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Metadata Modeling of LoRa Based Payload Information for Precision Agriculture Tea Plantation

Eddy Prasetyo Nugroho[1*], Taufik Djatna[2], Imas Sukaesih Sitanggang[3], Irman Hermadi[4], Agus Mulyana[5], Sri Wahjuni[6], Heru Sukoco[7]
[1,3,4,5,6,7]Department of Computer Science, Faculty of Mathematics and Natural Sciences,
IPB University, Indonesia
[2]Department of Agroindustrial Technology, Faculty of Agricultural Engineering and Technology,
IPB University, Indonesia
[1]Department of Computer Science Education, Faculty of Mathematics and Natural Sciences Education,
Universitas Pendidikan Indonesia, Indonesia

Abstract. Utilization of Agriculture Drones in rural and hilly tea plantations as Precision Agriculture (PA) with Payload Information from its communication with the Ground Control Station (GCS) is an implementation of information technology to manifest its use in the monitoring process related to the location of tea leaves that are suitable for picking.
Purpose: The purpose of this study is to model the metadata of Payload Information on Agriculture Drones which consists of the results of images computational and the Onboard system of the Drone.
Methods: The stages of the research were carried out with the process of forming Payload information metadata from the Agriculture Drone with sensors/actuators based on the architecture and computing with Image Processing or Computer Vision on the camera captures. This study describes the metadata modeling process formed from the Internet of Things system with Drone and GCS communication based on the Long Range or Long-Range Wide Area Network protocols with Payload information consisting of drone data and image computation results.
Result: The result obtained is the formation of Payload information from LoRa-based Drones with a frame size of 142 bytes.
Novelty: Payload information is formed into a metadata model indicator with the formation scheme being part of the tea plantation dataset. The metadata model will be test expected to obtain field data on Drones and GCS communication in the LoRaWAN Network in tea plantationswhich are rural environments.

Keywords: Agriculture drone, LoRa protocol, Payload information, Precision agriculture, Tea plantation
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INTRODUCTION

Indonesian tea production and exports from 2008-2016 experienced a decline [1]. This is suspected to occur because domestic tea consumption is not significant with a large Indonesian population and tends to increase consumption of premium (quality) imported tea. The trend requires getting a higher quality local Indonesian tea. The quality of tea is influenced by the analysis process of tea picking from picking analysis and analysis of tea leaves [2].

The existence of tea plantations consists of hilly blocks in large parts of rural areas [3], and it takes a long time for pickers to determine the location of tea leaves suitable for picking. The utilization of information technology by utilizing sensors/actuators and Internet of Things (IoT) technology in agriculture supports the potential to develop into Precision Agriculture (PA) technology by utilizing drones.

According to [4], Precision Agriculture (PA) is a management strategy that collects, processes, and analyzes temporal, spatial, and individual data and combines it with other information to guide site-specific management decisions, plants, or animals to increase resource efficiency, productivity, quality, profitability, and sustainability of agricultural production. PA is an integration of the use of information technology in agricultural matters such as monitoring plants, spraying plant fertilizers, and controlling soil chemical substances [4], [5].

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[*] Corresponding author.
Email addresses: eddypnugroho@apps.ipb.ac.id (Nugroho)
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Utilization of IoT technology on UAVs/Drones with their Wireless Sensor Network (WSN) makes PA goals more optimistic and effective. This can happen in Smart Farming or Smart Agriculture, which creates a collaboration process between various analytical processes and technological means related to all stages of production from sowing to harvesting. Among them is the implementation of the following PA[6]: a) the use of the Global Positioning System (GPS) in showing the position of vehicles or plants related to Agriculture needs; b) the use of the Geographic Information System (GIS) in the process of organizing, analyzing, processing, and visualizing information from the field in the form of digital maps; c) production mapping, identifying factors from each area that affect the production process. Thus, these map factors can be combined with terrain maps and other data, such as Remote Sensing(RS) and meteorological information; d) soil mapping, which provides variability of soil data consisting of the elements nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), Sulfur (S), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) and molybdenum (Mo) for soil analysis and sampling methods consisting of grid sampling & soil type sampling; e) soil Electrical Conductivity (EC) mapping, used in identifying homogeneous soil management zones. In general, there are two methods of EC mapping: electromagnetic induction and contact method; f) Remote Sensing (RS) technology, the process of capturing photo images with satellites or UAVs; g) Variable Rate Applications (VRA), a method of applying agrochemical products with different doses based on the needs of each region. In general, there are two VRA methods, namely map-based and sensor-based.

