Early Warning System For Farming Tea

Early Warning System (EWS) For Farming Tea project, kawasan Pusat Penelitian Teh dan Kina (PPTK) Gambung, Bandung, Jawa Barat

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Abstract

Pest and disease attacks are the biggest problem in tea plantations, because attacks can reduce the quality and quantity of the crop. On average, attacks can reduce 30 % of crop yields. This condition is made worst about lack of fild workers's knowledge to solve the pest/ disease. Case studies are conducted at Pusat Penelitian Teh dan Kina, Gambung, Ciwidey, Bandung, Indonesia or often called the Gambung PPTK. In PPTK Gambung, pest and disease control is always carried out by spraying pesticides. But this activities must do with an analysis from an expert / researcher for getting the type pest/disease and the type of pesticide used.

Keywords : Tea, Disease, EWS, expert System, fuzzy Logic, monitoring, Wireless Sensor Network, renewable energy

Nomenclatures

PPTK	Pusat Penelitian Teh dan Kina
EWS	Early Warning System
FC	Forward Chaining
BC	Backward Chaining
IoT	Internet of Things
WSN	Wireless Sensor Network
MQTT	Message Queuing Telemetry Transport
I2C	Inter Integrated Circuit
AWS	Automated Weather Station
LoRa	Long Range

1. Introduction

1. 1 Background

Tea plantation needed monitoring system to find out environmental conditions and pests. So, control of pests and diseases can be done immediately so that the quality of the harvest remains good. Case studies are conducted at Research Institute for Tea and Cinchona, Gambung, Ciwidey, Indonesia called PPTK Gambung. PPTK Gambung is located in the highlands and has an area of more 600 hectares making it difficult to observe.

The Wireless Sensor Network (WSN) and Internet of Things (IoT) technology can facilitate the process of environmental observation at the plantation. Condition forecast plantation can be monitored by data sensor such as temperature sensor, humidity sensor, light intensity sensor which is data will compare data from Automated Weather Station (AWS) PPTK Gambung. several sensors will group with microcontroller, solar panels, batteries and LoRa Transmitter to formed node. Each node will be connected to each other and can communicate to send sensor data to the central point or gateway. To determine type of disease and pests, the researcher need time that is not short

1.2 Utilization Artificial Inteligence

Artificial intelligence is a technology that can be implemented in agriculture to help and facilitate human work. In fact, this technology can replace the human role in doing the hard work, dangerous and repetitive. In fact, this technology can replace the human role in doing the hard work, dangerous and repetitive. One of the artificial intelligence systems of decision making in agriculture is using fuzzy logic algorithms and expert systems algorithm. Fuzzy logic is a rule-based decision-making algorithm that has the purpose of solving problems. Fuzzy logic is determined by logical equations rather than complex differential equations and takes decisions from grayness (uncertainty) between two extremes. An expert system artificial intelligence that seeks to adopt human knowledge to computer, so that computer can solve problems as usual by experts.

To making Early Warning System(EWS) for Farming Tea several sensors will group with microcontroller, solar panels, batteries and LoRa Transmitter to formed node. Each node will be connected to each other and can communicate to send sensor data to the central point or gateway Then the gateway will send to the cloud server through internet using MQTT Protocol. The sensor data will be processed in the cloud server as supporting data from the assessment data of the workers on the tea plantation that are sent each cycle of quotes. So that the system can make decisions that will be used for warning of attacks and recommendations for treatment of tea plants. In this study will be measured the level of accuracy and precision of decision-making systems that use fuzzy logic algorithm and expert systems algorithm.

1.3 Problem Identification

The main problem of Tea Plantation is pests and diseases. They can create a loss of crops up to 30% from the potential of yields. PPTK Gambung always controls pests and diseases by spraying pesticides on plants. But the use of pesticides can reduce the quality of tea leaves. Tea exports from Indonesia are often rejected by other countries, because export of tea comodity has restricted the maximum content of pesticide residues. Pesticide residues can cause negative effects on consumer health.

To find out the types of pests, diseases, and pesticides must be analyzed by the researcher. But PPTK Gambung has a limited number of researchers whose task is not only to analyze plant attacks. So the challenge is to build an automation system that can replace the role of researchers to analyze plant attacks. The automation system must be accessible online and provide attack notifications and reminders when spraying field workers. To build the automation system with artificial intelligence needed the sensor data as supporting data. However, PPTK Gambung has an area of 600 hectares. So that many sensors are needed to cover the entire area. To be monitored online, all of the sensor must be able to send their data to the internet. However, this method is not possible because the location of the tea plantation is in the highlands and not all areas are covered by telecommunications networks from the providers. So, Wireless Sensor Network is the solution of this case. All of sensor will send their data to central node (Gateway). Then the gateway will send the sensor data to cloud server through internet using MQTT Protocol.

1.4 Objective

The output of the research is **design and prototype** of a real time monitoring and early warning system to provide information about potential plant diseases and plant treatment recommendations. The system is designed as follows:

1. The system has database that holds rules for determining the type of pests and diseases on tea plantation
2. The system can communicate node to gateway and then continue to cloud server through internet using MQTT protocol.

