowered tools) are all part of the burgeoning agriculture mechanization. In addition to making agriculture smart and effective, these technologies also help agriculture to become more sustainable conserving resources like seeds, fertilizer, chemicals, water, and electricity.

Even though it has undergone a profound transformation over the past decade, the farm machinery business still confronts several difficulties. With the use of sensors, actuators, and motors over the past few decades, the agricultural production system has undergone a significant transformation. In addition, lack of manpower in crop production has highlighted the need for alternative

solutions like AI, robots, big data analytics, IoTs, etc. for a secure and long-lasting agricultural system that makes use of technologies. Precision and cloud-based data are predicted to rule agriculture in the future, supported by high-tech equipment including smart tractors, unmanned aerial vehicles, wireless technologies, and autonomous vehicles for multi-purpose field operations. For these technologies to be accepted by the farming community as widely as possible, they must be made simple and affordable. With the help of a decision support system or mobile app-based system, farmers may make strategic decisions, which is more data-centric.

Robotic manipulators would be the future for performing seeding and transplanting seedlings automatically with high precision and accuracy. By using machine vision or embedded systems for seedling localization, extraction and release can be done with ease (Khadatkar, et al., 2021; Khadatkar, et al., 2023). It consists of a robotic arm for seedling pick-up, a path manipulator, and an end-effector.

Drones are a versatile choice for many agricultural tasks, including crop monitoring, disease detection, agricultural surveying, crop scouting, yield estimation, animal monitoring, etc. (Shina, 2020; Khadatkar, et al., 2021). In addition, attempts were made to use drones to spray pesticides on field crops too. Agriculture practices that integrate drone-based aerial intelligence produce effective data-driven decision-support systems. It is very helpful to employ thermal, multi-spectral, and hyper-spectral sensors to find crops that are infested with weeds and pests. Advanced image processing combined with data collection can help to determine the precise quantity of pesticides needed to combat infestations in addition to targeted spraying. Other advantages include reduced chemical

runoff into rivers and groundwater, optimum use of irrigation water, fertilizer, and pesticides, which in turn helps to keep food costs low and lessens the impact on adverse natural ecosystems, and most crucially, enhanced worker's safety. In the upcoming years, it is also anticipated that there would be fewer workers available in agriculture. Concerns about food security, population expansion, and climate change have prompted the agriculture sector to look for more creative ways to safeguard and boost crop productivity. The demand for food will rise along with the supply of high-quality food, forcing farmers to embrace precision farming on a broad scale. The need for agricultural drones will increase in the future as a result of the issue of trained labour and the automation of agriculture through information and communication technology.

With the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.), IoT smart farming solutions automate irrigation systems and keep an eye on agricultural fields. IoT technology is allowing farmers to manage their fields and livestock more accurately and effectively than that of previous physical practice. Large qualitative datasets are made available by these technologies, which may be leveraged to identify hidden patterns and create decision support systems. Sensing technology has demonstrated its importance in monitoring agriculture and analysing animal behaviour, which was previously challenging using a manual technique. The best welfare for dairy cows will be ensured by incorporating these technologies into "smart" husbandry support systems, which will also increase farm profitability.

The use of IoT applications in agriculture has produced a number of advantages, including improved access to farm data, forecasting of plant diseases, improved crop protection, irrigation management, decreased resource waste, and the detection of patterns and trends, among others. These technologies have made it possible for farmers to get more accurate data on a variety of agricultural characteristics, enhancing the quality of decision-making and increasing return on investment (RoI). Although IoTs currently have certain challenges, they are outweighed by their benefits. Additionally, IoT and AI technologies have the ability to provide a greater return on investment for successful farming.

At first glance, the employment of robots in agricultural operations may appear impractical, yet it is now absolutely necessary to

both address the labour crisis as well as ensure the food security of the world's expanding population. Robotic farm equipment not only has the potential to be used for labor-intensive repetitive farm tasks, but also provides further benefits to get around labour shortages or unavailability for tasks like weeding, spraying, and harvesting fruits and vegetables. Drones may be used to evaluate the geographical and temporal management of field crops, according to research, which can be applied for more effective large-scale agricultural planning and monitoring. Again, due to rising manpower costs, robotic technology in agriculture needs to be used and timeliness in field operations should be ensured.