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IoT-Driven Smart Farming: Enhancing Efficiency and Sustainability

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Abstract:

The use of IoT in modern farming is not only essential but is a requirement for small farmers which lack resources. IoT device creates physical network that forms intermediate connection for communication in data exploitation. As the data is interrelated and the monitoring is done systematically, it is expected to provide further aid in technical aspect to the farmers for their decision support. The IoT Farming Sensor Integration will assist with data collection to measure various parameters including temperature, air humidity, soil, and sunlight intensity. Through this method, IoT changes the conventional farming monitoring approach towards optimal solution that is cost efficient and lowering crops waste. It expects to contribute to achieve six Sustainable Development Goals (SDGs) mission by the end of 2030. The custom prototype is built based on the customized framework identified and expected to be available at affordable price.

Key words: *IoT, decision support, small farmer, data exploitation, Sustainable Development Goals (SDGs*)

Introduction

As one of the 193 members of the United Nations body since 2015, Malaysia is committed to achieve the mission contained in the 2030 Agenda for Sustainable Development to be recognize as a developed country. Farming is one of the sectors that requires the use of technological facilities in the process of crop monitoring. Several reviews disclose that the most applied in Smart Farming application would be crop monitoring inclusive on agricultural environments such arable land, orchard, greenhouse, and others [2][4]. It is a crucial sector that needs highlighting to ensure food sustainability in line with global rapid population [3][4]. Worsen is the fact of how urbanization nationwide causes harm to the environment that affects the capacity of plant growth in terms of quality and quantity of crops [3] and its available cultivation site [5].

Smart Farming is an adoption of technologies and data-driven on farm operations to optimize the output production and to maintain its sustainability. This is done by using Internet of Things (IoT) to help farmers to effectively monitor their crops on a regular basis. The concept embedded in IoT Farming Sensor Integration is aimed to be used by small farmers who lack capital. With recent technological advancement, IoT offers solutions to a simpler implementation of devices on hardware size, power consumption and affordable price [2].

Factor that affects the outcome of a plant is the incompatibility of weather changes that will shift the density of light, soil moisture and the optimal temperature needed. In addition, each plant needs to be adapted to different needs for healthy growth. These changes will certainly affect the final production of crops, especially for small farmers. A standard periodic monitoring method needs to be implemented to ensure a conducive atmosphere for the mature growth process of a plant. One of the approaches used to help overcome this problem is through the integration of Internet of Things (IoT) sensors in Smart Farming.

The study discusses the use of sensors connected to IoT networks to monitor and control the above parameters in real time. These sensors are used to measure various parameters including temperature, air humidity, soil humidity, and sunlight intensity. The website platform then provides integration of services such as device management and real-time data storage, used to ensure that it's function properly, and that the data collected regularly is accurate and being stored systematically. The data collected by all these sensors can provide technical support to farmers when needed [1].

Methodology

This project focuses on integrating IoT devices in Smart Farming, specifically targeting small farmers to create a significant positive impact on local communities and contribute to achieving the Sustainable Development Goals (SDGs). The development process follows a structured prototype methodology, illustrated in the provided flow chart as Figure 1, and includes several key phases:

1. **Requirement Gathering & Analysis**
   The first phase involves defining the objectives of the prototype to identify key features and functionalities. This includes comprehensive research on existing IoT solutions for smart farming to determine the best hardware components, sensors, and technologies to use. By reviewing current solutions, we can select the most suitable and cost-effective options that align with the project's goals.

2. **Quick Design**
   In this phase, the focus is on sensor selection and hardware integration. Suitable sensors are chosen based on the identified framework. The sensors used include:

   - Humidity Sensors: To measure air moisture levels.
   - Temperature Sensors: To monitor the ambient temperature.
   - Soil Moisture Sensors: To check soil humidity.
   - Light Dependent Resistor (LDR) Sensors: To gauge sunlight intensity.

