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Innovative Dashboard Designs for Real-Time Smart Farming Data Visualization

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Abstract:

The global population is projected to increase rapidly by 2050, intensifying the need for sustainable agriculture to support food security and the bioeconomy. Rapid urban development has caused the lack of arable land, necessitating innovative solutions like Smart Farming, which leverages IoT technology. This study investigates the suitable sensor that can be implemented for data collection. This study also suggests dashboard design elements with multiple-view concepts from different perspectives focusing on enhancing productivity, resource management, and ecological sustainability. The methodology approach was through Google Trends on the breakout or rising key words search followed by research question specifically to solve the related objectives. By using IoT sensors, parameter factors such as temperature, humidity, soil moisture, and light intensity, are collected and visualized through dashboards. This helps farmers to make informed decisions in real-time. This approach addresses the inefficiencies of conventional farming, providing reliable, synchronized data. The research identifies suitable IoT sensors and optimal visualization techniques for dashboard displays, proposing improvements in data presentation to facilitate better crop management.

Key words: IoT, Smart Farming, Sustainability, Dashboard, Data Visualization

Introduction

The rapid global population is estimated to reach between 9.4 billion to 10.1 billion by 2050 [2][14]. Globally, the agricultural industry is also growing rapidly due to the increasing need for food sustainability [3][6][8] and as a source of bioeconomy [7]. Bioeconomy is defined as capability of the energy to be renewed effectively and to responsibly utilize the natural resources from water and land that lead to economic growth across diverse industries and human society [9]. It is divided into three key types that offer distinct strategies to achieve economic and ecological co-ordination which are the economic-ecological bioeconomy, the mainstream bioeconomy and the socio-biodiversity bioeconomy [10].

Research by [9] states that ASEAN region countries such as Thailand, Vietnam, Brunei, Malaysia, Laos, Myanmar, Indonesia, Columbia, Singapore and Philippines main source production are an export of livestock, plants, trees and crops that contribute to Gross Domestic Product (GDP) of ASIAN economy worth 3 trillion USD. This shows that maintaining crops production plays an important role in the sustainability of economy of the country indirectly providing benefits of food to human for survival. Thus, this study aims to achieve the economic-ecological bioeconomy to maintain balance between economic gains and ecological sustainability.

The fact is, how urbanization has reduced land for agriculture to accommodate development and causing the surroundings to be unsuitable for farming [5]. This study will focus on the implementation of Smart Farming concept in suburbanization and rural areas. The main challenge faced in this area would be the lack of technological resources and deficiency of initial investment from the small farmers.

However, with the fast-developing technology in Internet of Thing (IoT), it now offers a wide market of devices at affordable admission. The device that can collect farming environment data through sensor to be send via the Internet to servers where those data can be processed, distributed and used. This is term as Smart Farming where adoption of technologies and data-driven on farm operations [8] are used to optimize the output production [1] and to maintain its sustainability and conserved nature by minimizing waste [2].

Conventional farming in rural areas normally involves best practices through trial and errors which are then handed down through generations. These methods frequently rely on manual labor, basic tools, and natural resources without modern technological aids. Implementing IoT in traditional farming practices can globally transform agriculture, enhancing productivity, improving resource management, fostering economic growth, and providing climate resilience. These advancements not only benefit individual farmers but also contribute to global food security and the development of a sustainable bioeconomy [9].

Internet of Things (IoT) helps farmers to effectively monitor their crops on a regular basis [2]. In this study, different data on environmental factors that affect plants' health such as temperature and humidity in the air, soil moisture and light collected are analyzed. To enable the interpretation process of the data to take place efficiently, the data needs to be presented in an understandable form. The dashboard provides information in the form of clear visualization for the purpose of "Decision making process" at glance [12].

In addition, the use of the dashboard allows the process of detecting trends and patterns of change that affect the conditions of plant health development throughout their growth phase. This holistic monitoring through access to important information quickly and in real time, allows for more timely action. This contributes to more efficient and effective plant management.

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The Google Trends search shows that in Malaysia, within duration of 1 year period, it indicates the concurrent relation between IoT and agriculture with the rising of dashboard at a high-rate request (Figure 1) [13]. The trends also noted the resulting query and topic that is rising and causing breakout. Among the top queries for Agriculture is ‘regenerative agriculture’, ‘Ministry of agriculture and food security’, ‘Ministry of agriculture and food security of Malaysia’ and ‘controlled environment agriculture’. The focus topic causing breakout is keywords ‘important’ and ‘farm’ followed by highly rising ‘industrial agriculture’ and ‘e-agriculture’.

