Integrating Artificial Cognitive Systems in Smart Agriculture

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***Abstract**: Agriculture is one of the most crucial sectors in the world since the livelihood of both the human beings and animals depend on the attempts taken to upheave the agricultural sector. The concept of smart agriculture has been a research arena that has been broadly researched and discussed by researchers around the world and is being applied in almost all the aspects of the agricultural sector, namely, soil, weed, cultivation, and crop management. Yet, all the systems deployed in smart agriculture still try to automate a narrow action thus increasing the efficiency. The integration of cognition into the agricultural process by utilizing the new trends in artificial intelligence can result in major improvements in the concept of smart agriculture. Nevertheless, artificial cognition and embodiment of cognition to the agricultural process have not been achieved to a greater extent. A comprehensive literature review has been carried out in this research and this study aims on overviewing the role of artificial cognition in smart agriculture. The agricultural aspects namely, soil, crops, and plant diseases have been overviewed with the contemporary artificial systems along with the challenges to the concepts of smart agriculture and artificial cognition in order to add knowledge for future research.*

***Keywords**: Artificial Intelligence, Artificial Cognition, Cognitive architectures, Smart agriculture*

1. Introduction

Cognitive computing is one of the core areas of Artificial Intelligence (AI) and researchers in this field obtain inspiration from human cognition for their research work (Wang, 2018). Cognitive computing is the imitation of human thought process as a model in computer (Dharmaraj & Vijayanand, 2018). The term cognition primarily derives from the notion of human cognition where human cognition refers to the ability of humans to use the five senses, vision, sound, smell, tongue, and touch and respond accordingly. In addition, the ability of humans for self-reliance, figuring things out for independent, adaptive and anticipatory action are referred as cognition (Vernon, 2014). At present, the advancements in Artificial Intelligence has upheaved the aspects of embedding cognition into systems. Although there exists advanced tools, technologies, and theories in the field of computer science and artificial intelligence, there is a gap in fully embedding cognition in to these artefacts (Wang & Xia, 2021).

Artificial cognition is the process of embedding human level of cognition in to either hardware or software systems to achieve human level capabilities. The field of artificial cognitive systems is contributed by various other fields such as cognitive neuroscience, and development psychology etc. Nevertheless, embedding cognition into systems is not an easy task due to the fact that human cognition is not yet fully understandable and there are still no known techniques to fully embed cognition into systems. Furthermore, human level of thinking is not achievable yet via a system although the human knowledge can be embedded to a greater extent. Human cognition tasks are therefore, evident to be not fully achievable up to now and however, if it can be achieved that will be one of the greatest achievement in the field of artificial intelligence. Furthermore, psychological science and AI keep on improving each other as the studies related to these two fields invent and uncover new theories (Ruhela, 2019). Artificial cognition has headed its way towards many industries and agriculture is one such domain that is being investigated.

As all living organisms solely depend on food for their existence, enhancing the agricultural sector with the use of AI and related cognitive systems is of greater importance to increase the efficiency and productivity. Agriculture will continue to be a significant source of revenue for many countries, and smart agriculture will transform the agricultural landscape in the coming years. Throughout the history of humankind, significant advances have been made to boost agricultural productivity with fewer resources and labour demands. In the past, agriculture was based on the experience of the farmers who involved in the agricultural activities and the digital era has made the agricultural aspects also to be enhanced with the integration of AI (Awasthi, 2020).

Among the advantages of cognitive ergonomics approaches, improved work efficiency, reduced human error, and strengthening the knowledge available in how humans process information are much prominent (Vasconez et al., 2019). Therefore, the agricultural sector is also obtaining a greater advantage by the approach of cognitive ergonomics.

Robots that are involved in agricultural sector are typically either autonomous or semi-autonomous and the use of robots with some cognitive capabilities are noted in several stages of the agricultural process (Vasconez et al., 2019). The field of smart agriculture is yet to explore the integration of fully autonomous cognitive systems that will enhance the productivity and efficiency in all the aspects of agriculture.

This study deeply investigates on the role of agricultural systems that have been developed in relation to the agriculture and that have brought out the term smart agriculture. The rest of the paper is laid as follows. The section 2 deals with the methodology of the research conducted while section 3 briefly discusses different aspects in agriculture that utilize smart techniques. The section 4 discusses the challenges to the concept of smart agriculture while section 5 includes few scenarios where cognition can be embedded artificially to the smart agricultural systems. Final section concludes the research findings.

2. Methodology

In order to be precise in terms of the objective of this research, the authors have identified the motives to conduct the research as research questions for this study, which are stated below.

