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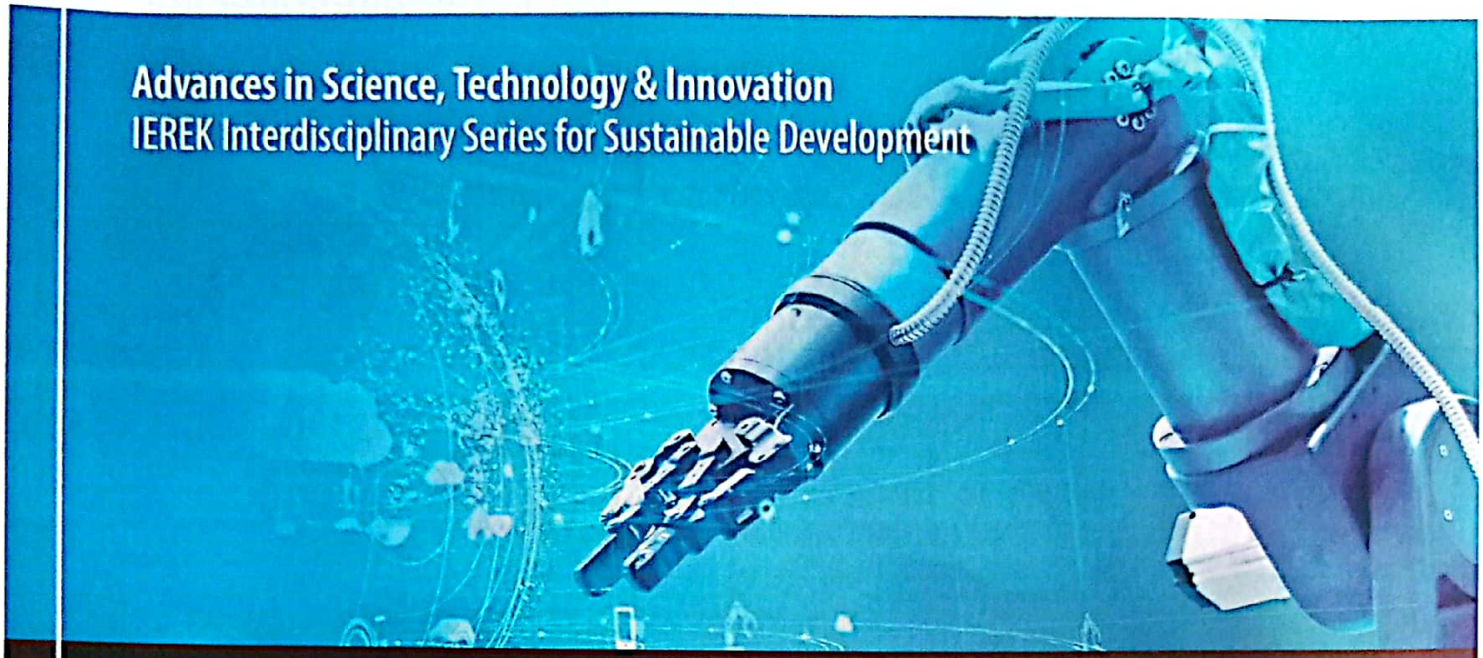

Krishna Kant Singh · Anand Nayyar · Sudeep Tanwar ·
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Emergence of Cyber Physical System and IoT in Smart Automation and Robotics

Computer Engineering in Automation

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Contents

An IoT-Based Autonomous Robot System for Maize Precision Agriculture Operations in Sub-Saharan Africa

Jibril Abdullahi Bala, Olayemi Mikail Olaniyi, Taliha Abiodun Folorunso, and Emmanuel Daniya

Abstract

The importance of agriculture to the economic growth in sub-Saharan Africa suffers from several challenges. One of the major problems faced by the sector is the lack of suitable technology to optimize yield and profit to reduce the reliance of farmers on manual techniques of farming which is accompanied by drudgery, wastage, and low yields. Precision agriculture has been applied to maximize agricultural outputs while minimizing inputs. This study presents the design of an Internet of things (IoT)-based autonomous robot system that can be used for precision agricultural operations in maize crop production. The robot consists of a camera for remotely monitoring of the environment and a tank incorporated with a liquid level sensor which can be used for irrigation and herbicide application. The real-time feed from the camera as well as the output from the liquid level sensor is accessed from a cloud database via a Web application. This system can be adopted for improved crop production which in turn will increase crop yield, profit, and revenue generated from agriculture.

Keywords

Artificial intelligence • Fuzzy logic • Image processing • Internet of things • Precision agriculture • Robot navigation

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1 Introduction

1.1 Background of the Study

In the twenty-first century, there has been a rapid growth in the information and communication technology (ICT) sector. This development has influenced human operations and industrial services. One of the most important developments in the ICT sector is the introduction of the Internet (Yusuf et al., 2019). Internet of things (IoT) is a system of interconnecting computing devices that are interrelated. These devices can transfer data over a network with the absence of human involvement (Iwayemi, 2018). The IoT is a network of physical devices, objects, buildings, people, animals, and other items that are embedded with sensors, software, electronic devices, and network connectivity that supports communication, collection, and exchange of data (Dubey et al., 2020; Nayyar and Puri, 2016a, 2016b; Padikkapparambil, 2020; Singh et al., 2020a, 2020b; Tanwar 2020a, 2020b). This technology allows devices to be remotely controlled and sensed using network infrastructure. This process allows the integration between the physical world and computer systems, which in turn, results in improved economic benefits, efficiency, effectiveness, and accuracy (Amadin et al., 2017). The IoT has a wide range of applications in various sectors including agriculture.