There are various types and characteristics of drones or Unmanned Aerial Vehicle (UAV) that can be used in PA implementation, both fixed-wing and rotary-wing/multi-captor types of drones that can be described according to the needs of PA [5]. In tea plantations that are rural and extensive with hills, it requires Drone Architecture that is in accordance with the needs in picking the tea leaves.

The implementation of an Agriculture Drone with its sensors will get datasets which are ready to be processed in computing. With the camera sensor, you will get streaming images of tea plantations which are used as computational material for picking analysis. The process of capturing streaming images and computing them requires techniques in Image Processing or Computer Vision with algorithms accompanying each stage. The use of drones in monitoring tea plantations communicates between Agriculture Drone and Ground Station Control (GCS) which generates the payload information it captures.

The management of tea gardens is based on tea production targets with international standard quality. According to [7], Indonesia as the world's 6th largest tea producer after Vietnam, India, Sri Lanka, and Kenya, is required to meet demand with tea quality standards that are acceptable to the world. This is influenced by the processes carried out in the management of tea from seeding, planting preparation, plant maintenance, picking, transportation of tea leaves, and production processing in tea factories [2].

The implementation of Precision Agriculture in tea plantations can be applied in the use of Agriculture Drones in the process of picking high-quality tea leaves according to standards so that Indonesian tea production and exports increase. The process of picking tea leaves requires analysis of picking and shoots of tea leaves by knowing the locations of tea leaves that are suitable for picking according to the standard of green tea leaf analysis. The captures of drone camera will be processed using Computer Vision Techniques to obtain classification results from tea leaves that are suitable for picking on the tea plantation.

In carrying out the stages of the Computer vision technique on tea plantation image frames, several algorithms are implemented in data acquisition process to actuation [8] which decides the classification results. The process in the series of stages is a land drone mapping process with image stitching, which consists of the Image Alignment process, namely Feature Extraction with Feature Detection according to the object, Feature Matching, Outlier Rejection, Image Wrapping, and ends with the Image Blending process for the composition of the images [9].

Payload information for Agricultural Drones using the LoRa protocol allows it to include sensor data such as temperature, humidity, or soil moisture levels, and imaging data from the camera. This information will be used to monitor and analyze tea plantations in terms of the feasibility of picking their leaves. Furthermore, the Drone will transmit this data via the LoRa protocol to the GCS receiver for further use.

Data Engineering is a mechanism for designing and building systems that make it possible to collect and analyze raw data from various sources and formats [10]. Data Engineering consists of [10]: a) Gathering data requirements, related to how long the data needs to be stored, how the data will be used, and what people and systems need access to the data; b) Maintaining metadata about the data, related to what technology manages the data, schema, size, how the data is secured, data sources, and the final owner of the data; c) Ensuring security and governance for the data, related to using centralized security controls such as LDAP, encrypting data, and auditing access to data. d) Storing the data, related to the use of specific technologies optimized for specific data uses, such as relational databases, NoSQL databases, Hadoop, Amazon S3, or Azure blog storage; e) Processing data for specific needs, related to using tools that access data from various sources, change and enrich data, summarize data, and store data in storage systems.

Data Engineering is needed to obtain the design of the dataset required model in monitoring tea plantations by utilizing IoT-Drone technology with its network which is specifically described in the Agriculture Drone system architecture and its communications. This metadata model is conceptually based on the LoRa Protocol.

The description of drone payload information requires a mechanism in Data Engineering to build the metadata model. Data engineering takes an important role in creating and maintaining the infrastructure and systems needed to store, process, and analyze payload information and metadata. The metadata model based on the LoRa communication protocol has the information content mentioned above with data packet limits between 51 – 222 bytes [11], [12].

This paper aims to describe the process of forming payload information. It is necessary to know how the process is formed as a dataset model that determines the information transmitted by Drones to GCS receivers on the IoT-Drone network in rural environments on tea plantations based on the Long Range (LoRa) or Long Range Wide Area protocol. Network (LoRaWAN) [3], [6], [7]. This data model becomes part of Data Engineering in Gathering Data Requirements, Maintaining metadata [10], which is influenced by the LoRa/LoRaWAN protocol in the dataset formed. The dataset consists of drone payload information and computational results of drone image capture using Image Processing or Computer Vision techniques. This paper ends with a data model that is described with a schematic algorithm for forming drone payload information from an openMV camera and the LoRa/LoRaWAN-based MCU ESP32 Onboard System which are part of the dataset.

METHODS

Achieving the objectives of this research requires stages so that the Payload Information metadata modeling from Agriculture Drone is compiled from the data collection process by processing images from the OpenMV Drone Camera which is part of the Image Area Mapping process and Sensor/Actuator Processing on the onboard system of the ESP32 Microcontroller (MCU) which includes sensors installed on drones including GPS sensors (latitude, longitude, altitude), drone movement speed, drone motion direction, drone voltage and current battery sensors. Figure 1 shows the next stage is integrating the two processed data in forming of Payload Information metadata from Drones with a data frame packet format based on the LoRa Protocol before being sent in Drone and GCS communications.