RQ1: How the agriculture has been affected by the concept of smart agriculture?

RQ2: What are the challenges faced by smart agricultural paradigm?

RQ3: How artificial cognitive systems can be integrated into smart agriculture?

Searching for literature was done from the IEEEXplore and Google Scholar databases. The published work after 2015 were considered as the inclusion criteria of the literature. The selection of the papers to extract data was decided on the applicability and the integration of cognitive abilities into agricultural systems in line with the objective of the paper. Finally, the extracted data were interpreted in the rest of the sections of the paper.

3. AgriculturalAspects

This section briefly overviews on the application of smart systems in soil, weeds, and crop categories with the use of literature that were obtained from the Methodology stated in the section 2 of this paper.

A. Soil

Soil is the crucial ingredient of agricultural operations due to the fact that most agricultural crops are grown in soil hence agriculture and soil are inseparable. Nevertheless, due to the growth in world's population and increased urbanization and industrialization the agricultural land areas are shrinking (Cullu et al., 2019). Crop production need to be improved and soil resources need to be conserved with a thorough understanding of diverse soil types and conditions. Therefore, soil testing is critical in modern agriculture in order to optimize productivity and protect the environment from overuse of fertilizers (Lukowska et al., 2019).

The authors (Lukowska et al., 2019) have researched on the soil sampling and have come up with a six-wheeled soil sampling mobile robot that has proven for the efficiency in productivity in agriculture. The information of soil fertilization has also been a concern of many researchers in the field of smart agriculture. The researchers have proposed an intelligent system that is based on the idea that farmers acquire all the important information about improving soil and agricultural fertilization with the use of Internet of Things (IoT) sensors (Maheswari et al., 2019). A four-wheeled agricultural robot has been implemented by the researchers (Fan et al., 2017) to collect information of both the soil and crop information in open fields that utilizes a touch screen for the generation of the control command and six motors for the mobility of the robot. Nevertheless, the researchers have not specifically stated a procedure for the collection of soil or crop information.

Moreover, soil monitoring systems are capable of responding quickly to adverse circumstances, such as extreme weather or chronic drought, by monitoring soil conditions. An autonomous soil monitoring robot has been implemented by the authors (Piper et al., 2015) that collect data on soil moisture and temperature at some specified points in the field. Nevertheless, the autonomous robot will not act on its own with the collected information of soil, whereas the collected data from the field will be forwarded to the farm manager for investigation.

The attempt by the authors (Isnanto et al., 2020) concerns on controlling the soil condition using the ESP-NOW protocol that works in real time to monitor the humidity of soil as well as the temperature and humidity of the air. This autonomous robot will both monitor the soil condition and act accordingly to water the crop. Furthermore, the protocol that has been utilized in this autonomous robot allows the operation without connecting to Wi-Fi.

The autonomous robot developed by (Martini et al., 2020) is capable of moving to any specific location within the field and water the plants without any human intervention according to a specified schedule to retain the moisture of the soil in the field. RoSS robot, implemented based on removing human dependency in soil sensing, penetrates the soil to send a sensor probe to detect the moisture level (Bourgeois et al., 2022). Moreover, it is a low cost robot that evaluate the soil health and send it to a cloud server. Further works of this research include, the integration of a GPS, camera and a LIDAR unit.

Autonomous fertilizing is also being considered by researchers in the field of smart agriculture. A robot has been proposed (Arivalagan et al., 2020) to fertilize the soil autonomously and this system is more efficient due to the reason that it can be used in gardens, agricultural, and horticultural fields as well.

B. Crops

Crop production is confronted with enormous difficulties mainly due to reasons such as diseases, low yield, damage from animals and natural disasters etc. Therefore, in order to ensure the security of food and ecosystem, future crops must be designed for sustainable agriculture development by boosting net production while minimizing negative environmental effects. The researchers (Tripicchio et al., 2015) have made use of drones for the purpose of distinguishing between techniques used for ploughing in fields with the use of an RGB-D sensor. Generally, image acquisition in smart agriculture is a crucial task since information gathering in smart agriculture mostly concerns on image data. Analysis and reasoning based on image data is a tedious, time-consuming task in large agricultural farms. The further works of this research includes achieving a high resolution for the designed system with the use of new sensors.

