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On-board Computer Unit Development for Precision Fertilization in Oil Palm Plantations Based on Data from a Precision Agriculture Platform

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Abstract: This study aims to develop the function of the On-Board Computer Unit (OBC) device to control the Variable-Rate Fertilizer Application (VRFA) device according to the recommendations of the precision agriculture platform for oil palm (Precipalm) platform integrated into the tractor system. Then, the operational movement of tractors integrated with VRFA is to be modeled using the Dead Reckoning (DR) algorithm to achieve the precision of space and place in the oil palm plantation before being applied to the actual conditions of the oil palm field. Precision agriculture in oil palm plantations can be applied using a mechanization system regulated by OBC devices and developed based on information from Precipalm. Precipalm is an application system based on precision agriculture, using Sentinel 2 satellite data for a fertilization decision support system that produces appropriate fertilization recommendations for plant needs. The results of this study show that the development of OBC can provide a reasonably accurate value for controlling VRFA tools. A liquid flow sensor for output measurement is used to confirm the accuracy of the OBC. Then, values are compared between the predetermined output of Preciplam data and the actual output value of the VRFA system controlled by OBC. The final result of the average percentage comparison value is 0.679% for the element Nitrogen (N), 0.846% for the element Phosphor (P), and 1.915% for the element Potassium (K). The values show that systems controlled by OBC have a very minimal percentage of system error values.

Keywords: Dead Reckoning, Mechanization System, On-Board Computer Unit, Precision Agriculture Platform for Oil Palm, Variable-Rate Fertilizer Application

Introduction

Today, the Industrial Revolution 4.0 is followed by advances in information technology that are multiplying and have also affected the concept of precision agriculture (Sung, 2018). The most critical factors in precision agriculture are accuracy and preciseness, which are essential for precision in decision-making (Seminar *et al.*, 2022). The purpose of precision agriculture can be applied to oil palm agriculture as resources and cultivation activities of oil palm plantations with soil conditions and crop needs (Seminar, 2018a). Management information systems in precision agriculture include Geographic Information Systems (GIS), Decision Support Systems (DSS), data crop models, and field history (Ane and Yasmin, 2019).

Fertilization is one of the stages in agricultural cultivation that determines production success (Barłóg *et al.*, 2022). Fertilization plays a role in supplying or replacing nutrient content. Lack of nutrients, especially macronutrients, will affect plants' growth development and productivity (Amu *et al.*, 2022). Fertilization is one of the crucial factors that cause high costs in cultivating oil palm plantations (Sudradjat *et al.*, 2018). So far, many fertilization techniques for oil palm plantations in Indonesia are still manually stocked by hand Lubis *et al.* (2023). This technique will undoubtedly produce fertilization patterns and doses that do not follow the recommendations of the Precipalm, so it will create growth that is not optimal (Seminar, 2018a).

Precision agriculture is applied through agricultural mechanization using agricultural tractors, commonly used by farmers to mechanize oil palm plantation land, combined with VRFA tools to achieve optimal agricultural results (Herdiansyah *et al*., 2023). This research is focused on developing the function of OBC devices that can control VRFA tools according to fertilization recommendations from Precipalm and applied with liquid fertilizer, then modeling the localization of tractor positions using the Dead Reckoning algorithm to achieve the accuracy of space, place, and condition of tractors on oil palm plantation land to achieve the goal of optimal and efficient precision agriculture. This study will have a real impact: Precision recommendations for the VRFA system in the tractor control unit to fertilize precisely based on information from Precipalm's recommendation.

On-Board Computer Unit

An OBC, more commonly known as a Single-Board Computer unit (SBC), is a complete computer built on a single circuit board with a microprocessor, memory, Input/Output (I/O), and other features required of a functional computer (Rosch, 2003). SBCs are usually created as demonstration or development systems and for agricultural systems (Butsenko *et al*., 2020).

Unlike desktop personal computers, SBC often does not rely on expansion slots for peripheral or expansion functions. SBCs have been built using a variety of microprocessors of simple design, using static RAM and low-cost 32 or 64-bit processors such as ARM (Gill *et al*., 2024).

Other types, such as blade servers, will appear similar to server computers, only in a more compact format (Biggs *et al*., 2021). The function of the SBC unit can be developed according to the user's wishes (Ochando *et al*., 2023) and this development is possible because the SBC unit itself is made for broader development functions (Rhinow *et al*., 2021). In the OBC ecosystem, the presence of SBC is becoming common (Coelho *et al*., 2023). Generally, an SBC is used as an edge processor or to process sensor information (Ariza and Baez, 2021). It can also transmit data to the primary system, either directly or through other gateways (Basford *et al*., 2020). If asked for one example, an easily recognizable model is the Raspberry Pi series (Pajankar, 2017).

Precision Agriculture Platform for Palm Oil

Innovation in the application of precision agriculture as a step to anticipate industrial disruption (Masi *et al*., 2022) in the form of utilizing information technology to determine recommendations for precision fertilization using satellite technology to identify, analyze, and process spatial and temporal diversity information on oil palm plantation land, called the Precision Agriculture Platform for Oil Palm (Precipalm) application (Seminar, 2018b), as shown in Fig. (1). Precipalm is a cloud-based application that provides information on the nutritional conditions of macro elements of oil palm land quickly and precisely in digital maps of land, processed from satellite images and mathematical models. This information on land characteristics is then used to be the basis for producing macro element fertilization recommendations in the form of Nitrogen (N), Phosphor (P), and Potassium (K). It can monitor the macro nutritional condition of postfertilization plantation land in real-time (Seminar, 2018b), as shown in Fig. (2).

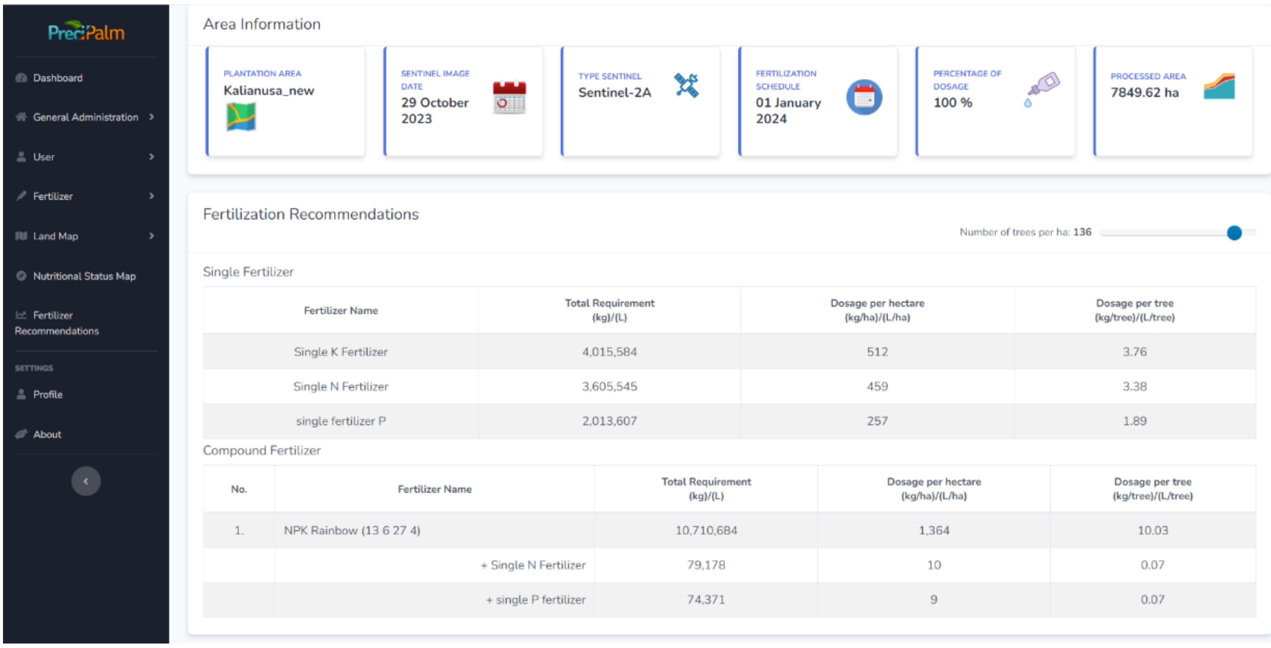
Precision agriculture is a revolution in information technology-based natural resource management. Management information systems in precision agriculture include geographical information systems, decision support systems, crop models, and field history data (Andujar, 2023; Rodrigues, 2022). However, if fertilization is done manually, the site-specific nutrient management system in the Precipalm reference will be challenging to obtain. Therefore, a controlled fertilization technology is needed and integrated with VRFA technology.