The Food and Agriculture Organization (FAO) estimated a 70% increase in global food production by the year 2050 (Ishengoma & Athuman, 2018). Also, the population of the African continent is projected to reach 2 billion by 2050 (Ishengoma & Athuman, 2018). Feeding this population would be quite challenging with limited farming methods. Currently, farmers in sub-Saharan Africa cultivate less area of land and harvest less due to a lack of technological development in the agricultural sector. Besides, traditional farming techniques predominantly used in the region results in low crop yield compared to mechanized farming methods. Africa has 25% of the world's arable land, yet it contributes

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only 10% of the global agricultural output (Ishengoma & Athuman, 2018).

Nigeria is West Africa's largest economy, and second largest in sub-Saharan Africa. The country is vast with approximately 68 million hectares of arable land, 12.6 million hectares of freshwater supplies, and an ecological diversity that provides the supplies required to produce and grow a wide variety of crops (Ewetan et al., 2017). Agriculture makes approximately a quarter of Nigeria's overall nominal gross domestic product (GDP).

In Nigeria, maize has evolved from a backyard crop to the third most important crop in terms of output and the area cultivated. Nigeria is the leading producer of maize in West Africa and the tenth-largest producer in the world. The 2008 FAO statistics reported that about 7.5 million tons of maize with an average yield of 1.9 metric tons per hectare produced in the country (Ammani, 2015). The crop is recognized as a major source of food and cash income among Nigerian farmers. Although the production of maize significantly increased in Nigeria between 1990 and 2011, an increase in population which leads to an increase in demand results in the need for improved maize production in the region (Ammani, 2015).

Precision agriculture (PA) highlights the fact that an understanding of variability within a crop field will achieve increased agricultural production. The goal is not to obtain the same outputs or yields all over the farm, but to evaluate the environment and distribute different site-specific inputs. This method can optimize agricultural benefits and produce a strong return on investment (Banu, 2015). In PA, the gap between mechanized farming and ICT is bridged by collecting farmland information and applying data analysis-based inputs. Farm operations such as application of herbicides, fertilizers, and irrigation can be done smartly, enabling farmers to achieve high yields, exact inputs use, reduce wastage, and maximize income (Beluhova-Uzunova & Dunchev, 2019).

The implementation of PA and IoT technologies has the potential to revolutionize the agricultural sector in sub-Saharan Africa. This study presents the conceptual design of an IoT-based autonomous robot system for maize production under precision agricultural operations. This system uses IoT, control, and AI technology to incorporate a smart, intelligent robotic device for precision maize farming. This system is expected to improve agricultural yield and profit, as well as bring a high return on investment for the region.

The remainder of the chapter is organized into four sections. Section 2 presents a review of existing literature including identified research gaps. The research implementation strategy and methodology is presented in Sect. 3. The expected results of the research are presented in Sect. 4 while the conclusion is given in Sect. 5.

1.2 IoT Advancements in Sub-Saharan Africa

The IoT development in the sub-Saharan African region has improved over the years as many African countries have already taken advantage of the technology. This stride can be seen in health care which tracks the health of their patients remotely to utility companies that monitor the usage of their resources for analytics purposes. However, despite the advancement in some sectors, the lack of suitable infrastructure makes it difficult for the region to make significant growth in areas that other developed nations find relatively easy (Ndubuaku & Okereafor, 2015a). West Africa has recently experienced rapid economic development with 90% of the population having access to mobile phones. With this trend, IoT has the potential of contributing immensely to various sectors (Dupont et al., 2018).

Several factors can lead to massive IoT deployment in numerous sectors. These include cost reduction for the majority of the products and services associated with IoT systems (Ndubuaku & Okereafor, 2015a). Other factors include:

i. Cheaper cost of bandwidth and sensors.
ii. Cheaper processing costs.
iii. Introduction and use of Big Data analytics.
iv. Widespread use of smartphones.
v. Cheaper and more accessible wireless networks.
vi. Alternative energy and low power technologies.

Despite the lag of IoT development in the sub-Saharan African region, there have been implementations of this technology in several areas across the region. These applications include vehicle tracking, air quality monitoring, railway tracks, and disease diagnosis in countries such as Kenya, Rwanda, South Africa, Nigeria, and Congo (Ndubuaku & Okereafor, 2015b).

The implementation of IoT systems in sub-Saharan Africa has been negatively affected by several factors which include low power supply, high poverty rate, network capacity constraint, illiteracy, absence of local content, low internet penetration, security challenges, cost of hardware and services, low ranges for rural access, dependency on proprietary infrastructure, and difficulty in deployment (Ndubuaku & Okereafor, 2015a; Dupont et al., 2018).

1.3 Problems of IoT Technology in Nigeria

In Africa, currently, the rate of adoption of IoT technologies is slow when compared to other continents. Nigeria, being the most populous country on the continent, has a large mobile market and, thus, numerous prospects in IoT implementation. Considering the benefits of IoT