Seed spreading is also an integral part of crop management where the farmer engagement is extensive if the agricultural area is large. The primary goal of automating the seeding process is to make it more efficient and precise than traditional seed sowing methods. Therefore, many researchers have worked on seed spreading robots that upheaves the smart agricultural concept. A seed spreading robot has been designed to perform seeding on a pre-defined fixed distance in the agricultural field (Arthaya et al., 2019). The further works include embedding intelligence to pick weeds in the agricultural field. An Agribot has been designed by (Naik et al., 2016) for the seeding process with the use of precision agriculture concept where each and every crop is treated independently. Furthermore, the researchers have utilized the concept of optimal depth and distance in the approach of seeding task.

The identification of crop rows is an essential task for almost all the activities in the agricultural sector. Both the tasks of crop row identification and navigation between the crop rows have been achieved successfully with the use of clustering algorithm in a mobile robot (Vachos et al., 2020). Agrobot (Prajith et al., 2020) can be stated as an all-in-one robot that does crop management in agricultural fields. Digging soil, seeding and watering activities are all autonomously done by this robot.

Crop harvesting robots are also gaining much attention where the humans are minimally involved in the process of harvesting in agricultural sector. Small and medium sized low hanging crops have been aimed and a harvesting robot has been implemented with the use of NI RoboRIO controller (Hsia et al., 2020). Nevertheless, since the fields are not even, the image acquisition without the background is a challenge. The robot developed by (Xu et al., 2019) for image acquisition can be remotely configurable. The aim of these researchers is to minimize the challenges that are encountered in traditional image gathering techniques with the use of cloud computing and wireless network technology. The attempt by the researchers (Feng et al., 2015) has concerned on a robot that harvest tomatoes with a higher success rate and prevent the fruits being damaged by integrating a sac with constant air pressure for grasping the fruit.

C. Plant Diseases

Plant diseases pose a serious threat to the agricultural process. As a result, it is critical for farmers to adequately deal with diseases and monitor them using prompt prevention methods. Crop diseases have been generally divided into two categories: abiotic (also known as non-infectious) and biotic (also known as infectious) (Anon, 2022).

A plant health monitoring system with an 83% accuracy level was implemented by (Rizk & Habib, 2018) for early detection of plant health with the acquisition of images from the crop. This system enables early detection of malnutrition conditions and classify the plants as healthy or unhealthy and the system is able to sprinkle pesticides according to classification.

A robot has been developed by the researchers (Murugan et al., 2020) for the purpose of spraying pesticides and this robot can be operated with a mobile phone. This system comprises of three units, namely, input, spray and control processing, and output. Nevertheless, this system is not fully autonomous since the farmer has to manually operate the robot functions of movements, spraying, and stop spraying functions with the use of the mobile interface. The autonomous robot that has been implemented by (Dhumale & Bhaskar, 2021) is capable of acting autonomously for spraying the pesticides and is based on image processing where the plant disease detected by the robot. The work done by (Dharanika et al., 2021) is much similar to the previous work, however the concern is only towards leaf disease detection.

The uniqueness of the work done by researchers (Nooraiyeen, 2020) in leaf disease detection is that the autonomous robot that has been designed is voice controllable and after the detection of the accurate disease by the robot and alerting it to the user, it provides with the measures that can be taken to encounter the identified disease. Another approach taken by researchers in preventing plant diseases in agricultural sector is removing the unwanted part of the plant once the disease is detected. The research work (Rahul & Rajesh, 2020) focuses on the automatic detection of the plant diseases and to cut the stem where the leaves are affected and is with an accuracy of 79%.

It is clearly evident that all the above discussed methods and technologies in smart agriculture have mainly focussed in automating a very specific task. Yet none of those methods and techniques are capable enough of embedding general cognition into any of these systems.

4. Challanges To Smart Agriculture

This section briefly discusses the challenges to the smart agriculture concept and limitations in embedding cognitive aspects in smart agriculture. The developments in Artificial Intelligence has enabled farmers to adopt autonomous farming technology and make use of predictions based on past and current conditions. All these approaches involve many hardware systems that need power and connectivity to function. The challenges to the concept of smart agriculture has been the focus of many researchers (Kassim, 2020) (Ayaz et al., 2019). Based on the reviewed literature, Figure 1 illustrates the challenges to the concept of smart agriculture.