Variable-Rate Fertilizer Application

Land processing is the activity of manipulating land mechanically for good crop planting. This activity aims to build a good land structure to support the growth of healthy plants and strong root growth (Daum, 2023). Land processing can be done using agricultural mechanization that utilizes tractors. Ease of maneuverability of tractors is essential in oil palm fields. The tractor is designed to turn with a short radius at the end of the field and can follow the path in the row of plants (Mohan *et al*., 2021).

VRFA is one technology that can provide appropriate fertilization applications according to land conditions and plant needs (Chandel *et al*., 2016). The proper fertilization application includes the correct dose, location, and time. Proper dosing treatment is dosing according to what plants need. The right location and fertilization with the correct dose are given at the right location, while on-time fertilization is based on the phase of plant growth. Precision agriculture is a sustainable technology that uses an information technology approach (Azis *et al*., 2020).

The advantages of VRFA technology are that it can increase production efficiency, reduce environmental pollution from agrochemicals, and increase farmers' profits by reducing the use of fertilizers and pesticides. Reducing the amount of nutrients (fertilizers) provided to plants benefits the environment. VRFA technology can reduce pollution caused by the uncontrolled use of inputs. One indicator of precision agriculture is reducing fertilizer use and increasing efficiency by identifying site-specific management zones (Dicu *et al*., 2018).



Area Information

PLANTATION AREA: Kalianusa_new
SENTINEL IMAGE DATE: 29 October 2023
TYPE SENTINEL: Sentinel-2A
FERTILIZATION SCHEDULE: 01 January 2024
PERCENTAGE OF DOSAGE: 100 %
PROCESSED AREA: 7849.62 ha

Fertilization Recommendations

Number of trees per ha: 136

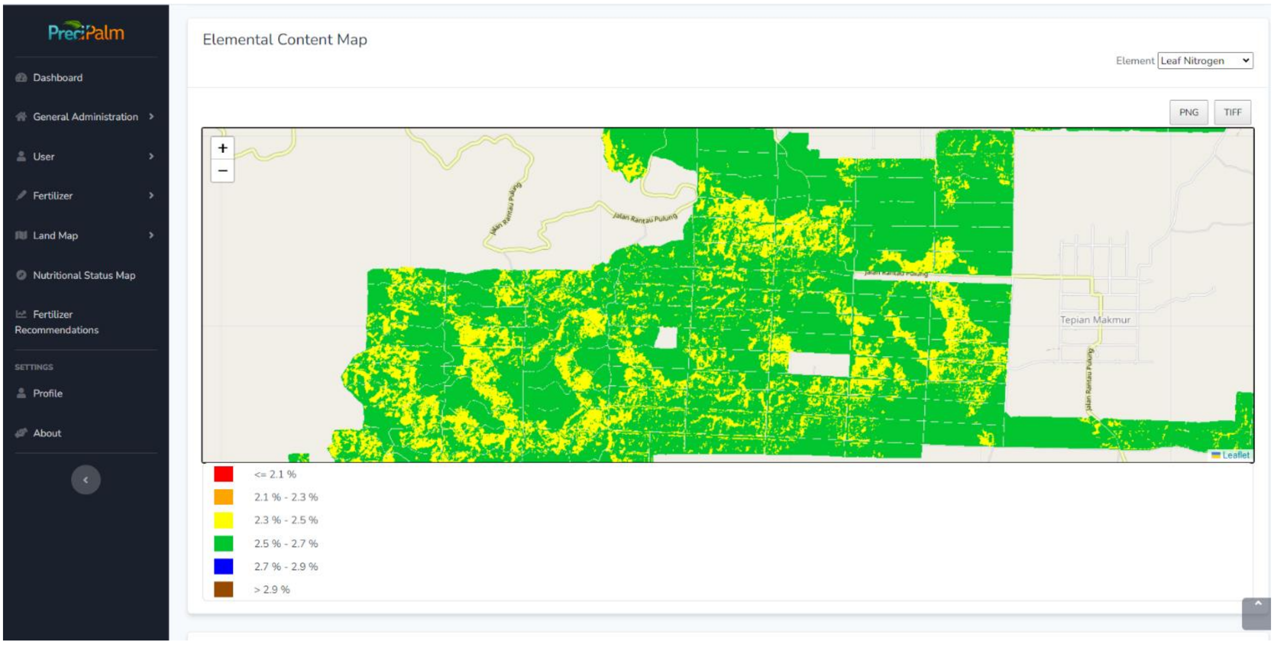
Single Fertilizer

Fertilizer Name	Total Requirement (kg)/(L)	Dosage per hectare (kg/ha)/(L/ha)	Dosage per tree (kg/tree)/(L/tree)
Single K Fertilizer	4,015,584	512	3.76
Single N Fertilizer	3,605,545	459	3.38
single fertilizer P	2,013,607	257	1.89

Compound Fertilizer

No.	Fertilizer Name	Total Requirement (kg)/(L)	Dosage per hectare (kg/ha)/(L/ha)	Dosage per tree (kg/tree)/(L/tree)
1.	NPK Rainbow (13 6 27 4)	10,710,684	1,364	10.03
	+ Single N Fertilizer	79,178	10	0.07
	+ single P fertilizer	74,371	9	0.07

Fig. 1: Graphical user interface of fertilizing area information (IPB University. Pupuk Kaltim, 2023)



Elemental Content Map

Element: Leaf Nitrogen

🟥 <= 2.1 %
🟧 2.1 % - 2.3 %
🟨 2.3 % - 2.5 %
🟩 2.5 % - 2.7 %
🟦 2.7 % - 2.9 %
🟫 > 2.9 %

Fig. 2: Graphical user interface of macroelement status (IPB University. Pupuk Kaltim, 2023)

VRFA applicators are divided into map-based VRFA bases and sensor-based bases based on both. Map-based VRFA uses a map of plant nutrient needs and is supported by Global Positioning System (GPS) technology. In comparison, sensor-based VRFA uses sensors that detect nutrient content or plant nutrient needs. The control system receives sensor readings to determine the target dose of fertilization. Sensor-based VRFA technology operates in real time and does not require GPS assistance (Azis *et al*., 2020). For VRFA-based systems, the combination of map base, sensor base, and Precipalm data is the focus of this study, as shown in Fig. (3).

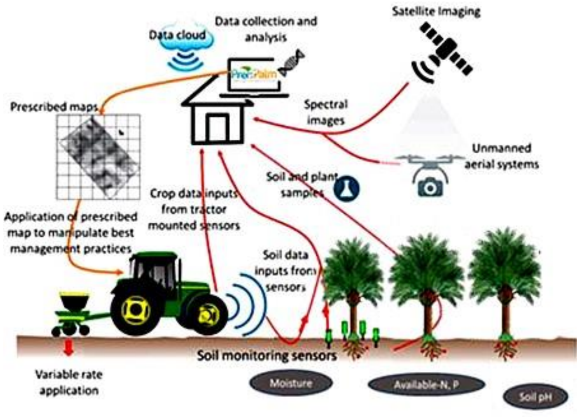


Fig. 3: VRFA based on precipalm data

Dead Reckoning Algorithm

The dead reckoning algorithm is a method of calculating positions based on previous movements and initial position information. In the navigation context, this algorithm has been widely used to track the movement of vehicles, including tractors. This approach leverages inertial data from sensors such as gyroscopes and accelerometers to predict vehicle position. The advantages of the dead reckoning algorithm include reduced delays and low bandwidth requirements. The dead reckoning technique is a viable solution to provide tractor vehicles uninterrupted positioning when GPS fails, especially when entering oil palm land with a dense tree canopy cover. Land processing is manipulating land mechanically for good crop planting (Bevly, 2001).