   The NodeMCU platform, incorporating the ESP8266 microcontroller, is utilized for its cost-effectiveness and compatibility with various sensors. Additionally, a Wi-Fi-based network is established to connect the sensors for data transmission, ensuring seamless communication between the devices.

3. **Build a Protoytpe**
   This phase involves the physical and virtual integration of the sensors with the NodeMCU platform to form a functioning model. A simple web interface is developed to allow users to configure settings and view sensor data. This interface ensures that the system is user-friendly and accessible to small farmers.

4. **User Evaluation**
   Following the prototype building, a user evaluation stage is conducted. This involves deploying the prototype in a real-world farming environment and allowing selected users (small farmers) to interact with the system. The evaluation aims to gather detailed feedback on the usability, functionality, and overall satisfaction with the prototype. Users are asked to perform typical farming tasks using the IoT system, and their experiences are recorded and analyzed. This stage helps identify any practical challenges and areas for improvement from the user's perspective.

5. **Testing and Refinement**
   The prototype is further tested in a controlled environment to simulate the farming conditions and verify the accuracy of sensor readings and the reliability of data transmission. User feedback from the evaluation stage is incorporated to identify any usability issues or areas for improvement. Based on this feedback, iterative improvements are made to the hardware, software, and user interface to enhance overall functionality and user experience.

6. **Final Implementation**
   After thorough testing and refinement, the final product is implemented. A maintenance plan is established to ensure ongoing functionality and adaptability, addressing any future issues or updates needed to keep the system efficient and effective for the users. This phase ensures that the product is ready for launch and capable of providing long-term benefits to small farmers.

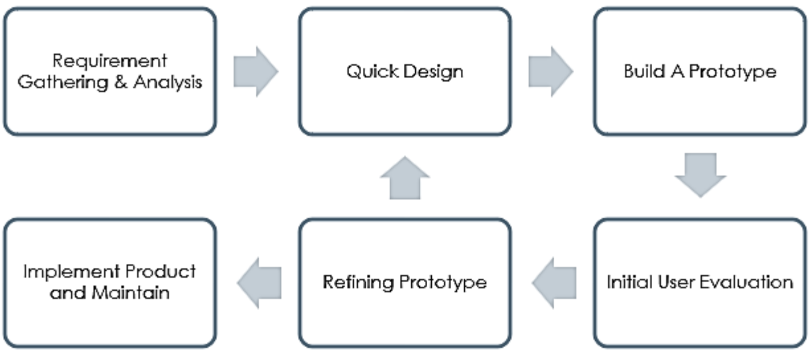

Figure 1: Prototype Methodology

Analysis and Discussion

During Requirements Gathering and Analysis, the IoT farming sensor integration framework is generated (Figure 2) based on the hierarchy of probable applications, facilities and devices for smart agriculture as reference [5]. The category was chosen to match small farming possible environments resources. In the referred framework, soil and water monitoring are prioritized as the main applications. Environmental monitoring is also included as an additional element to support the primary applications, ensuring a comprehensive approach to Smart Farming. The chosen parameters for monitoring include soil moisture, temperature, and humidity, which are critical for maintaining optimal growing conditions.

The efficiency of the IoT farming sensor integration framework is evaluated through the development and testing of the project prototype. The key parameters used to assess efficiency include time execution, accuracy, and energy consumption. The proposed IoT farming sensor integration framework was implemented using the NodeMCU platform with various sensors, including humidity, temperature, soil moisture, and LDR sensors. Data was collected from these sensors over a specified period to evaluate the system's performance under real farming conditions.

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To measure time execution, the time taken for data collection and transmission from sensors to the central database was recorded, along with the time required for processing and displaying data on the web interface. Accuracy was measured by comparing sensor readings with standard reference measurements to ensure data accuracy and analyzing the consistency and reliability of sensor data over time. Energy consumption was monitored by observing the energy usage of the IoT devices during operation and evaluating the battery life and energy efficiency of the sensors and the NodeMCU platform.