In the search of IoT, the breakout search topic related are ‘consumer’, ‘adoption’, ‘collaboration’ and ‘digital transformation’ with related queries focusing on ‘bandwidth’. In the search of dashboard, both related topics and queries show the use of request on usage for companies that provide services such YouTube, Ninja Van, Carsome and dashboard tools such as Looker Studio.

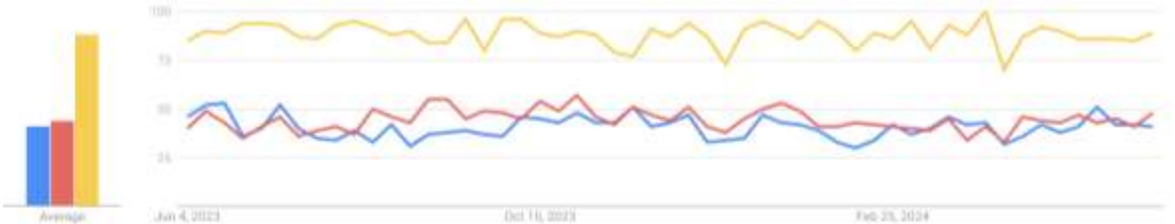

Figure 1: Relation comparison of Google Trends search for Agriculture (Blue), IoT (Red) and Dashboard (Yellow)

The trends help to formulate the research question to comprehend the objectives that would guide this work. The research question is presented below:

RQ1. What suitable IoT sensors are commonly used in monitoring crops?
RQ2. What types of visual presentation is suitable to be used for each sensor?

The objectives, related for this study are:

1. To find suitable IoT sensors which support initial investment for small farmers.
2. To identify types of data visual presentation suitable for each sensor parameter for insightful information.

Research Methodology

The primary focus of this study is to develop an effective smart farming dashboard design that leverages data from soil moisture, humidity, light, and temperature sensors. The methodology follows a structured approach to ensure that the dashboard provides valuable insights and supports informed decision-making for farmers.

First, the selection of suitable IoT sensors was conducted. For monitoring critical environmental parameters, the YL-69 soil moisture sensor, DHT11 temperature and humidity sensor, and LM393 light sensor were chosen. These sensors were strategically installed in the farming environment to capture accurate and relevant data: soil moisture sensors at various soil depths, temperature and humidity sensors in both shaded and open areas, and light sensors at the canopy level to measure crop light exposure.

Once the sensors were in place, real-time data collection commenced. These sensors continuously monitored soil moisture, air temperature, humidity, and light intensity, transmitting this data wirelessly to a central server via the Internet. IoT communication through Wi-Fi at the farming location were utilized to ensure efficient data transfer. The collected data was stored in an online-based database, allowing for real-time data analysis.

The next phase involved processing the raw data. Data from the different sensors was aggregated and pre-processed to eliminate anomalies and errors, ensuring the data's integrity and reliability. Statistical analysis and machine learning algorithms were applied to this cleaned data to identify patterns and trends, providing a robust foundation for visualization.

With the processed data ready, the focus shifted to the design and development of the dashboard. The dashboard was developed using HTML, CSS, and JavaScript, and Chart.js libraries employed to create dynamic and informative visualizations. For soil moisture data, visualizations included gauge/bar graphs to display current levels, line charts to show historical trends, and alerts for critical thresholds. For humidity data, line charts and digital displays were used for real-time and historical data visualization, accompanied by threshold alerts. Light intensity was represented using dials/gauges for current measurements and line charts for historical trends, while temperature data was displayed through heat maps, digital displays, and historical trend line charts.

The user interface design prioritized user-friendliness, ensuring that the dashboard featured intuitive navigation and interactive elements. Farmers could customize their views, set alerts, and access historical data seamlessly. Real-time data updates on the dashboard ensured that farmers always had access to the latest information, facilitating timely and informed decision-making.

Finally, the dashboard system was deployed on a server, making it accessible via web browsers or mobile devices. Ongoing maintenance was planned to incorporate new features, enhance performance, and ensure data security, thus providing farmers with a robust tool for smart farming. This comprehensive methodology ensures the development of a smart farming dashboard that effectively utilizes data from soil moisture, humidity, light, and temperature sensors to support sustainable and efficient farming practices.

