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A Comprehensive Analysis of Smart Farming Using Wireless Sensor Networks

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Abstract

In research, technology, agriculture, and many other domains, including surveillance, military use, and intelligent vehicles, wireless sensor networks (WSNs) are indispensable. WSNs have great applications in the field of smart farming (SF). Implementing WSNs in SF aims to evaluate several environmental factors, including humidity, temperature, soil moisture, pH, and so on, to enhance the quantity and quality of the crops. The WSNs help to lower agricultural resource use. This study aims to identify the several WSN technologies applied in SF and their effects on SF attainment. This work investigates numerous ecological aspects, including irrigation, tracking, soil properties, and temperature control, that help to achieve SF. Many crops under WSN monitoring are subjected to a thorough investigation. This assessment underlines the several sensors and channels of communication available via public speech systems. By addressing many research issues and looking for their answers, the essay attempts to investigate how WNs affect farming.

Keywords: Smart Farming, Wireless Sensor Networks, Review, Agriculture.

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Introduction

Sensor nodes define Wireless Sensor Networks (WSNs (Adday et al., 2022)). From their installed context, these sensor nodes help to detect, gather, and quantify data and forward it to users. A WSN consists of many sensor nodes—between ten and thousands—that cooperatively monitor the chosen deployment region and have either minimal or no equipment. WSNs fall into both structured and unstructured categories. Designed within a particular area, structured WSNs can be easily rearranged in case of sensor node problems (Bukar & Othman, 2022).

Unstructured WSNs, on the other hand, are composed of sensor nodes placed without a precise construction, usually in areas that are difficult for people to reach and collect data from. Managing sensor nodes in unstructured WSN gets challenging when they stop working or have node failures (Babu & Santhosh Kumar 2022). Five categories define WSNs for tracking terrestrial elements, subsurface conditions, aquatic ecosystems, multimedia material, and sensor mobility-based monitoring of supervisory areas.

Smart farming (SF) (Mohamed et al., 2021) is a farming paradigm that helps farmers to handle temporal and geographical variance within crops, including maximizing natural resource use, irrigation leadership, production oversight, fertilizer application, insect control, and continual information monitoring. The objective of implementing sensors in SF is to improve crop yield. Sensors measure many aspects of agricultural land (Weiss et al., 2020), such as humidity, moisture in the soil, meteorological conditions, incursion identification, and water levels, thereby enhancing production. Sensors can gather data on many aspects and analyze the information to improve agricultural practices. The crucial function of sensors in agriculture is outlined below.

- Gathering data on meteorological conditions, soil characteristics, and crop status.
- Land mapping for enhanced agricultural practices.
- Assessing the resource requirements for crops.
- Ascertain the temporal requirements for crops regarding chemical fertilizers, irrigation, herbicides, etc.
- Safeguard agricultural fields against invader incursions.

Background

Communication Systems

Various methods are employed in WSN communications to transport data from agricultural fields to a central location.

1. ZigBee (Bianchi et al., 2018) is a cost-effective, low-rate, and low-power consumption wireless technology that facilitates the safe and effective transfer of information from source to target. A WSN utilizing ZigBee transmits agricultural field data concerning circumstances to the user at a high transfer rate.

2. Bluetooth is a low-power, short-range wireless technology utilized in sensor networks, facilitating data transmission between users within a range of one hundred meters. It functions inside the 2.4 GHz frequency spectrum (Collins, 2022).

3. Wi-Fi, or wireless fidelity, adheres to the IEEE standard 802.11b for wireless local area networks, operating within the 2.4 GHz band and deployed in a dispersed format to encompass a range of one hundred meters. Wi-Fi is the most effective technology inside networks of sensors. A few decades ago, Wi-Fi was exclusively accessible on laptops; however, it is now readily available on smartphones, cameras, televisions, and other devices.

4. General Packet Radio Service (GPRS) (Tsao, 2001) offers rapid data transmission speeds to consumers. It operates inside the 2.4 GHz frequency band. GPRS facilitates expedited and long-range transfer of data. The transmission distance of GPRS extends up to several kilometers, depending on the service region.