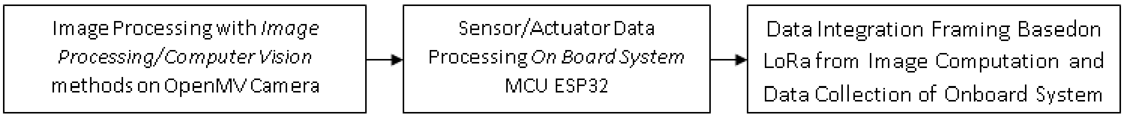


Figure 1. Process of forming metadata on payload drone information

A detailed explanation of the formation of the metadata model from Payload Information in the chapter on Results and Discussion with a discussion of Communication Agriculture drones and GCS based on LoRa/LoRaWAN with Communication Architecture between OpenMV Camera Drone and GCS as well as Modeling Drone Payload Information Metadata with the formation algorithm.

RESULT AND DISCUSSION

The Agriculture Drone system architecture is needed to describe the components that form drones, specifically in Precision Agriculture according to their needs, such as in their duties in tea plantations which have hilly and rural blocks. This system requires a functional and physical architecture for hardware specifications and relationships between the components that make up the precision with their needs.

Functional Architecture

Figure 2 shows the functional architecture required in a rural tea plantation environment. Rural here relates to communication to the hilly environment where there are lots of tea plant cover trees which allow it to become a communication barrier between the Drone and the Ground Control Station (GCS).

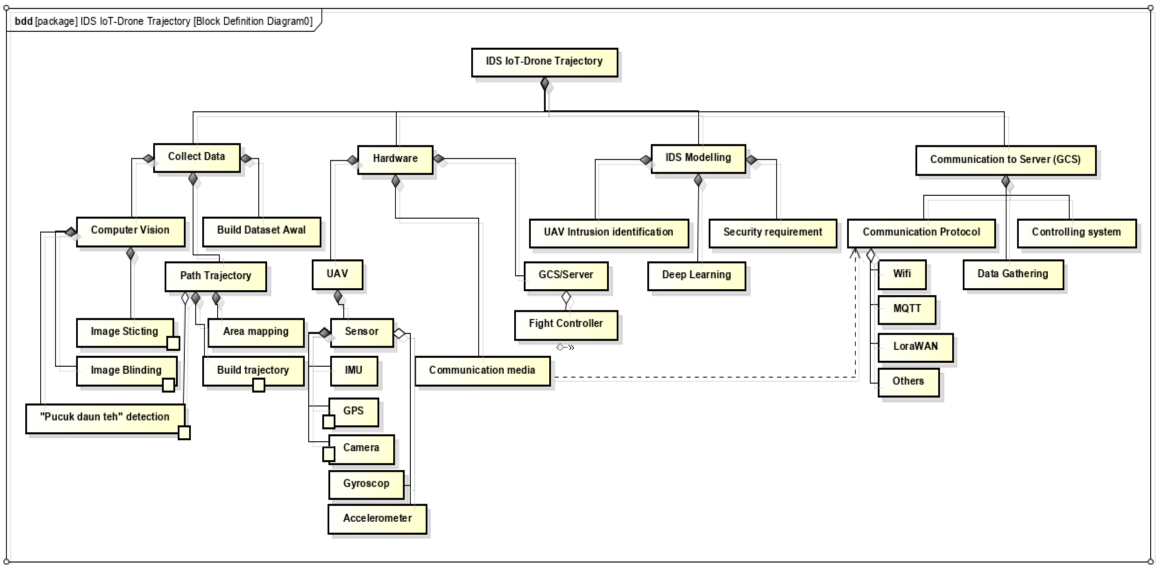


Figure 2. Agriculture drone functional architecture

Hardware Specifications

The Agriculture Drone system architecture is implemented in a physical architecture by providing drone-forming specifications, GCS specifications, and drone-GCS datalink communication. The physical form of the Agriculture Drone can be seen in Figure 3 and the OpenMV Camera installed on the Drone and the GCS Module can be seen in Figure 4.