The results obtained from these efficiency parameters provided valuable insights into the overall performance and reliability of the IoT farming sensor integration framework. The findings indicated that while the system performed well in terms of data accuracy and energy efficiency, there were areas that required optimization, such as minimizing delays in data processing. Recommendations for improvement included optimizing time execution, enhancing data accuracy, and improving energy efficiency. These suggestions aimed to enhance the practical applicability of the framework and its potential for improving farming practices. Further research and development were identified as necessary to continue refining the system and addressing any remaining challenges.

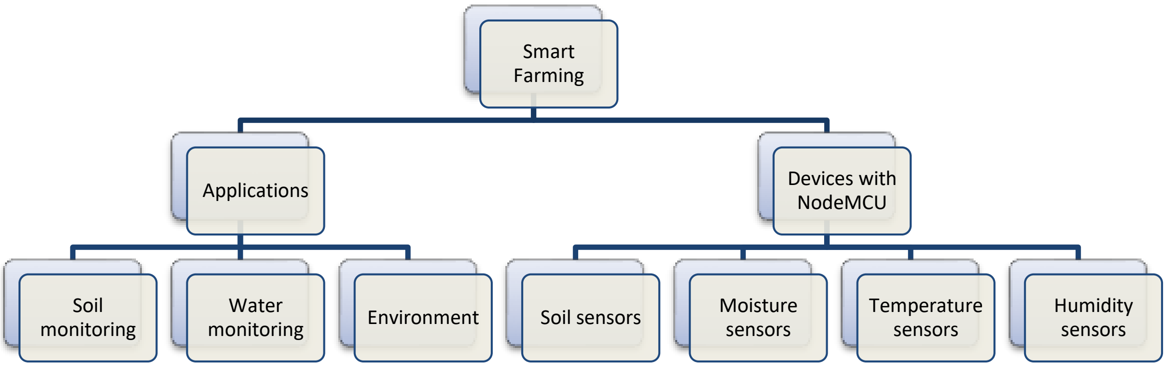

Figure 2: Framework of IoT Farming Sensor Integration

Conclusion and Recommendation

The prototype of IoT technologies integrate may be produce at affordable price and the cost is expected to be further reduced with mass production. Hence it will be available as an advanced technology even for small farmers or bigger farming sectors. With this advancement the crops are expected to be reproduced at a higher rate with better quality. For long term effect, it is targets to be able to fulfil six out of seventeen Sustainable Development Goals (SDGs) which is of Zero Hunger (2), Clean Water and Sanitation (6), Decent Work and Economy Growth (8), Responsible Consumption and Production (12), Climate Action (13) and Life on Land (15). Table 1 is referred.

Table 1: The SDGs relevance and contribution

Goal	Sustainable Development Goal (SDG)[6]		
	Section	Relevance	Contribution
2	Zero Hunger	Improved crop management, yield prediction, and resource utilization that led to higher agricultural productivity and better food security.	Optimizes farming practices, helping to increase crop yields and reduce losses due to unsuitable environment surrounding monitoring
6	Clean Water and Sanitation	Efficient water uses in farming	Optimization of periodic irrigation helps conserve water usage in farming.
8	Decent Work and Economic Growth	Modernizing technologies can drive economic growth and create jobs opportunities	Improves labor efficiency, reduces manual labor, and creates opportunities for tech-based farmed employment.
12	Responsible Consumption and Production	Sustainable agricultural practices are essential for responsible production	IoT systems promote precision farming, reducing the overuse of fertilizers and pesticides, thereby minimizing environmental impact.
13	Climate Action	Impacts climate change in long-term for the environment	

			Enable more efficient resource use and reduce the carbon footprint of farming operations.
15	Life on Land	Sustainable management of land and ecosystems is vital for environmental health.	Supports sustainable land management and conservation of biodiversity by monitoring soil health and crop conditions.

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