5. WiMAX, or global interoperability for radio access, is an IEEE 802.16e specification utilized for long-distance communication technologies. The incorporation of the WiMAX protocol can elevate network bandwidth to 70 Mbps.

ML methods

ML is a kind of Artificial Intelligence (AI) (Shaikh et al., 2022) that enables machines to acquire knowledge through experience. Its methods employ computational techniques to learn from observations without relying on pre-established equations as a framework. The methods gradually adjust to improve their performance as training data increases. Using sensor data or other varied, linked resources, ML techniques are powerful tools for autonomously

addressing complex non-linear problems. Practically, with minimum human involvement, decision-making and informed behavior are improved. ML methods are constantly developing and applied in almost all spheres. They possess intrinsic restrictions regarding their uses. The precision of the forecast is influenced by data quality, appropriate model participation, and the relationships among input and variables of interest.

ML methods are classified into two primary groups: Supervised Learning (SL) and Unsupervised Learning (USL). SL employs a predefined set of labeled data to train an algorithm for predicting the target variable in data that is out of sample. Regression and classification methods are prevalent uses of SL. USL depends on concealed patterns or inherent structures within data to infer conclusions from unlabeled data. It is beneficial for exploratory operations lacking a defined objective or when the data's content is ambiguous. It is an optimal strategy for decreasing dimensionality in datasets with numerous features. Fig. 1 shows the classifications of ML algorithms.

Segmentation is the predominant learning paradigm in this category, with applications in exploration data analysis, including sequencing and object recognition. The choice of methods is contingent upon the data's amount, nature, and anticipated insights. There is no universal guideline for algorithm choice; it is a process of experimentation and error. SL and USL methods are extensively employed in IoT innovative data analysis across various fields. SF, which is facilitated by WSN and the Internet of Things (IoT), is a sector where ML techniques are increasingly utilized to analyze and comprehend the extensive data present. The application of ML in SF can be classified into the management of crops, animal management, water handling, and soil management. The application of ML in agriculture encompasses forecasting yields, diagnosing diseases, weed identification, and phenotypic categorization. The article will concentrate on WSN-driven AI uses in SF.

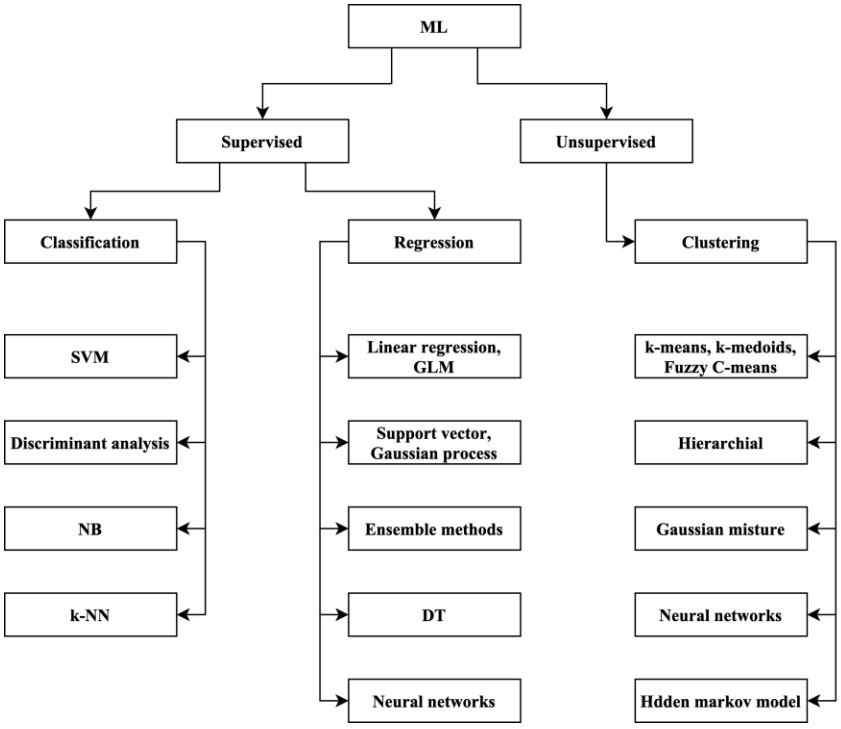


Fig. 1: ML models

Case Study on IoT-based SF

This section discusses a distributed WSN constructed utilizing open-source hardware architectures, an Arduino-based microprocessor, and ZigBee modules to monitor and regulate essential elements for crop growth, including the state of the soil and climatic and weather factors.