Figure 3. Agriculture drone

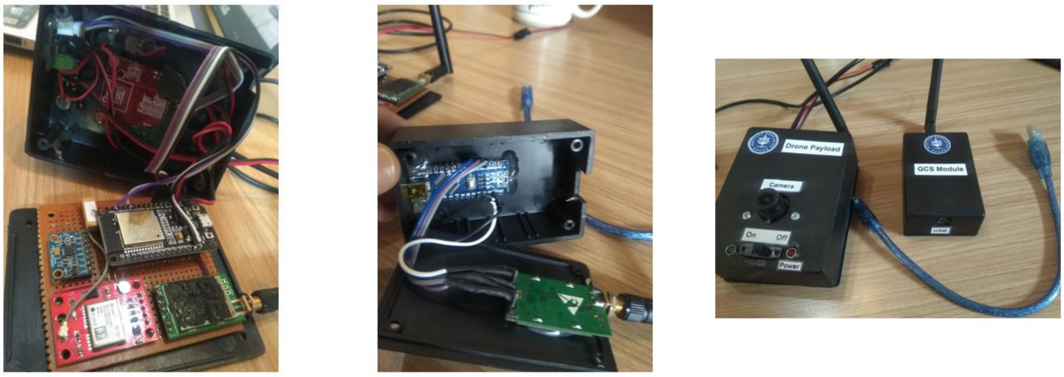


Figure 4. OpenMV camera drone and GCS module component

Table 1 shows detailed drone specifications for precision agriculture needs, especially in monitoring tea leaf picking.

Table 1. Agricultural drone specifications

No	Item	Specification	Total	Unit
1	Model	Quad rotor, Vertical Take Off-Landing	1	Unit
2	Dimension (PxLxT) cm	50x50x20 cm	1	unit
3	frame	Fiber / Frame 450 DJI F450	1	Unit
4	Popeller	Fiber / plastic	4	Pcs
5	ESC (Electronics Speed Controller)	30A SimonK Firmware Brushless ESC with 3A 5V BEC	4	Pcs
6	Controller	Ardupilot APM 2.8 Flight Controller	1	Pcs
7	Actuator	A2212 KV1000 Brushless Motor	4	Pcs
8	GPS and ceramic antenna	GPS UBLOX Module 6M L5883	1	Pcs
9	Camera	Serial Camera, PX4FLOW Optical Flow Camera -OpenMV Camera	1	Pcs
10	IMU Sensor	6 DOF (Gyroscpoe + Accelero meter)	1	Unit
12	Power Source	Lipo Battery 3s 3000mah	1	Pcs
12	Communication (2 ways, duplex)	Radio 3DR/Lora SX 1276 , 433 Mhz	1	Packet
13	Radio Antenna	Omni directional, ¼ lambda	1	Pcs
14	Firmware	C/C++	1	Packet
15	Framework & IDE	Arduino 2.0	1	Packet

Table 2 shows the specifications of the communication technology between drones and GCS that can run in rural areas in hilly tea plantations.

Table 2. Data link communication specifications

No	Item	Specification
1	Model	Omnidirectional
2	Communication Media	Dual (Wifi: 2.4 Ghz, dan Radio 433 Mhz)
3	Communication Protocol	Wifi, dan LoRaWAN
4	Communication Path	Wireless

Table 3 shows the specifications of the GCS technology used to receive data from drones based on the LoRa/LoRaWAN Protocol.

Table 3. Ground control station specification

No	Item	Specification
1	Model	Omnidirectional
2	Communication Media	Dual (Wifi: 2.4 Ghz, dan Radio 433 Mhz)
3	Communication Protocol	Wifi, dan LoRaWAN
4	Message Protocol	Fiber / plastic
5	Antenna	Omnidirectional , ¼ Lambda
6	Cable Type	RG 58
7	Connector	Indusrtial Connector RG58
8	GPS and ceramic antenna	GPS UBLOX Module 6M L5883
12	Power Source	Lipo Battery 3s 3000mah / DC PSU 12 V /2 Ampere
12	Software	Desktop based, Python / C#
13	Configurator Tool	Mission Planner

Agriculture Drone and Ground Control Station (GCS) Communication based on LoRa/LoRAWAN Protocol

When the Agriculture Drone performs the Precision Agriculture task, namely monitoring the picking of tea leaves in tea plantations with the computational results on the Drone side, it is then sent to the Ground Control Station (GCS). This involves the process of transmitting Drone and GCS data via LoRa technology. With LoRa (Long Range) or LoRaWAN (Long Range Wide Area Network) technology affects the formation of payload data that is sent to the receiving side. In the Open System Interconnection (OSI) reference model, LoRa Technology operates at the Physical Layer and LoRaWAN at the Data Link Layer, which governs the communication network that is formed [13], [14].

The IoT-Drone and GCS communication network installed in Figure 5 in a rural tea plantation environment greatly influence the dataset formation process. The communication network is affected by the LoRaWAN Protocol which consists of Servers, Gateways, and End Nodes [13], [15]–[17].