Modern agriculture increasingly relies on technology to increase efficiency and productivity. Using sensors and smart devices in tractor movement helps farmers more effectively manage farmland. The application of this technology can also reduce fuel consumption, optimize uptime, and increase agricultural yields (Akhtar *et al*., 2023).

The palm oil industry has experienced significant developments in terms of agricultural technology. Using technology, such as dead reckoning algorithms, is still needed to optimize tractor movement (Tan *et al*., 2022). This study review shows that modeling dead reckoning algorithms in tractor movement on oil palm fields. Therefore, this study is expected to significantly contribute to agricultural technology development in the palm oil industry. The selection of the DR algorithm for tractor positioning in this study is based on several technical and practical considerations. The DR algorithm is particularly suitable for oil palm plantation environments, where stable GPS signals are often limited due to dense vegetation.

This algorithm uses data from inertial sensors to estimate position based on previous movements, allowing for continuous positioning even when GPS signals are lost or degraded. Additionally, DR is more economical as it does not require expensive additional hardware like differential navigation systems. Although DR has limitations in terms of cumulative errors over time, integration with information from Precipalm and periodic correction of sensor signals on the tractor can reduce these errors, thereby ensuring precise and reliable results in precision fertilizer applications.

Developed Stages

This section presents the stages of a fertilization system developed with integrated control by OBC. This system gets information from the cloud-based Precipalm application. The Precipalm system allows satellites to monitor oil palm fields in real time.

Study of the On-board Computer Unit Development for Precision Fertilizing in Oil Palm Fields Based on Information from the Precision Agriculture Platform for Palm Oil is divided into several study stages, which will be carried out in sequential stages with the following research methods, as shown in Fig. (4).

Data Integration

The initial process is taking data from Precipalm, which is in the form of a GeoJSON file formatted and processed by Precipalm in which there is accurate information about the location and fertilizer needs by each hectare of oil palm plantations. An example code segment of GeoJSON data will be used due to processing from the Precipalm system, as shown in Fig. (5).

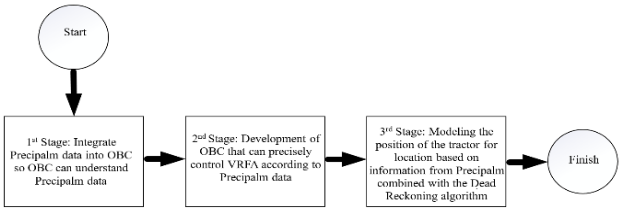
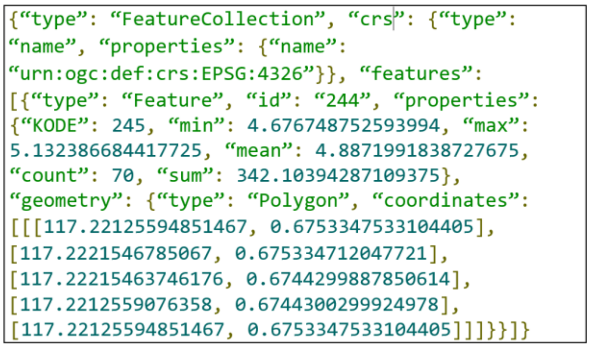