3. The system can make decisions that provide information about plant attacks and plant treatment recommendations using Fuzzy Logic algorithms and Expert Systems algorithm with input parameters in the form of sensor values and assessment data from tea plantation workers.

2. Concept & fundamental theory

2.1 Internet of Things

The Internet of things refers to a type of network to connect anything with the Internet based on stipulated protocols through information sensing equipments to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and administration. Internet of Things is refer to the general idea of things, especially everyday objects, that are readable, recognisable, locatable, addressable through information sensing device and/or controllable via the Internet, irrespective of the communication means (whether via RFID, wireless LAN, wide area networks, or other means)

2.1. 1 IoT Architecture

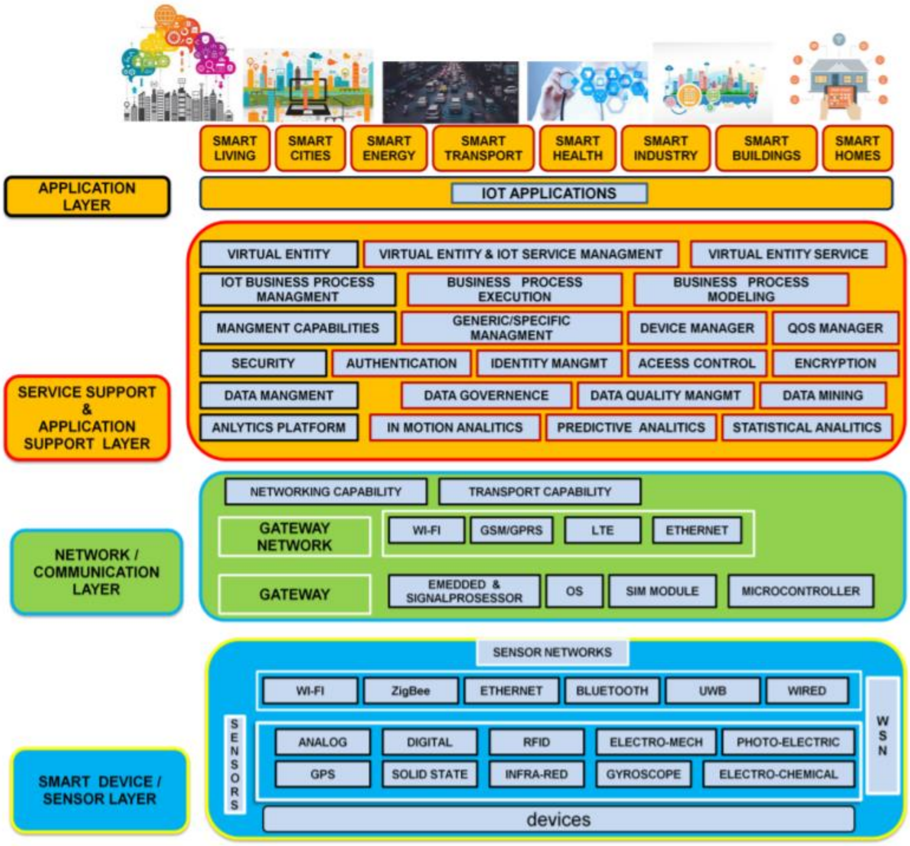
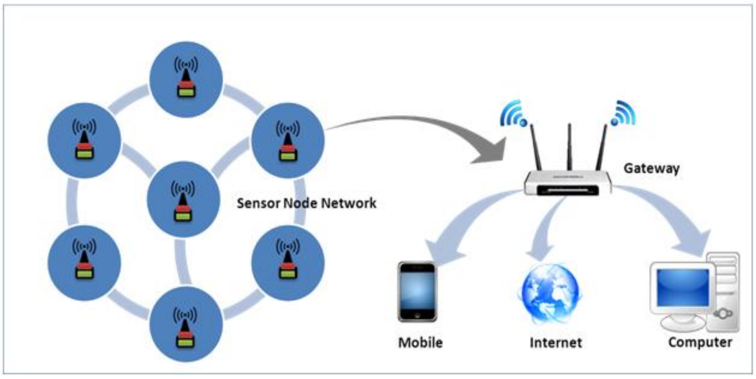


Figure 1. IoT Architecture

IoT architecture consists of various layers of supporting technology. It serves to describe technologies interconnected with each other and to communicate the scalability, modularity, and configuration of the IoT deployments in different scenarios. The challenge at IoT is to increase the scale that must be overcome by the IoT solution. Another challenge is the increasing heterogeneity of devices and device technology. Both require new approaches to support interoperability in various layers of the communication stack for resource constraint devices, which must be adequately reflected in the IoT experimental environment.