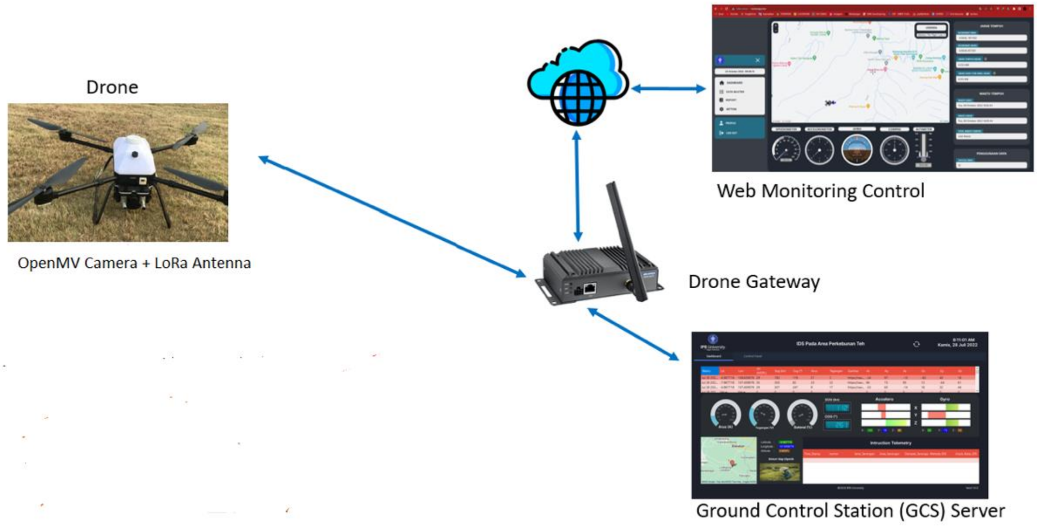


Figure 5. Drone-GCS network architecture based on LoRaWAN

The data transmission occurs in LoRa followed by the data frame structure mentioned in Figure 6. The Preamble header is the program code that needs to be transferred. The PHY header mechanism is applied to data packets. CRC is a cyclic redundancy check that handles the same correct received data bits. The payload is formed using the Medium Access Control (MAC) approach [15], [18] containing LoRaWAN or MAC data bits [19].

Preamble	PHY Header	CRC	Payload

Figure 6. LoRa data frame [19]

The transmission rate on a LoRa network is calculated using the following formula with Spreading Factor (SF) and Bandwidth (BW) in Hertz as shown in equation 1 [19]:

$$Symbol\ Rate\ (Rs) = SF * \frac{BW}{2^{SF}} \tag{1}$$

A mathematical solution has been developed to authenticate customized and developed LoRa devices. Data transmission is illustrated using the Poisson process. Transmission power in LoRa: Probability Pi, where i is the data transmission rate. Transmission power that has a probability of success is represented as shown in equation 2 [19]:

$$\boldsymbol{P_i^{S,1} = P_i^{Data} P_i^{Ack}} \tag{2}$$

$$\boldsymbol{P_i^{Data} = e^{-\left(2Ti^{Data}i + Pi^{Data} * Ti^{Ack}\right) r_i} + \sum_{k=1}^{N-1} \frac{(2r_i {T_i}^{Data})^k}{K!} e^{-2r_i {T_i}^{Data} W_{i,k}^{GW}}} \tag{3}$$

P_i^{Data} is the probability of transmission of data frame without collision together with data rate I as shown in equation 3; $\mathrm{P_i^{Ack}}$ is the probability of receiving a signal with acknowledgment of full transmission success; λF/Pi = ri is the equation representing the load at stage I with a single channel F; ${T_i}^{Data}$ represents the duration of the data frame; and represents receiving the duration of a data frame with acknowledgment.

$$\boldsymbol{P_i^{Ack1} = e^{-\left(min(Ti, Ti^{Data}i) + Ti^{Ack}\right) r_i} + \sum_{k=1}^{N-1} \frac{(r_i {T_i}^{Data})^k}{K!} e^{-2r_i {T_i}^{Ack} W_{i,k}^{Mote}}} \tag{4}$$

P_i^{Ack1} is the probability of receiving a signal data frame with successful reception. Successful transmission and reception of data is represented by Equations 3 and 4.

OpenMV Camera-Drone and GCS Communication Architecture

The following is the communication architecture between the OpenMV camera, ESP32 MCU, and LoRa Antenna with a frequency of 433 MHz [19]–[21] which is in the Agriculture Drone in Figures 7 and 8 which affects the formation of the Payload metadata.