Fig. 4: Stages carried out in this study



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[117.2212559076358, 0.6744300299924978],
[117.22125594851467, 0.6753347533104405]]]}}]}
```

Fig. 5: Code segment of GeoJSON data from precipalm

GeoJSON is a geospatial data format supported by various Geographic Information System (GIS) software and platforms (Peuralahti, 2014). This data ensures better interoperability between Precipalm and other software used in farm management or further analysis, as shown in Fig. (6). The European Petroleum Survey Group (EPSG) 4326 format defines geographic coordinate systems using latitude and longitude as coordinate units (Abdillah and Nawangnugraeni, 2023). In agriculture, especially in fertilization precision, it is essential to have location information in a format that can be interpreted geographically, as this allows accurate mapping and navigation in the field (Dhonju *et al*., 2023).

OBC Development

OBC development begins with creating block diagrams and flow charts to depict the relationship between processes. Data from the Precipalm is needed to control the output on the VRFA system for precision. The basis for developing is to control VRFA technology based on Precipalm data.

This system's integrated OBC control involves a Raspberry Pi 4B-based processing unit to control the VRFA system directly so that the output produced will match the input from the Precipalm application. The overview of the OBC controlling the VRFA system is in the block diagram, as shown in Fig. (7).

Python syntax was chosen to control various system functions in OBC for several reasons. Python is known for its simple and easy-to-understand syntax (Sayeth Saabith, 2019). Python has a variety of modules and libraries that provide extensive functionality, including modules for data processing (such as pandas), network communication (such as urllib), hardware control (such as RPi.GPIO), and data visualization (such as matplotlib). Python supports controlling hardware via General Purpose Input/Output (GPIO) pins on devices like the Raspberry Pi.

Python programming allows easy development in connecting and controlling sensors and other devices (Fisher *et al*., 2021). The Python program syntax is beneficial for controlling liquid flow using the data from a liquid flow sensor. Raspberry Pi is the central brain controlling all VRFA functions.

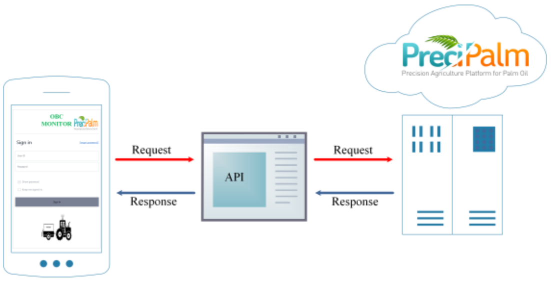


Fig. 6: Precipalm application interoperability

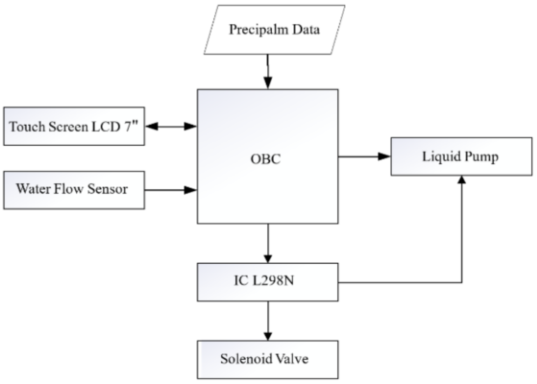


Fig. 7: Block diagram of controlled VRFA by OBC

The data read is then processed using pandas. In the loop, the program reads the value of the liquid flow sensor and calculates the pulse frequency and fluid flow in liters per minute. The pump control program is based on the total liquid flow that has been accumulated. The pump will be turned on if the total liquid flow is less than the Preipalm data.

The program will then check whether the total liquid flow follows Precipalm data. If it has, the loop stops, and the program displays the time taken on the Liquid Crystal Display (LCD) screen. In the final step, the program creates a plot using matplotlib to visualize the liquid flow and the total liquid flow during measurement. This Python program can be described in its working steps using a flow chart. as shown in Fig. (8).

Several fail-proof methods have been implemented to ensure the reliability and sustainability of the precision fertilization system controlled by the OBC. The system is equipped with hardware redundancy, such as dual sensors for critical parameters, allowing one sensor to take over if the other fails. Additionally, routine failure checks are performed through error detection algorithms that can identify anomalies in sensor data in real time and activate automatic recovery procedures. These procedures include switching to manual operation mode or using historical data to continue operations temporarily until repairs are made. This approach ensures continuous, reliable operation and reduces the risk of total system failure that could disrupt fertilization.

Upon repeated tests, the VRFA, controlled by the OBC system that was assembled and presented, showed stability between each device. VRFA module connection pattern between the pin and the node in each electronic device, as shown in Fig. (9). Security and data integrity are crucial aspects of IoT systems for precision agriculture. Several best practices have been implemented to ensure that the data collected and analyzed is valid and protected from unauthorized access. Data transmitted from various sensors and controllers is encrypted using industry-standard encryption algorithms to protect it from interception during transmission.

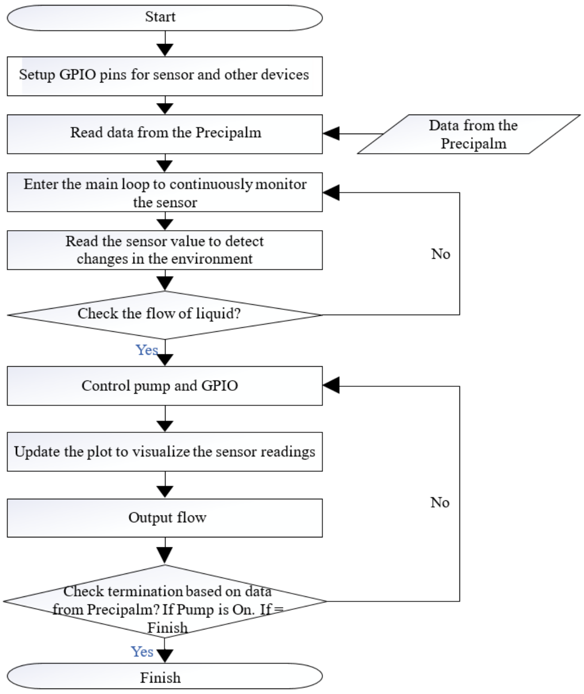


Fig. 8: Flowchart of controlled VRFA by OBC