2.3 Wireless Sensor Network (WSN)



A Wireless Sensor Network is one kind of wireless network includes a large number of circulating, self-directed, minute, low powered devices named sensor nodes. These networks certainly cover a huge number of spatially.

distributed, little, battery-operated, embedded devices that are networked to caringly collect, process, and transfer data to the gateway, and it has controlled the capabilities of computing & processing. Nodes are the tiny computers, which work jointly to form the networks [1].

2.2 MQTT Protocol

MQTT (Message Queuing Telemetry Transport) protocol is a protocol that operated on the application layer and it is designed specifically for machine to machine that don't have a specific address for example arduino and raspberry pi. MQTT protocol consists of 3 main parts: publisher, broker and subscriber. The publisher is the part that functions to send data taken from sensors and has been processed by controller to broker. The broker has an address can be accessed by publisher and subscriber, MQTT broker also recognizes data through a grouping or it is called topic, when publisher send sensor data A, B, C with topic data 1 and one time there is a subscriber to the same topic data 1, then we can be sure that the subscriber will receive sensor data A, B, C from publisher. The last part is subscriber, it's operated for subscribing data on data1 topic after obtaining data consist of sensors from the publisher we can process the data to be entered into a database, analyzed or maked a structure monitoring system.

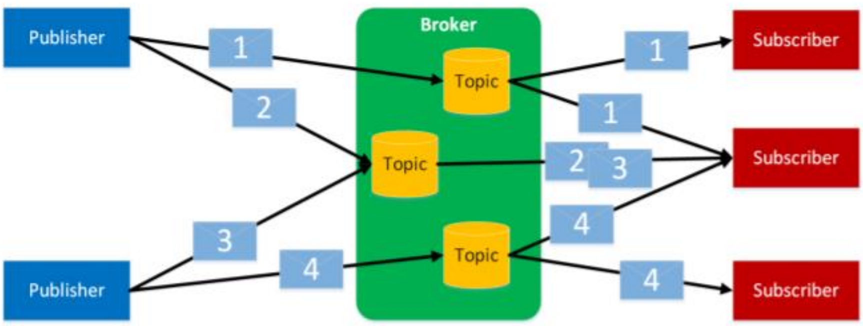


Figure 2. MQTT

2. 3 Expert System

Expert System is system design capabilities into computer so that they have a knowledge base which is similar to people who are expert in certain fields

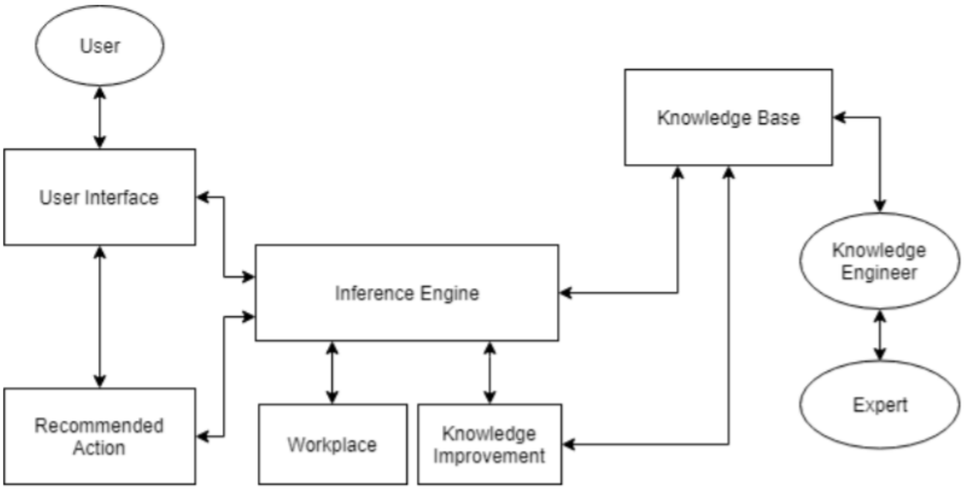


Figure 3. Expert System Architecture

2.3. 1 User Interface

A user interface is the method by which the expert system interacts with a user. These can be through dialog boxes, command prompts, forms, or other input methods.

2.3. 2 Knowledge base

The knowledge base is a collection of rules or other information structures derived from the human expert. Rules are typically structured as If/Then statements of the form.

2.3. 3 Inference Engine

The inference engine is the main processing element of the expert system. The inference engine chooses rules from the agenda to fire. If there are no rules on the agenda, the inference engine must obtain information from the user in order to add more rules to the agenda

1. Forward Chaining

   In forward chaining, the expert system m will test whether each condition is true or false.

2. Backward chaining

   In backward chaining, the selection of a rule and considers it to be a problem that must be solved.

2. 4 Fuzzy Logic

Fuzzy logic is a rule-based decision-making algorithm that has the purpose of solving problems, which is a method to formalize human capacity from improper reasoning. Reasoning represents the human ability to think and judge under uncertainty. Fuzzy logic is determined by logical equations rather than complex differential equations and takes decisions from grayness (uncertainty) between two extremes. Fuzzy logic has several components that must be understood such as fuzzy sets, membership functions, operators in fuzzy sets, fuzification, fuzzy inference, and defuzification.