Analysis and Discussion

The chosen parameters for monitoring include soil moisture, temperature, humidity and light. Factor contributing to the imprecision content development of the dashboard was the weakness of the organization dealing with the data for interpretation of the necessary information and the difficulty in identifying the relationship between the information. A well-designed dashboard can help optimize time in interpreting and analyzing data. This directly helps farmers to identify important information in making long-term or short-term decisions.

Table 1 is a proposed sensor analysis requirements followed by the necessary data visualization suggestion for the use of dashboard display for the data collected from the Integration of IoT device. The multiple view concept of the same data from different perspectives may complicate the dashboard content creation [13]. For this reason, the suggested graph or data visualization is suggested.

Table 1: Proposed component of data visualization on dashboard base on device functionality

Sensor	Setup Component	Functionality	Proposed Visualization
Soil Moisture	YL-69 Soil Moisture Sensor [15]	Optimizes irrigation schedules to maintain optimal soil moisture levels, ensuring healthy crop growth and water resource management	**Gauge/Bar Graph:** Display current soil moisture levels. Interpreted by a bar that fills or empties in percentage or volumetric water content. **Historical Trends:** Line chart showing soil moisture over time. A line chart to indicate changes throughout the day, week, or season **Alerts:** Notifications for too dry or too wet conditions. An indicator of maximum and minimum set up as standard condition value to be notified if break.
Humidity	DHT11 Temperature and Humidity Sensor [16]	Assists in controlling humidity levels in farming area to prevent fungal diseases and to predict humidity patterns and their impact on crops outcome.	**Line Chart:** Shows real-time and historical humidity levels. A line to indicates humidity levels over real-time during day or longer durations. **Current Humidity:** Digital display of current relative humidity. Providing immediate information on the air moisture level on the relative humidity. **Threshold Alerts:** Notifications when humidity goes beyond optimal range. An indicator is set up to its optimal value and to be notified if defy.
Light	LM393 Photosensitive Light-Dependent Control Sensor LDR Module [17]	Monitor continuity of optimal light standards for continuous process of plant growth and optimizing plant exposure to sunlight.	**Dial/Gauge:** Displays current light intensity. Current light intensity displays indicate that plants will only receive adequate light at optimum level. **Historical Trends:** Line chart showing light intensity variations over time. A line chart on light intensity changes over time patterns to help in setting light schedules. **Sunlight Exposure Chart:** Shows cumulative sunlight exposure over a day/week. Ensuring plants get the necessary amount of light for photosynthesis with the cumulative sunlight value.
Temperature	DHT11 Temperature and Humidity Sensor [16]	Monitor continuity of optimal temperature standards for continuous process of plant growth	**Heat Map:** Visual representation of temperature variations across different sections of the farm/greenhouse. Allows farmers to spot areas that are too hot or too cold for plants growth based on the color variation indicators. **Current Temperature:** Digital display of real-time temperature.

	Providing immediate information on the temperature value to indicate the state of plants surrounding. **Historical Trends:** Line chart showing temperature changes over time. A line chart that intensifies daily and seasonal temperature patterns.

Conclusion and Recommendation

The proposed visualization of dashboard is expected to generate an effective display that performs based on its supposed usage functionality. The light sensor data visualized and projected to aids in managing both natural and artificial lighting in greenhouses to optimize light exposure at it supposed intensity. This will help farmers to enhance the process of photosynthesis, improve plant growth, and increase yields. The presence of light will influence the humidity levels indirectly. By monitoring and controlling humidity levels, farmers can create optimal conditions for plant growth, reduce the risk of diseases, and improve crop quality.

The soil moisture presentation when visualized will aid in monitoring soil moisture levels, where irrigation schedules can be optimized to ensure plants receive sufficient water, preventing both overwatering and underwatering. This will improve the efficiency in water usage and promote healthy plant growth. Whereas the temperature data helps in managing the environment climate around crops. Decision such adjusting ventilation, managing shades, or controlling the heating systems will protect crops from extreme temperatures and create optimal growing conditions.

These dashboard design elements provide comprehensive and easy-to-understand visualizations of critical environmental parameters, enabling farmers to make informed decisions to optimize crop production. This study only focuses on the content of the parameter visual presentation. Nevertheless, the arrangement of how the visualize presentation display will affect decision making [12] and misleading if wrongly emphasize [14]. This, however, will be examined further in the next project.

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