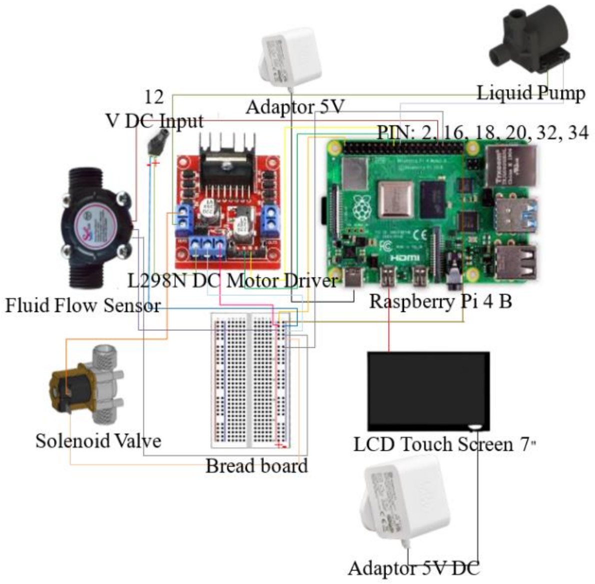


Fig. 9: Module connection pattern

Additionally, device authentication is performed using digital certificates to ensure that only authorized devices can connect to the system network. Each data input from controllers is verified for authenticity using checksumming and time-stamp-based validation methods to detect and reject suspicious or corrupted data. These practices enhance security and ensure that the analysis and decision-making are based on accurate and trustworthy data.

Dead Reckoning Modeling

Dead Reckoning Model (DRM) is used to simulate and model DR. The kinematic model was simplified into DRM. DRM is traditional DR based on predictions of future movements (Fujimoto, 2015). DRM also shows the sequence of kinematic equations used for motion prediction of an entity, denoted in S_0, that is, the last position of an entity. v indicates the speed of an entity, α indicates the acceleration value of the entity and Δt indicates the change in time from the beginning of the entity's move up to the current time. The formula for kinematic value can be seen below:

$$s = s_0 + v\Delta t \tag{1}$$

$$s = s_0 + vt + \frac{1}{2}a\Delta t \tag{2}$$

In this study, the focus is on improving the accuracy of DRM predictions. The proposed path-assisted DR (PADR) approach extrapolates with consideration of environmental factors and human behavior. A sequence of predefined points can be used to represent these paths in modeling. A path P_i (for $i = 1, 2, \ldots, M$, where M is the number of paths) is defined as a sequence of sampled points along an actual path. The element of the sampling sequence is denoted by:

$$\alpha_{ik} = (x_{ik}.y_{ik}.z_{ik}), k = 1,2,...,N_i \tag{3}$$

Where:

Ni = The number of sampling points on Pi

Path-assisted mapping is the process of determining which entities move on a predetermined path. The pathassist model is a predictive model for a specific entity (Chen and Liu, 2018) an example of path-assisted mapping, as shown in Fig. (10).

In Fig. (10) the proposed space is partitioned into a uniform grid. The points on the path are sampling points. The sampling grid is represented by a point located at its location. All grids form the corresponding detection zone of the sampling point.

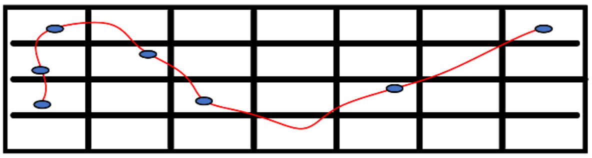


Fig. 10: An example of path-assisted mapping

Results and Discussion

Developing an OBC involves using the Raspberry Pi 4B as a control platform to regulate VRFA precisely. The integration of this technology also involves the Precipalm application, which provides precise fertilization recommendations based on satellite data that monitors the macroelement needs of oil palm plants in real time and dead reckoning algorithms to improve the accuracy of fertilization sites. Using Variable-Rate Fertilizer Application (VRFA) tools offers significant advantages in fertilizer management for oil palm plantations. One of the main benefits is increased fertilization efficiency, where fertilizers can be applied precisely according to the specific needs of each area, reducing overuse and optimizing operational costs. Additionally, VRFA can enhance crop yields by ensuring plants receive the proper nutrients tailored to soil conditions and plant requirements at each point of the field. This technology also supports sustainable farming practices by minimizing the environmental impact caused by inappropriate fertilizer use. Data from the system show that VRFA usage can reduce application errors, potentially increasing crop yields compared to conventional fertilization methods.

Hardware Implementation

The Raspberry Pi 4B was chosen for its formidable capabilities and flexibility in developing complex control applications. In addition, the presence of GPIO ports allows easy integration with sensors and actuators required for VRFA systems. Integration with the Precipalm application enables OBC to receive up-to-date data on the macronutrient needs of oil palm plants precisely to adjust fertilizer applications appropriately in dosage Liter (L) and location. The dead reckoning algorithm will improve the fertilization site's accuracy by calculating the tractor's movement and direction in real time, ensuring that fertilizer is applied accurately at every point in the farmland. Actual test results in this chapter are carried out to evaluate the precision and effectiveness of fertilizer application.

The researchers employed several hardware components to construct this VRFA controller system, such as the Raspberry 4B as a control center, liquid pump, liquid flow sensor, L298N DC motor driver module, and solenoid valve, each with unique functions and specifications. The Raspberry 4B hardware is configured to continuously read all environmental parameters in real time from all attached sensor devices and then convert all inputs into human-readable visual data, as shown in Fig. (11).