3. Experimental Design

3.1 System design

Basically the system will be made consists of several components, namely nodes that contain the sensor system, gateway, cloud and end users in the form of computers and smartphones.

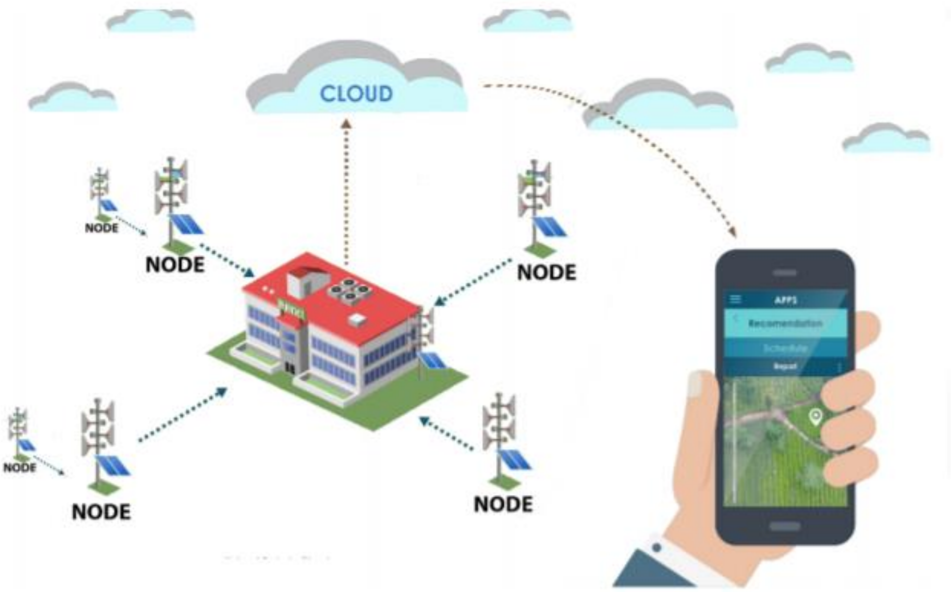


Figure 4. System Design

The system will have several node installed in the tea plantation area. Node consists of integration between temperature sensor, humidity sensor, light intensity sensor, solar panel and RF Transmitter. Next data sensor will sent to gateway and data will send to cloud serving using internet network and MQTT protocol. In the cloud server has a decisionmaking system to determine the type of attack and treatment recommendations for tea plants. In addition there is also a monitoring system that can be seen directly using a computer via internet.