Figures 6 and 7 depict the communication between Agriculture Drone and Ground Station Control (GCS) building the transmitted Payload data. The Process of Forming Payload Data carries out processes with the following stages: 1) Capture the surface of tea leaves on a Tea plantation with an OpenMV Camera on Drone. 2) Capture results will be processed in OpenMV, the tool support to conduct training and produce a library according to the programming language used in this study using MicroPython. 3) Computational processing of data (Capturing results) in the form of video/image frames on OpenMV with Image Processing or Computer Vision algorithms (SIFT/RANSAC/FLANN.CNN) with the results of image classification with status ready to be picked or not. 4) Combining data from Drone sensors (GPS, Gyroscope, Accelerator) and Image Processing or Computer Vision computational results on the ESP32 MCU. 5)Transmit the ESP32 MCU's Payload to the LoRa Transceiver SX 1278 433 MHz unit to GCS.

The process of sending Payload information data uses LoRa communication media at an operating frequency of 433 MHz[15], [18], [22] using an Omni directional antenna. The data delivery scheme is based on event-driven. Data related to GPS information based on standards from the National Marine Electronics Association (NMEA) 0183 [23]. The results of receiving image data depend on the OpenMV camera's specifications.

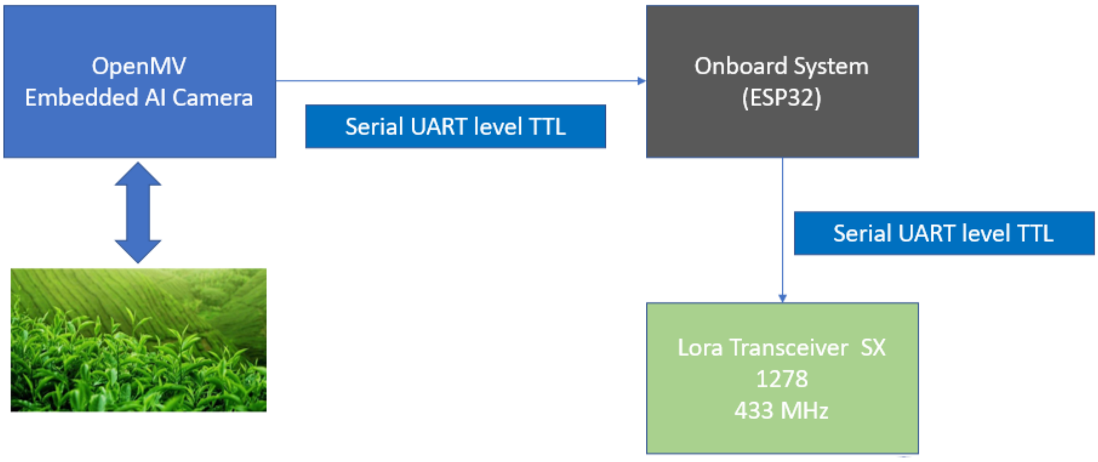


Figure 7. Agriculture drone-GCS communication architecture with LoRa

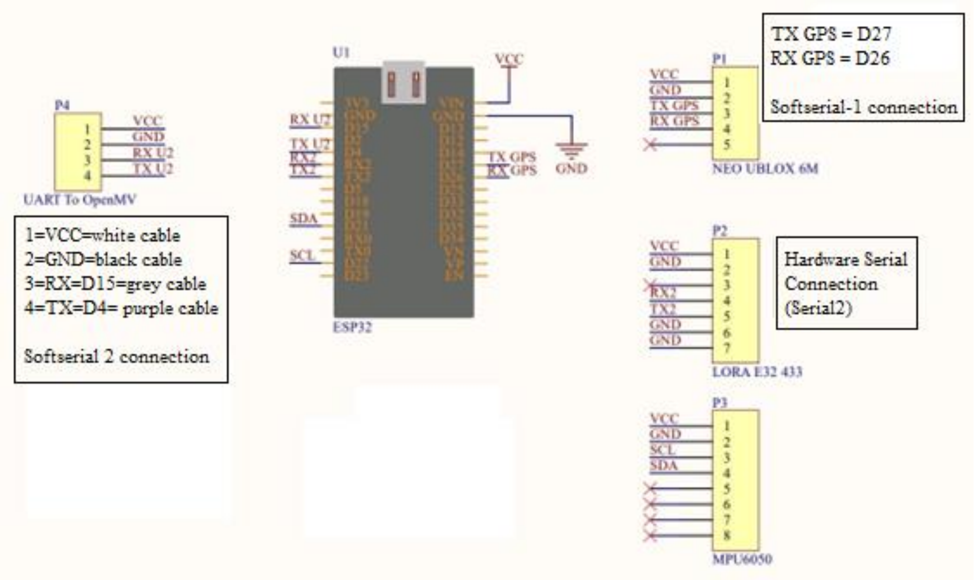


Figure 8. Physical architecture of openMV-MCU ESP32-GCS with LoRa

Metadata Modeling of Drone Payload information

The metadata modeling of the Payload Information Agriculture Drone was compiled from the process of collecting image data from the OpenMV Drone Camera which is part of the Image Area Mapping process and the onboard system of the ESP32 MCU. According to Figures 7 and 8 above, this data payload is formed in Drone and GCS communication via LoRa.