Sensor nodes

The WSN sensing unit is a tailored Arduino microprocessor with the primary activity module card and an external sensor interface card. The sensing board can be connected to many sensors to assess the moisture content of the soil, pH value, temperatures of the soil, leaf moisture, external temperatures, UV rays, pressure in the atmosphere,

humidity, and meteorological data such as the velocity of the wind, rainfall, and wind speed. It employs the ZigBee standard with 2.4 GHz to transmit sensor information to the gateway and facilitate communication among other nodes. The Integrated Development Environment (IDE) can accomplish sensor connection and coding. Every WSN has 3.8 V, 1200 mAh lithium-ion batteries to address power concerns.

IoT Portal

A Linux-based mesh router is an IoT gateway storing every sensor's information in a local MySQL server. The gateway accommodates several communications technologies; this research utilizes the ZigBee standard for interaction with the sensor nodes. It facilitates Ethernet or Wi-Fi connectivity, enabling seamless data synchronization from a local database to an outside database using Wi-Fi or cellular networks. The gateway is capable of transmitting sensor information to an online platform. The gateway offers a user interaction app for viewing newly recorded data, offerings, and cloud integration. The gateway transmits information from sensors to the Microsoft Azure internet system, a restricted premium service, and Google Firebase, a complimentary service with substantial storage capacity. The cloud offers accessible and adaptable data retrieval for the designated user. It facilitates data access beyond the farm network, supports long-term uses such as crop recommendations, and allows data analysis. Data from this SF system is accessible via websites and cell phones.

Utilization

This paper aims to extend the data architecture to the cloud and live-streaming sensor data via a smartphone app. The smartphone or tablet platform allows customers to monitor their farm's activities in real time and monitor essential data on energy usage, watering incidents, and weather conditions. The information from the sensors retained in the local file of the IoT gateway is continuously synced with an outside the MySQL server situated in a simulated machine and Google Firebase online. It has been deployed effectively to Microsoft Azure cloud computing services. Google's Firebase has been chosen for this program because of storage constraints and expenses. The mobile use is presently created for Android OS and will eventually be expanded to iOS shortly.

Data Evaluation

This research aims to utilize high-resolution data from sensors to anticipate crop productivity, weather, and the quality of the crops. This IoT technology regulates field variables to enhance crop output, augment efficiency, and minimize agricultural input use. The data-driven physical representation informs farmers about energy production and consumption, water usage and recycling, and yield quality while monitoring weather information. Long-term data will enhance the efficacy of a time-series forecasting technique that can adequately anticipate the weather one day in advance, thereby empowering farmers with the capacity to make informed irrigation decisions. The smartphone app platform offers this functionality, indicating when to plan irrigation on the instrument panel. The multitude of measures that sensors capture renders the data collection and administration process daunting, although it will assist in refining possible predictor features within information on crop sets. The initiative is currently in progress, and information evaluation is at the preliminary stage, requiring further data handling and finalization of the catalog.

Conclusion

WSNs are crucial in SF, enhancing production, tracking water resources, and assessing soil quality and structural properties. This presentation addresses the fundamentals and significance of WSN and SF. The research has summarized the different types of sensors utilized in agriculture. It encompasses the attributes of sensors when used in soil and diverse weather. The distributed devices in the field must gather information and transfer it to the base station for processing and supervision. The fundamental and diverse communication methods utilized in data transmission to the base location have been cataloged. The characteristics of WSNs are delineated in precise farming.

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