3.2 IoT Platform

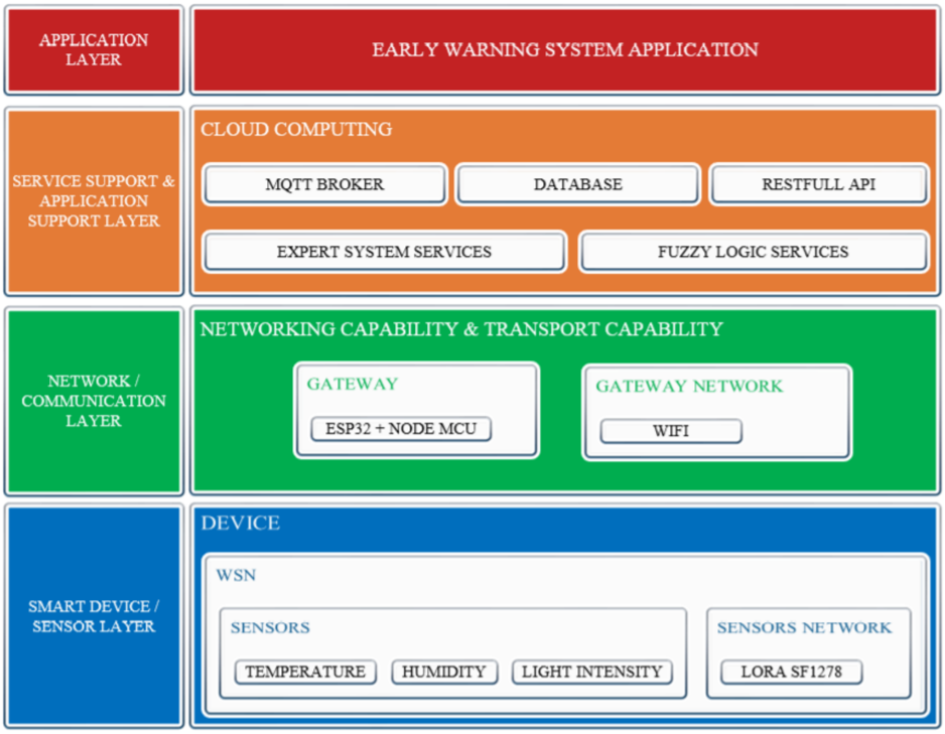


Figure 5. IoT Architecture

3. 3 Hardware Design

3.3. 1 Node and Sensor Design

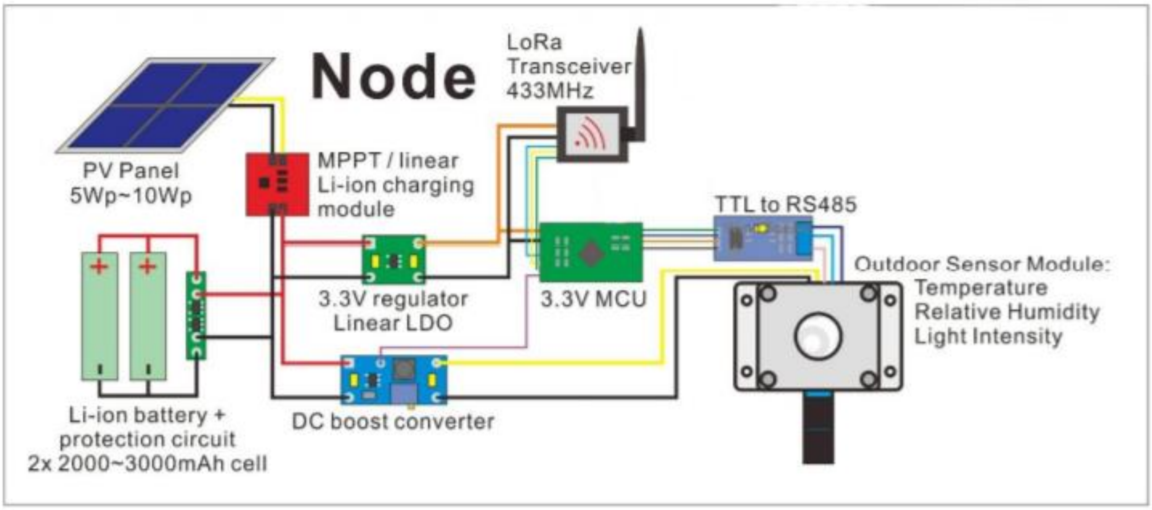


Figure 6. Node of Sensor System

Sensors used in this node system are sensors of air temperature, air humidity and light intensity. The communication system on this sensor uses RS485, which will then be used to convert TTL to RS485 to be able to communicate with the microcontroller. Data from the sensor will be processed by a microcontroller and will be sent to Lora Transceiver SX1278 using the I2C protocol. This microcontroller uses 3.3 volts of power with a voltage source in the form of a Li-ion battery with a capacity of 4000 - 6000 mAh. In the node system there will also have solar panels that will be used as a power resource in charging the battery.

3.3. 2 Gateway Design

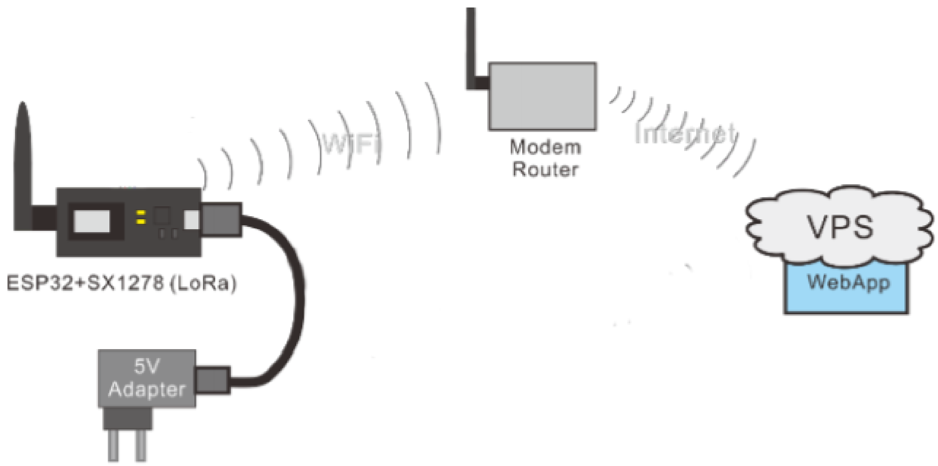


Figure 7. Design of Gateway

This gateway serves to collect data from each node. Data from the node will be received through LoRa ESP32 + SX1278. The data can be monitored directly using a computer. In addition, the data will be sent via ESP32 which has been connected to the internet network through a modem or router. The data transmission uses the MQTT protocol

3. 4 Design of Algorithm

The system is designed by combining two algorithms, namely Expert System Algorithm and Fuzzy Logic Algorithm. Expert System Algorithm will diagnose types of pests and diseases based on observational data, temperature sensor data and air humidity sensor data next Fuzzy Logic Algorithm will recommend a solution to resolve pests and diseases based on type, last type of pesticide and evapotranspiration.