The process of collecting data by capturing images of the tea garden area is part of the Image Area Mapping process, carrying out the stages as shown in Figure 9. When the image capture process is carried out, the Image Stitching process stages are carried out, as shown in Figure 10.

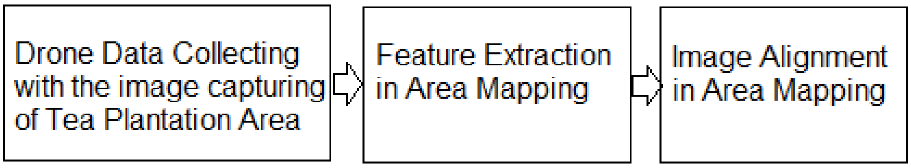


Figure 9. Image area mapping process

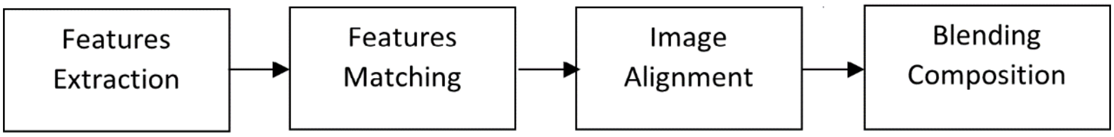


Figure 10. Image stitching process in land drone area mapping

The metadata in the payload information from this drone is generated from the combination of two main parts, namely the OpenMV camera to sense the color of tea leaves and the onboard system module which contains a microcontroller unit, sensors, and LoRa radio communication module to process data while sending data to the Ground Control Station (GCS). The metadata forming process of drone payload information is part of the research result and the conceptual architecture model is shown in Figure 11.

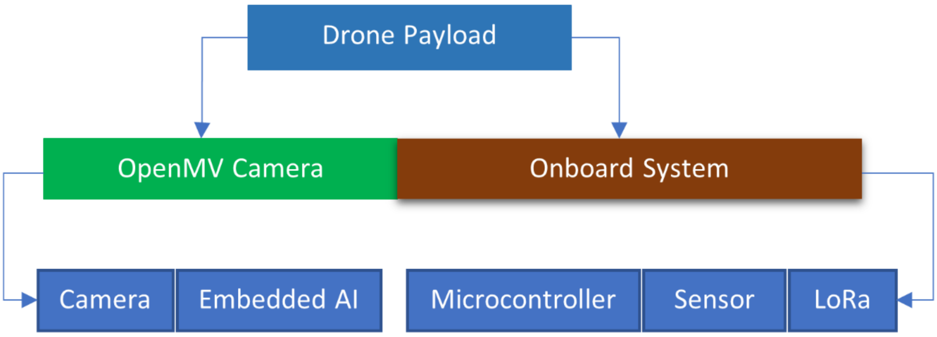


Figure 11. Metadata forming framework on drone payload information

In general, the mathematical formula for Drone Payload is as shown in equation 5:

$$f(Paylod) = \sum_{i=1}^{n} OpenMV\_data(i) + \sum_{i=1}^{n} Sensors_{data}(i) \tag{5}$$

Each Drone Payload sub-system has a specific function as described in Table 4.

```
Drone data packet Algorithm

Result:Drone data packet
Pseudocode:

While (Drone & GCS Connection Status == True}
 do {
    payload_data_complete == False;
    If (OpenMV_Data == True)then
   {
         Check serial_channel to onboard;
         If (Serial_available ==  True)then
         {
          Serial_Connection == True;
          OpenMV_Data_Sending == True;
          Append OpenMV_data With Sensor;
          Drone_packet_data(i) = Sensors_Data(i)+ OpenMV_Data(i);
          Payload data complete  == True;
          Data_sending_From_Lora_to_GCS(i)= +1;
          Sending Status == True;
         } else
         {
          Serial Connection == False\;
         }
        }else
     {
         Open MV Data  == False\;
         }
   }
    Drone & GCS Connection Status == False;
  }
```