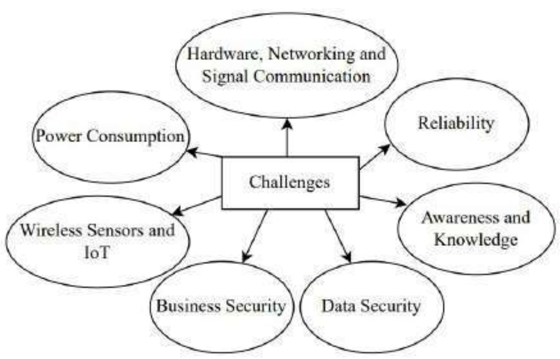

Figure 1. Challenges to Smart Agriculture

When the extent of the farming area is very large, the power consumption is high in autonomous systems. Therefore, the concern is to either reduce the power usage or to improve the battery life. Moreover, hardware aspect has also been challenged since the autonomous systems must deal with harsh environmental situations while performing smart agriculture. Networking aspect has also been challenge since there are many physical obstacles in cultivating fields where the Internet of Thing (IoT) devices that are embedded in the cognitive system gets interrupted. These IoT devices stream real time data that needs to be analysed for making smarter agricultural decisions. The infrastructure in autonomous systems in agricultural fields are highly complex and also, in rural areas in most countries, the network communications are very slow or not at all present. Reliability and scalability is really essential since the autonomous system must not fail in any situation and must be scalable if the cultivation field is widened. Nevertheless, it is understood that most of the farmers are not aware and familiar with the latest technologies in the aspect of smart agriculture. Data security and business process are also crucial while implementing such systems.

Moreover, none of the present smart agricultural systems are integrated with cognition where these systems can evaluate the current internal and external conditions and reason out, adapt to changing situations and take decision over anticipated situations. Adaption of proper cognitive architectures in smart agriculture is yet a research challenge. In addition to the above, knowledge gap in identifying and modelling of human level cognition is a challenging task that limits embedding of cognition into these smart agricultural systems.

5. Integrating Artificial Cognitive Systems Into Smart Agriculture

Artificial cognitive systems are embedded with the ability of learning, reasoning and anticipation as fundamental capabilities. Thus, these capabilities can be harnessed into smart agriculture for developing cognitively able autonomous systems. Further, farmers will be able to deploy autonomous farming technology and make better predictions of the future, based on current and past conditions, reducing crop diseases and pest invasions, due to the recent surge in Artificial Intelligence. Identifying the correct architecture to integrate cognition is a much researched area at present. A combination of cognitivist and emergent architectures will be a good approach for smart agriculture as it allows the leverage to utilize the inherent and integrated knowledge while accounting for emerging situations.

The real world examples given next, discusses how cognition can be integrated in smart agriculture. In the scenario of soil sample collection what would be if the system has the ability of deciding whether the designated place is the most suitable place for collecting the sample. If the designated place where the sample to be collected is trampled and damaged by wild animals, then that soil could be contaminated with animal waste. By integrating cognition into the system it will be capable of identifying such situations and reason out to avoid such places thereby avoiding taking erroneous decisions. In the sprinkling water scenario if the system is capable of identifying weather it is about to rain, already rained or the crop does not require water or else the leaves do not look healthy therefore some nutrient needs to be added to the water etc., facilitate cognition in smart agriculture systems. The process of autonomous fertilizing can also be uplifted if the soil fertility can be predicted and fertilize accordingly. Another agricultural process that can be embedded with cognition is the cultivation phase where the robot can be made to identify the relevant places in the agricultural field to cultivate the particular plant types in the seeding process. Spraying pesticides can be stated as an agricultural activity where farmers tend to be more careful, and therefore, the full control has not been given to the agricultural robots yet.

Therefore, it is apparent that artificial cognition concept allows the robots not to work only according to a pre-programmed rules and knowledge yet there needs to be room for learning and improving itself by interacting with the environment. Moreover, once the smart agricultural robots are integrated with cognitive capabilities, less human interaction may be needed since artificial cognitive systems are capable of acting on their own to achieve goals by perceiving their environment, learning from experience, anticipating the need to act and adapting to changing circumstances.

6. Discussion And Conclusion

Through this research, it was identified that the concept of smart agriculture is strongly based on automating the routine steps of agriculture to enhance efficiency and effectiveness. Integration of AI and IoT have further improved and accelerated the adaptation. Yet it was noted that no cognitive abilities are integrated to any of these systems to a significant extent. This was clearly evident based on the literature review done with respect to soil, crops, and plant diseases. To achieve cognition, it is required to integrate the proper cognitive architecture into systems that are deployed in smart agriculture. Hence we propose a hybrid architecture which is a combination of the cognitivist and emergent architectures to integrate cognition into the agricultural systems. Yet this poses a great challenge due to the fact that complete knowledge on how human cognition gained and works is not completely understood yet. This gap is further widened due to limitations in infrastructure and connectivity. Nevertheless, the research in this field will further enhance the cognitive facet of smart agriculture in future.

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