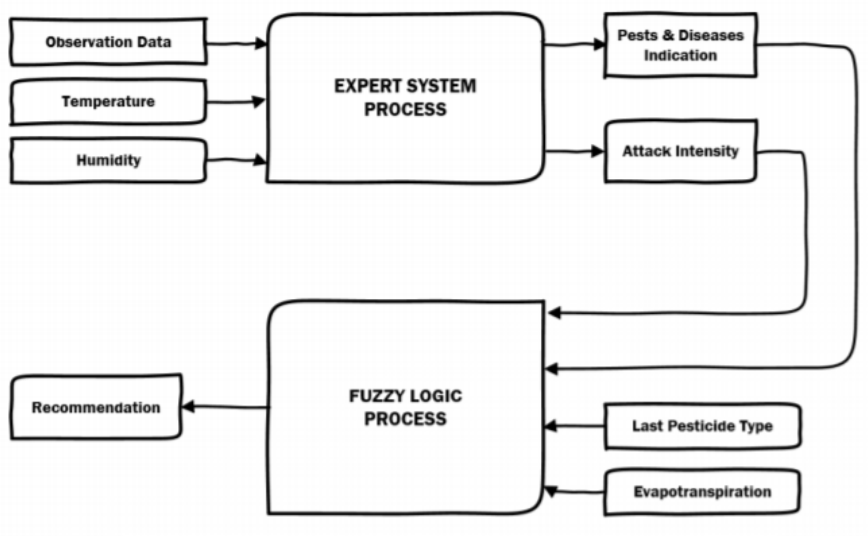


Figure 8. Design of Decision Making Algorithm

3.4. 1 Expert System Algorithm

A. Knowledge Based

Knowledge Base is a database that contains knowledge data about indications of pest and disease attacks. This knowledge was obtained from PPTK Gambung researchers. The knowledge data used in this study are follows:

Attack Categories	**Indications**
Empoasca	Insect, curved leaf, yellowing of the leaf bone, dried leaves, high temperature and low humidity
Helopeltis	Insect, Black spots, black spots spread,
Ulat Pucuk	Caterpillar pest, leaf curl up,
Ulat Jengkal	Caterpillar pest, perforated leaf, bald leaves
Cacar Daun	small green patches, white patches, white patches, high humidity

In this study, 5 types of attacks were used because these pests and diseases were the most common attacks on tea gardens in PPTK Gambung.

B. Inference Engine

In this research the Backward Chaining method is used and adds the level of each attack indication. By using a leveling mechanism the intensity of attacks can be calculated using the following formula:

$$IS = \frac{\sum(n \times v)}{Z \times N}$$

Where:

IS = Attact Intensity

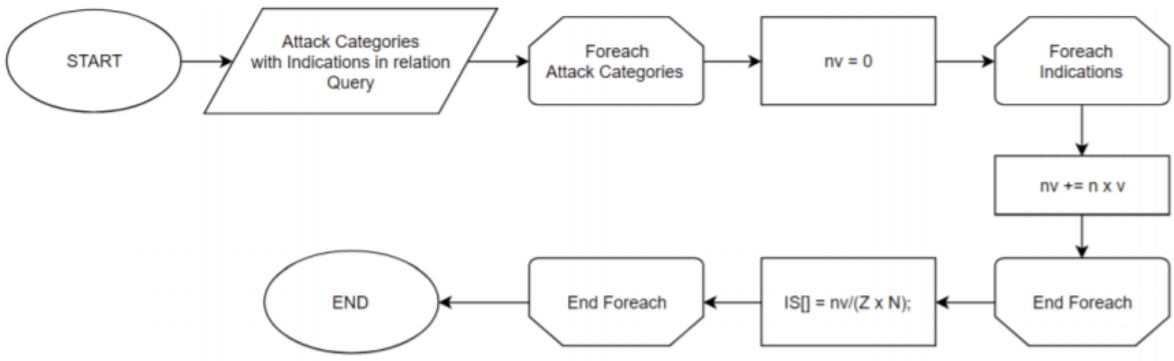
n = Number of damaged leaves each level of attack

v = level

Z = The highest level value of the attack category

N = Number of leaves observed

Flowchart of inference engine is as follows:



3.4. 2 Design of Fuzzy Logic Algorithm

This fuzzy logic algorithm is used to overcome the value of uncertainty in the decisionmaking process resulting from the value of the sensor that is always changing and not right at the threshold in the decision-making rule. The fuzzy logic algorithm process is as follows:

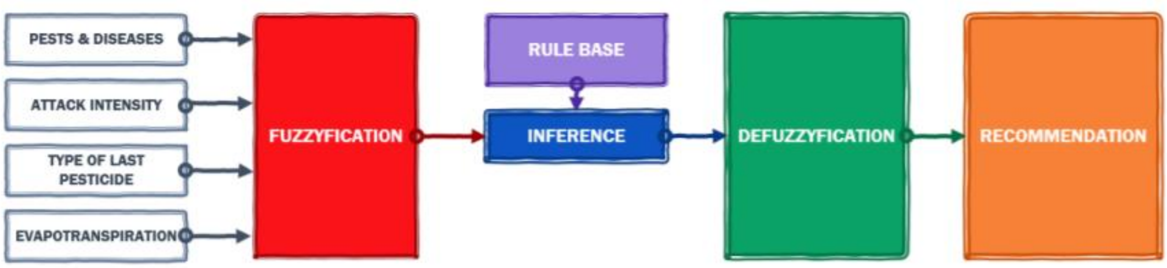


Figure.9 Fuzzy Logic Process

In the fuzzy logic algorithm there are important components including the Fuzzification process, Inference supported by Rule Base, and Defuzzyfication. Fuzzy Logic is designed to be able to do multi-process activity if there is more than one attack of pests and diseases. The multiple fuzzy logic process is shown in the figure bellow.