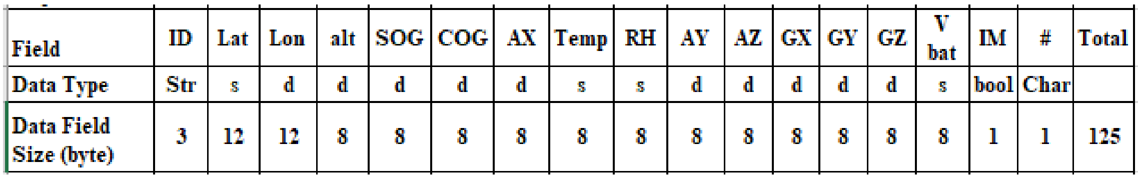
Table 4. Functions and formulas of the drone payload sub-system

Sub-System	Function	Formula
Open MV Camera	Taking aerial images of tea plantations, then processing them with the KNN algorithm or other image processing algorithms to classify tea leaves into the discrete category of ready to be picked or not ready to be picked	$f(OpenMV) = \begin{cases} 1, image \geq Threshold \\ 0, image < Threshold \end{cases}$ Where *Threshold* = Image classification result value (openMV computation result) readiness of tea leaves ready to be picked, with the boolean data type (Value 1, Ready to pick and 0, vice versa)

Sub-System	Function	Formula
Onboard sensor	measuring several parameters including GPS-based drone position (latitude, longitude, altitude), drone movement speed, drone motion direction, drone battery voltage and current sensors.	$f(onboard_{sensor}) = \sum_{i=1}^{n} sensors(i)$
LoRa	LoRa-based communication module to transmit a complete data package from the payload drone to the Ground Control Station	$f(LoraTx) = \begin{cases} 1, & payload \geq Threshold \\ 0, & payload < Threshold \end{cases}$ Where *Threshold* = the value of the complete drone payload package

The stages of merging data from the Open MV camera with sensor data from onboard are explained in the pseudocode of the algorithm process for Forming Drone Payload Data Packages.

From the drone packet algorithm, the results of forming metadata from Payload Information based on LoRa data frame are obtained. The detailed format of the Payload Metadata package sent to GCS consists of drone data identity information, timestamp, GPS sensor results, gyroscope, accelerometer, temperature, humidity, drone energy and image classification status. Payload Metadata details are detailed as follows: IDDrone, lat, lon, alt, SOG, COG, Temp, RH, AX, AY, AZ, GX, GY, GZ, Vbat, IM# with a total frame size of 142 bytes. Figure 12 shows that 125 bytes of the data field total size and 17 bytes of the separator frame packet. The data type in each field of the frame package is Str (string), s (single), d (double), bool (boolean), and char(Char).



Field	ID	Lat	Lon	alt	SOG	COG	AX	Temp	RH	AY	AZ	GX	GY	GZ	V bat	IM	#	Total
Data Type	Str	s	d	d	d	d	d	s	s	d	d	d	d	d	s	bool	Char	
Data Field Size (byte)	3	12	12	8	8	8	8	8	8	8	8	8	8	8	8	1	1	125

Figure 12. Metadata based on LoRa data frame of drone payload information packet

The results of this model are in the form of metadata from the payload information package which will then be tested on the Tea Plantation field in subsequent research activities. It is expected to obtain field data on Drones and GCS communication in the LoRaWAN Network in tea plantations which are rural environments. In future research, it is also possible to exploit attacks from intrusions in the process of transmitting payload data packets from drones to GCS [24]. However, it is possible to do this in an intrusion detection system on an IoT system [25] if an intrusion reference dataset has been formed on drone networks in tea plantations.

CONCLUSION

The formation of datasets on tea plantations with hilly characteristics for implementing Precision Agriculture with Agriculture Drones is arranged according to the rural tea plantation environment.

The need for drone technology in a proper tea leaf picking process requires an Internet of Things (IoT)-

Drone and GCS Network System Architecture that is formed according to the physical specifications of the components that make up the Quad-rotor Drone along with its sensors and actuators, including OpenMV camera, Micro Controller Unit (MCU) ESP32, Datalink specification Communication with LoRa omnidirectional Antenna with frequency 433 MHz and its GCS Specification.

The formation of this dataset requires a Payload Metadata model that is formed influenced by image processing with image processing techniques or computer vision from drone camera captures and the influence of the LoRa protocol in the data transmission process which requires communication between drones and GCS. The Payload Data Model is formed with LoRa frame packet constraints and the mechanism of the Drone Payload Data Package Formation Process algorithm. The Payload Metadata size that is formed consists of a frame size of 142 bytes.

Future research can take advantage of the metadata from this payload information package in testing Drone to GCS communications to an actual field in a rural tea plantation environment and further activities to exploit security from attacks or intrusions in the LoRaWAN network. This can be possible in an Intrusion Detection System for the IoT system in the Drone network.

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