Developing an onboard computer unit with the Raspberry Pi 4B shows integration between powerful hardware, flexible software, and connections with cloud computing-based resources, as shown in Fig. (12).

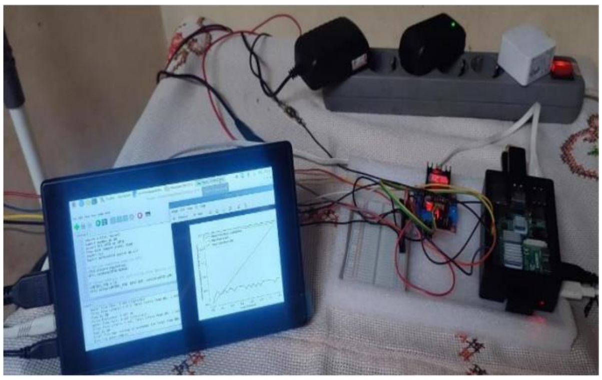


Fig. 11: OBC control development prototype

Fig. 12: Interconnection between hardware

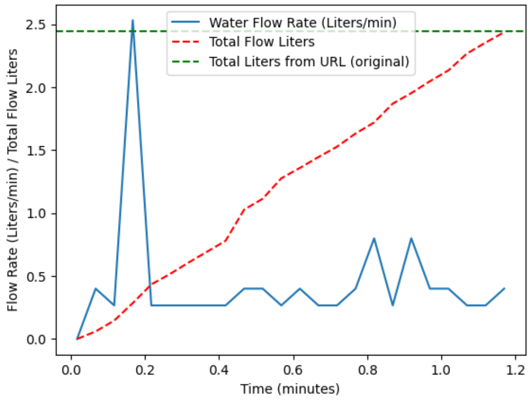
Software Implementation

The program code is developed using Python syntax, which utilizes modules such as RPi.GPIO is for interaction with hardware, pandas are for manipulating data and matplotlib is for data visualization. Python code applied to the Raspberry Pi 4B device is implemented to control liquid flow using the data from the fluid flow sensor device connected to the Raspberry Pi 4B.

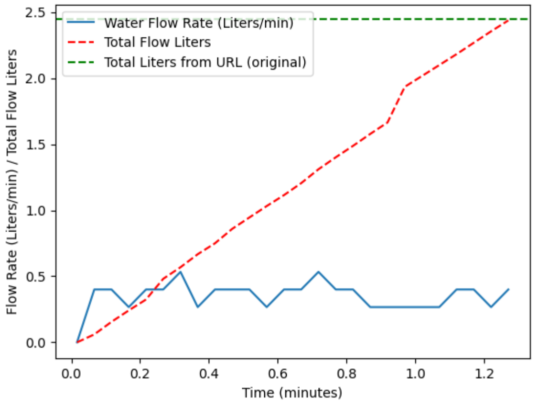
In the code, GPIOs control and monitor the hardware connected to the Raspberry Pi. First, GPIO pins are initialized according to needs, including pins to control other devices and pins to control liquid pumps. Then, a detection event is set to capture those changes called the 'countPulse' function, which counts the pulses received from the fluid flow sensor.

The data required to set up the liquid pump is retrieved from the URL using the 'urllib. Request' module, which, in this case, retrieves data from the Precipalm system resource. The data retrieved from the URL sets the liquid pump to the appropriate amount. The program will stop and record the liquid flow data, then display it in graphical form using the 'matplotlib' module.

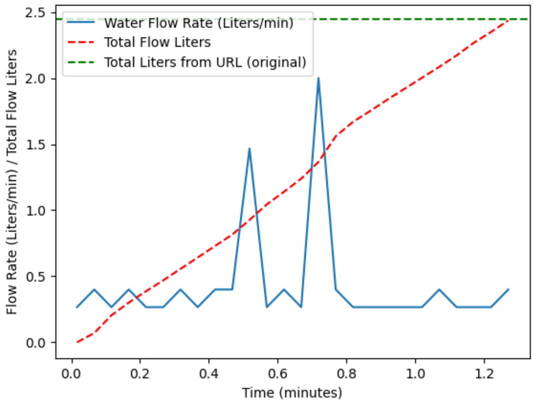
The line graphs in Figs. (13-15) and total liters from the URL for macroelement (P) represent a sampling of output provided by the system implementation of the ‘matplotlib’ module. The graph also illustrates the needs of each macroelement (N), (P), and (K) needed by oil palm plants. The fluid flow rate increases over time, indicating that the liquid pump works. However, after reaching a point, the flow rate of fluids tends to stagnate and stop as time passes and the volume of fluids produced by the pump.



Experiment 1



Experiment 2



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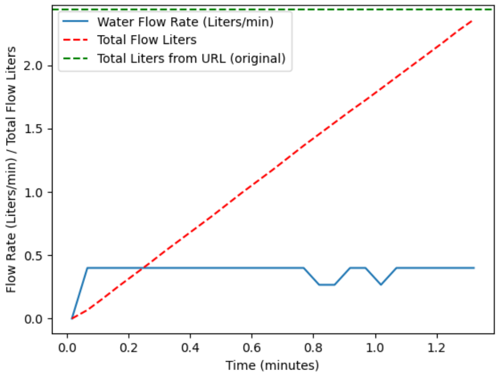

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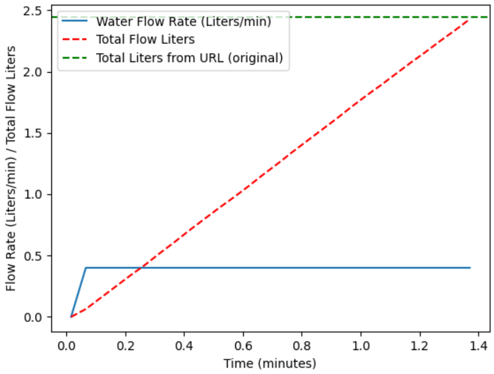

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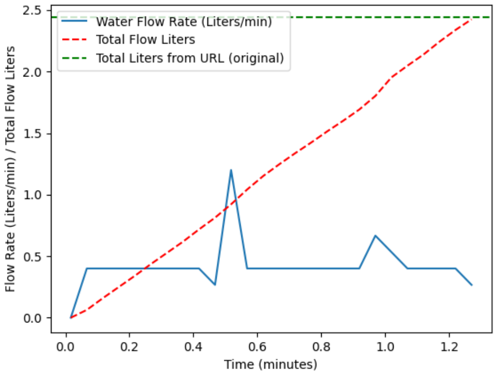

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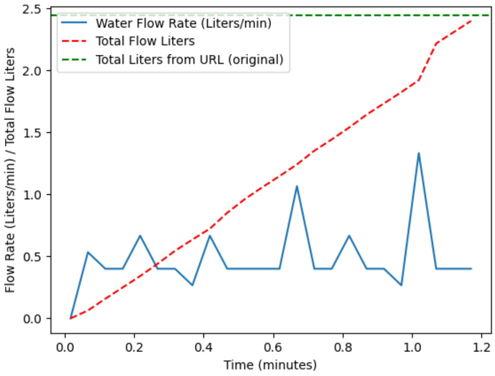

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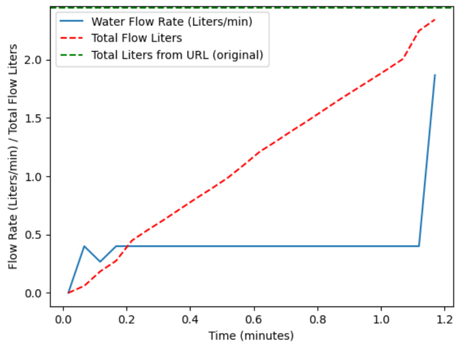

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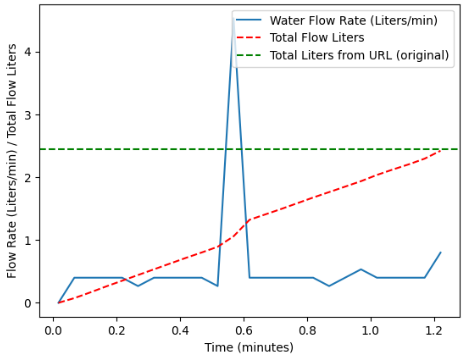
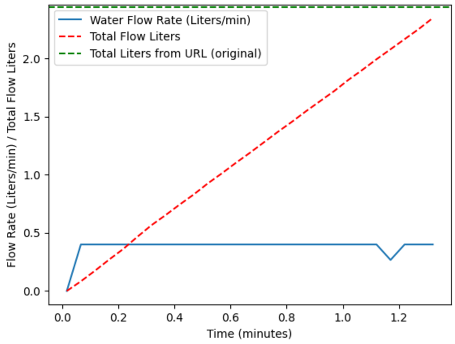
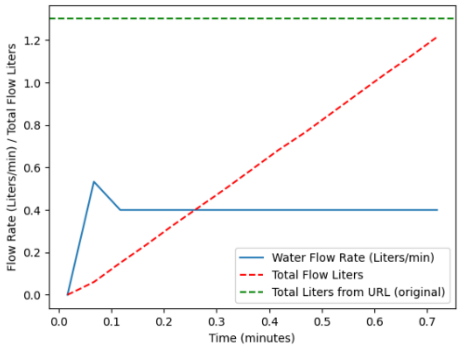


Experiment 9

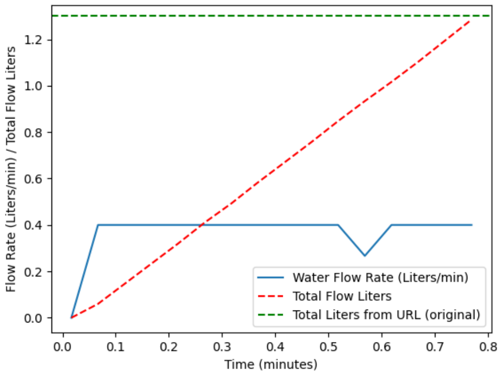


Experiment 10

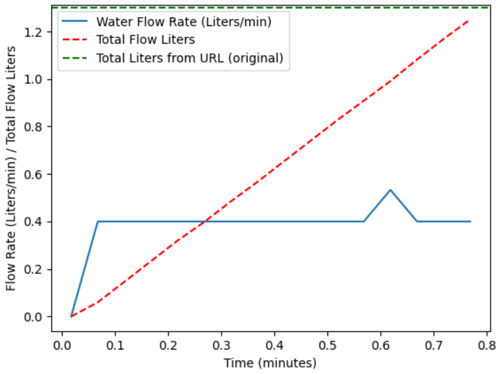
Fig. 13: Relationship between water flow rate, total flow liter, and total liters from URL for macroelement (N)



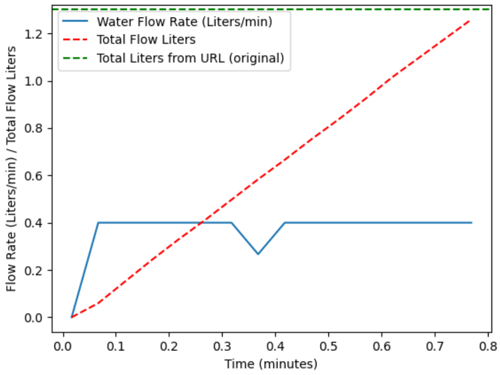
Experiment 1



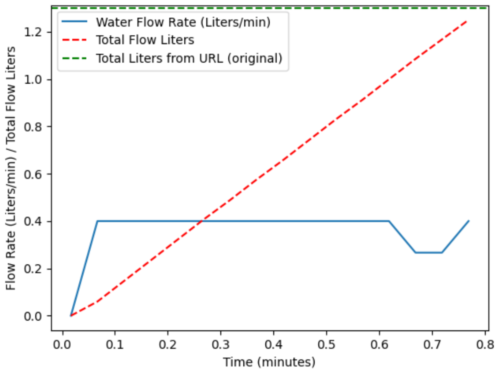
Experiment 2



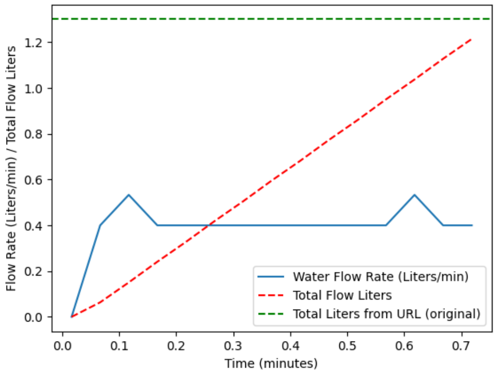
Experiment 3



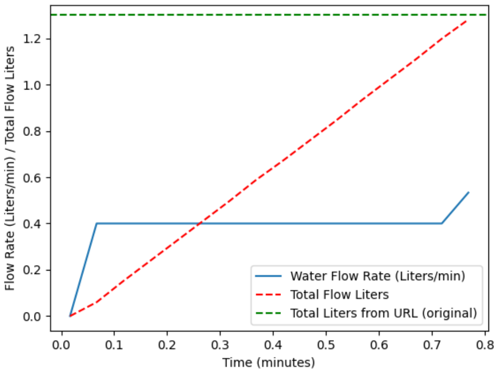
Experiment 4



Experiment 5



Experiment 6



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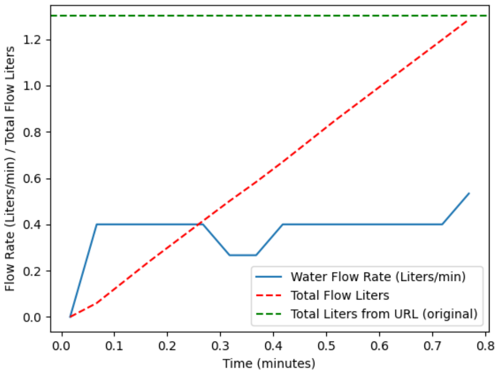
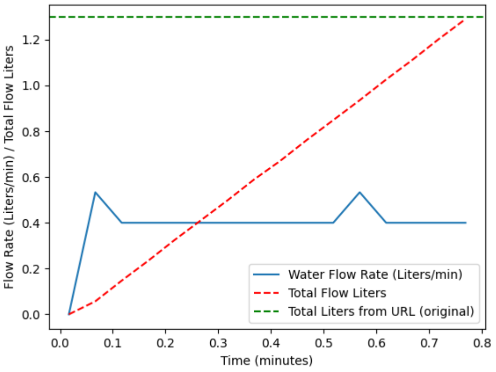
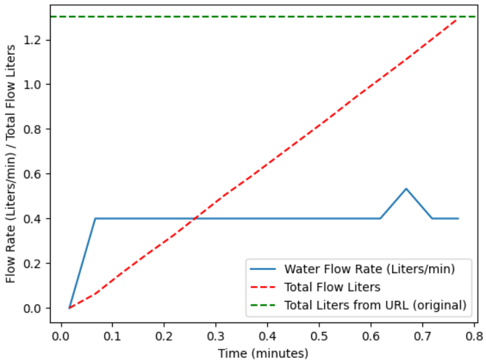


Experiment 8

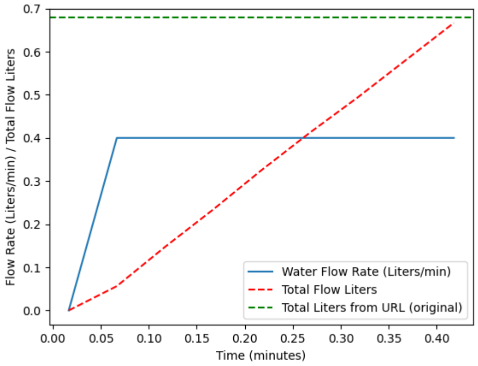


Experiment 9

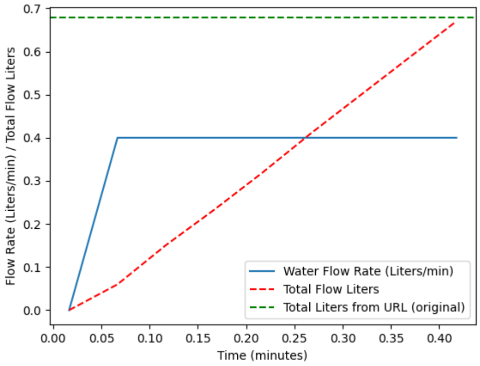


Experiment 10

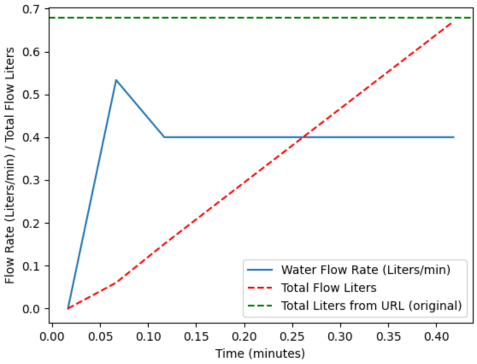
Fig. 14: Relationship between water flow rate, total flow liter



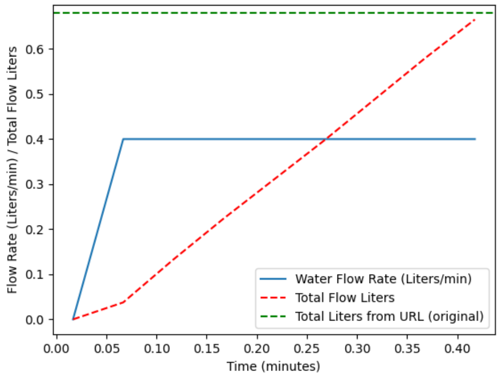
Experiment 1



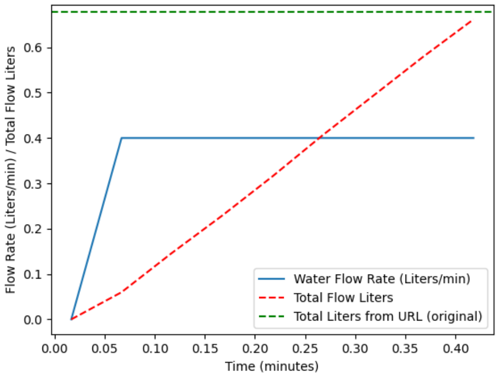
Experiment 2



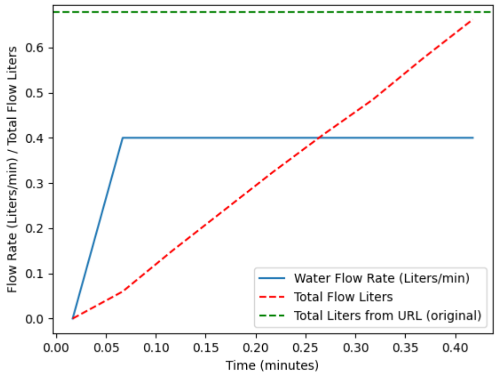
Experiment 3



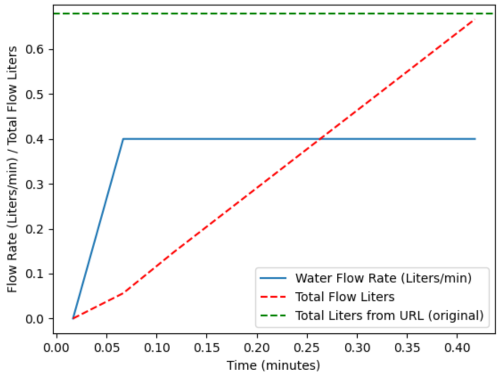
Experiment 4



Experiment 5



Experiment 6



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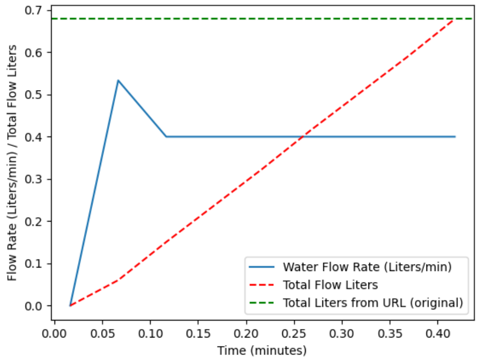
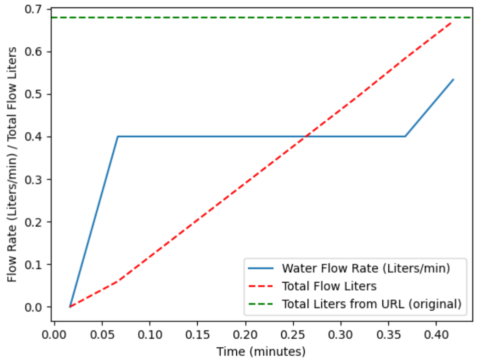
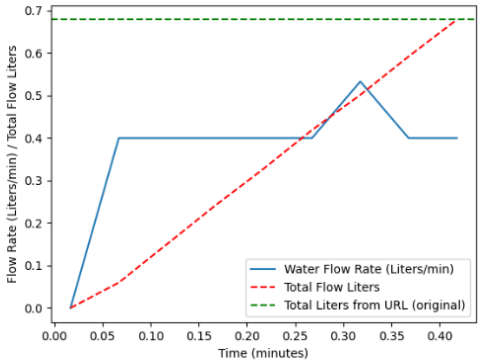


Experiment 8



Experiment 9



Experiment 10

Fig. 15: Relationship between water flow rate, total flow liter, and total liters from URL for macroelement (K)

From this graph, it can be concluded that the system can control fluid flow efficiently and responsively to the needs of plants, thus maintaining a balance of liquid delivery. Precipalm application uses complex mathematical modeling models and the app can predict plant nutrient requirements based on environmental conditions and plant growth phases. These output values for each element can be seen in the table. Each element is given an output target of element (N), element (P), and element (K). The output value of this target is generated from processed Precipalm data for the predetermined demo plot land; the results of Tables (1-3) show that the VRFA system controlled by the OBC device has a small percentage value from comparison data precipalm and actual data output from VRFA. The formula for comparison value in Tables (1-3) can be seen below:

$$|X| = (N_2 - N_1) \tag{4}$$

$$|Y| = \left(\frac{N_2 - N_1}{N_1} \right) 100\% \tag{5}$$

where:

N_1 = The value target of the Precipalm
N_2= The VRFA value outputs
X = The comparison value between VRFA value outputs and the value target of Precipalm (L)
Y =The comparison value between VRFA value outputs and the value target of precipalm (%)

Table 1: Output comparison of element (N)

	Element (N)			
Experiment sequence	Value target Precipalm (L)	VRFA value outputs (L)	(X) in liter	(Y) in percentage
1	2,444	2,422	0,022	0,900
2	2,444	2,418	0,026	1,064
3	2,444	2,427	0,017	0,696
4	2,444	2,423	0,021	0,859
5	2,444	2,431	0,013	0,532
6	2,444	2,426	0,018	0,736
7	2,444	2,416	0,028	1,146
8	2,444	2,437	0,007	0,286
9	2,444	2,436	0,008	0,327
10	2,444	2,438	0,006	0,245
Average value		2,427	0,017	0,679

Table 2: Output comparison of element (P)

	Element (P)			
Experiment sequence	Value target Precipalm (L)	VRFA value output (L)	(X) in liter	(Y) in percentage
1	1,301	1,293	0,008	0,615
2	1,301	1,283	0,018	1,384
3	1,301	1,291	0,010	0,769
4	1,301	1,284	0,017	1,307
5	1,301	1,292	0,009	0,692
6	1,301	1,289	0,012	0,922
7	1,301	1,285	0,016	1,230
8	1,301	1,290	0,011	0,846
9	1,301	1,296	0,005	0,846
10	1,301	1,297	0,004	0,307
Average value		1,290	0,011	0,846

Table 3: Output comparison of element (K)

	Element (K)			
Experiment sequence	Value target Precipalm (L)	VRFA value output (L)	(X) in liter	(Y) in percentage
1	0,679	0,667	0,012	1,767
2	0,679	0,670	0,009	1,325
3	0,679	0,649	0,030	4,418
4	0.679	0,653	0,026	3,829
5	0,679	0,665	0,014	2,062
6	0,679	0,666	0,013	1,915
7	0,679	0,675	0,004	0,589
8	0,679	0,662	0,017	2,504
9	0,679	0,679	0	0
10	0,679	0,674	0,005	0,736
Average value	0,667	0,013	1,915	

The use of OBC in controlling VRFA systems for automatic fertilization has given very satisfactory results, as seen in Fig. (16): The results show that OBC has successfully provided accurate control of VRFA. The graph illustrating the comparison between the amount of fertilizer applied shows the high accuracy of VRFA value output.

These promising results reflect OBC's ability to collect and process data efficiently to make informed predictions about plant fertilizer needs. The final result is the average percentage of comparison value between the actual output VRFA value and the target value from Precipalm data. The average percentage value is minimal.

Percentage of average comparison value between VRFA value outputs and the value target of precipalm Using sophisticated and responsive algorithms, OBC can adjust fertilizer applications precisely based on crop conditions, thus optimizing fertilizer use and increasing agricultural land productivity. Each of these figures can be seen from Fig. (17) as 0.679% for element (N), 0.846% for element (P), and 1.915% for element (K). The value shows high accuracy for the controlled output of VRFA systems.

Field Path-Assisted Modelling

A vital component of the PADR algorithm is the heuristic motion prediction field, which creates path assisted modeling, as shown in Fig. (18). It is assumed that the tractor will tend to follow a predetermined general path and deviations will be avoided. The accuracy of the algorithm's prediction will be equivalent to that of traditional DR algorithms. In this applied scenario, system development with GeoJSON data integration and assistance using dead reckoning algorithms can be an essential step in improving the productivity and sustainability of oil palm farming.

By combining spatial information and sensors, the system can provide more innovative and adaptive on-the-ground monitoring and control solutions, assisting farmers in making more informed and efficient decisions in oil palm land management. Precipalm can offer a high precision value in optimal fertilization recommendations for oil palm plants. The limitations of GPS signals when entering oil palm plantation land are the background of this study, so it is necessary to know the tractor's position more precisely when it is on the oil palm plantation field.

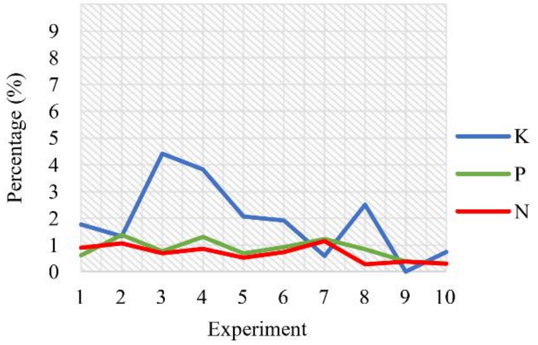


Fig. 16: The percentage ratio between the amount of fertilizer

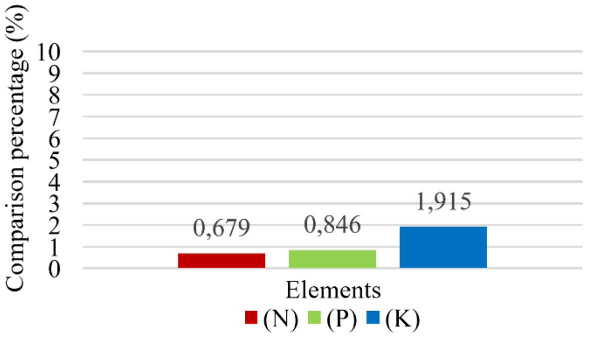


Fig. 17: Percentage of average comparison value between elements

Fig. 18: Field path-assisted mapping model in oil palm plant (Measurement is in 'meter')