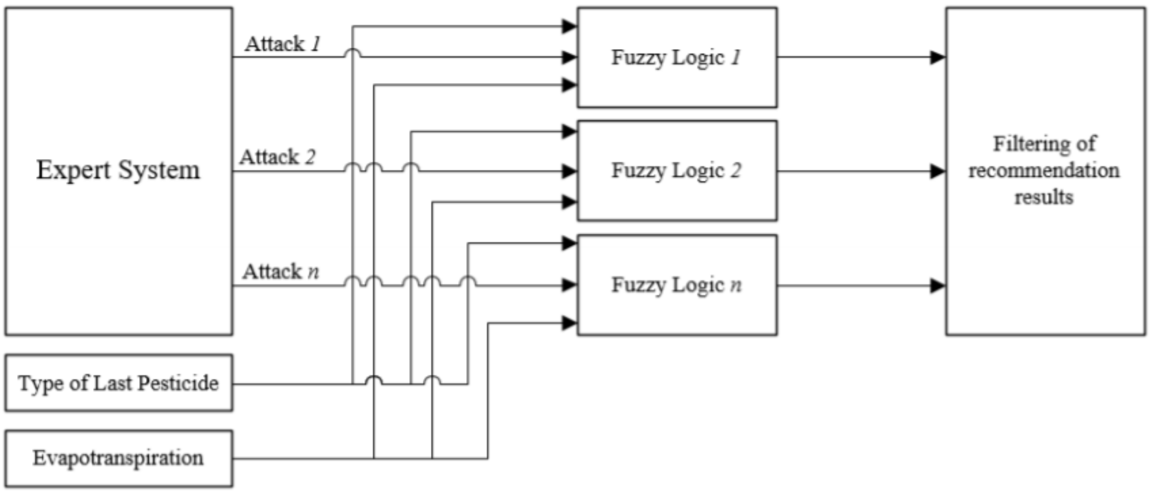


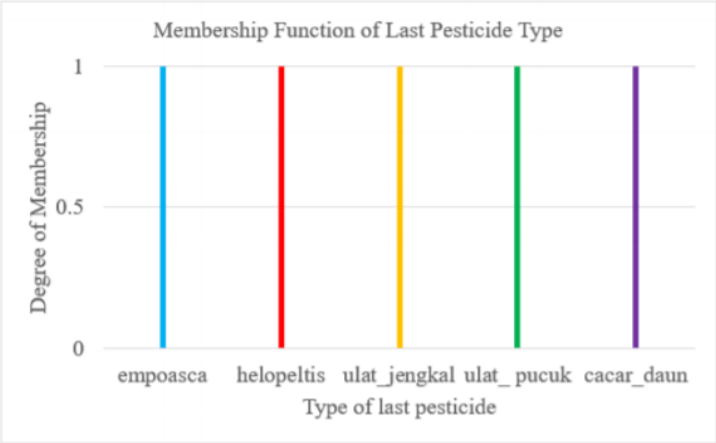
Figure.10 Multiple Fuzzy Logic

A. Fuzzification

In the fuzification process, the input values of all variables will be mapped and converted into linguistic value. The linguistic values applied in this research are shown in the table below.

Parameter	**Linguistic Value**
Attack Category	$P(x) = \{emposaca, helopeltis, ulat\_pucuk, ulat\_jengkal, cacar\_daun\}$
Pests Attack Intensity	$A(x) = \{light, medium, heavy\}$
Type of Last Pesticide	$T(x) = \{natural, chemical\}$
Evapotranspiration	$E(x) = \{low, high\}$

In this study the Attack Category and Attack Intensity Parameters are used, because each type and level of attack is handled differently. In addition, the use of the last pesticide is also an input parameter because in one cycle only one type of chemical pesticide can be used. So that pesticide residues can be minimized. In this study, the Evapotranspiration parameter was also used because the use of natural or chemical pesticides was not very efficient if used when the value of water evaporation was high. Thus, the use of chemical pesticides becomes more inefficient, because pesticides will evaporate faster while pesticide residues remain behind in tea plants. Based on the four parameters, the membership function is used to determine its linguistic value. The membership functions is used to determine the linguistic value of each variable. The membership functions of the type of pest and disease as follows:



$$empoasca(x) = \begin{cases} 1 & , x = Empoasca \\ 0 & , x \neq Empoasca \end{cases}$$