In this applied scenario, developing a system with GeoJSON data integration, coupled with the assistance of dead reckoning algorithms, represents a significant step forward in improving the productivity and sustainability of oil palm farming. GeoJSON, a format for encoding various geographic data structures, enables the integration of detailed spatial information, which is critical for precise location-based applications. By leveraging GeoJSON data, the system can effectively map and monitor the terrain, providing valuable spatial context that enhances the DR algorithm's performance.

The development of OBC, which uses Raspberry devices as brain controllers, has shown promising capabilities in controlling VRFA systems with minimal error rates. OBC not only provides variable control of fertilizer application but also allows control of tractor direction of motion based on data from Precipalm. With comprehensive input from Precipalm, including macroelement requirement data on oil palm plants and longitude latitude data on crop position, OBC can provide accurate directions to tractors.

This data from Precipalm allows the OBC to translate the received data into a relief line using a dead reckoning algorithm, which is helpful, especially when tractors working in oil palm fields do not have a GPS signal. To improve the performance and functionality of OBC, GeoJSON data-driven dead reckoning algorithms emerged as the best-preferred solution. By accurately knowing the tractor's position within the plantation, the system can ensure that all agricultural operations are performed at the correct locations, thereby maximizing the effectiveness of interventions like fertilization and reducing the risk of over-application or missed areas.

Overall, integrating PADR algorithms with GeoJSON data and sensor inputs provides a comprehensive solution that addresses the unique challenges of oil palm plantation management. This approach enhances the accuracy and efficiency of agricultural operations and promotes sustainable farming practices by optimizing resource usage and reducing environmental impact. Through continuous monitoring and adaptive control, the system supports achieving higher productivity and sustainability in oil palm farming.

Conclusion

This study has successfully developed a Raspberry Pi-based liquid flow control system that integrates liquid flow sensors and pump settings based on data from Precipalm. Using Raspberry Pi, the system can measure and control fluid flow automation with high accuracy and efficiency. In its hardware development, this study has succeeded in determining and configuring the GPIO pins of the Raspberry Pi according to the system's needs. Program integration using Python allows periodic reading of liquid flow data, setting up liquid pumps based on received data, and connection to cloud resources. The results show that this system has great potential in developing applications that demand high precision, especially in controlling liquid flow for various purposes, such as precision agriculture, industry, and households. The level of precision can be seen in this study. The final result of the average percentage comparison value between the actual output of VRFA values and the target value from Precipalm data, the average value of each percentage is 0.679% for element (N), 0.846% for element (P) and 1.915% for element (K). Integrating liquid flow sensors with the Raspberry Pi enables more efficient monitoring and control while using cloud data for adaptive pump settings, increasing the system's flexibility in adjusting environmental conditions.

The development of OBC has opened horizons towards a more intelligent and adaptive agricultural future. The application of the dead reckoning algorithm is a significant breakthrough because it allows the OBC to model for better control over tractor direction and fertilizer distribution in the field. Integrating high technology and comprehensive data enables the system to provide intelligent and responsive solutions to various challenges in agricultural practices, particularly in oil palm cultivation.

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Author's Contributions

Indra Permana Solihin: Participated in all experiments, conducting the data analysis and writing the manuscript under the supervision of supervisors.

Kudang Boro Seminar: Lead research supervisor, designed the research roadmap, initiated the leading research, and provided direction for analysis and theoretical aspects in computer science, as well as applied engineering.

Desrial: Supervisor of the research, provides guidance on the experiments carried out during research, especially concerning applied engineering theory and VRFA device.

Karlisa Priandana: Supervisor of the research, guides the simulations and experiments carried out during research.

Ethics

This study is original and contains unpublished material. The author confirms there is no conflict of interest involved.

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