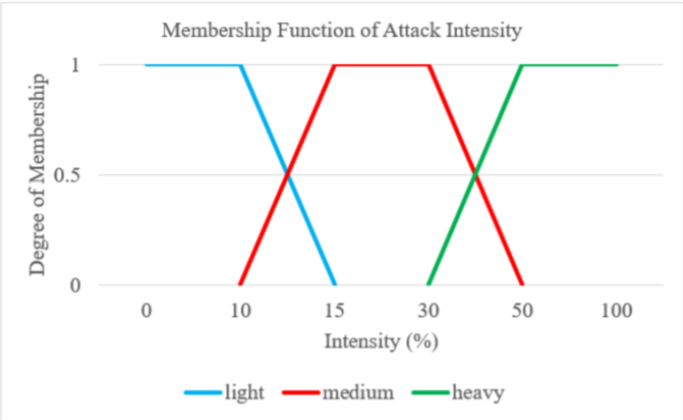
$$helopeltis(x) = \begin{cases} 1 & , x = Helopeltis \\ 0 & , x \neq Helopeltis \end{cases}$$

$$ulat\_jengkal(x) = \begin{cases} 1 & , x = UlatJengkal \\ 0 & , x \neq UlatJengkal \end{cases}$$

$$ulat\_pucuk(x) = \begin{cases} 1 & , x = UlatPucuk \\ 0 & , x \neq UlatPucuk \end{cases}$$

$$cacar\_daun(x) = \begin{cases} 1 & , x = CacarDaun \\ 0 & , x \neq CacarDaun \end{cases}$$

Attack intensity of Pests and disease have 3 linguistic value such as light attack, medium attack, and heavy attack.

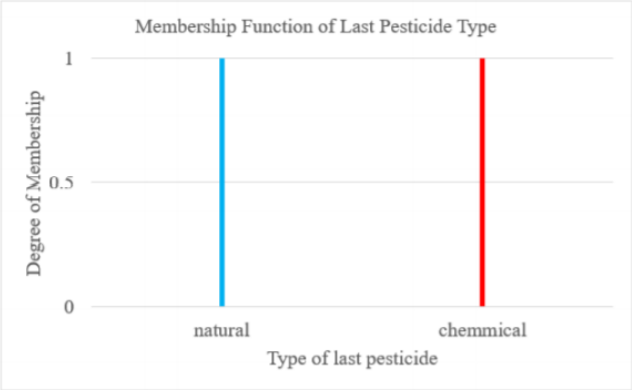


$$light(x) = \begin{cases} 1 & , x \leq 10 \\ \frac{15-x}{15-10} & , 10 < x < 15 \\ 0 & , x \geq 15 \end{cases}$$

$$medium(x) = \begin{cases} 0 & , x \leq 10, x \geq 50 \\ \frac{x-10}{15-10} & , 10 < x < 15 \\ \frac{50-x}{50-30} & , 30 < x < 50 \\ 1 & , 15 \leq x \geq 30 \end{cases}$$

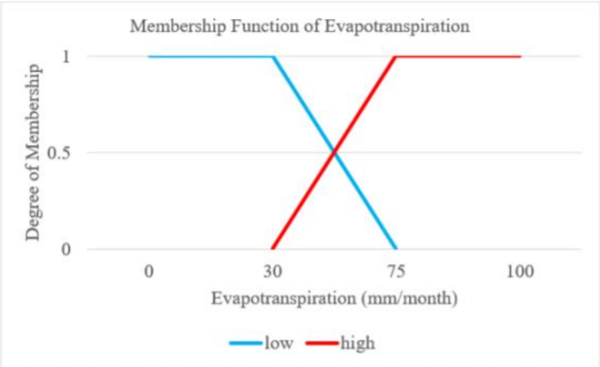
$$heavy(x) = \begin{cases} 0 & , x \leq 30 \\ \frac{x-30}{50-30} & , 30 < x < 50 \\ 1 & , x \geq 50 \end{cases}$$

The Last Pesticide variables has 2 linguistic value, that are natural pesticide and chemical pesticide.



$$natural(x) = \begin{cases} 1 & , x = NaturalPesticide \\ 0 & , x \neq NaturalPesticide \end{cases}$$

$$chemical(x) = \begin{cases} 1 & , x = ChemicalPesticide \\ 0 & , x \neq ChemicalPesticide \end{cases}$$



The evapotranspiration has 2 linguistic value such as low, high. To calculate evapotranspiration using Blaney-Criddle Modification Method

$$ET = K\frac{P((45.7 \times 7t) + 8130)}{100}$$

Where:

K = K(t) × Kc

K(t) = 0.0311t + 0.24

Kc = 0.94 (constants)

t = average temperature of last 30 days (◦C)

P = Percentage of daylight in one year.

ET = Evapotranspiration (mm month)

The membership function of evapotranspiration variable as follows:

$$low(x) = \begin{cases} 1 & , x \leq 30 \\ \frac{75-x}{75-30} & , 30 < x < 75 \\ 0 & , x \geq 75 \end{cases}$$

$$heigh(x) = \begin{cases} 0 & , x \leq 30 \\ \frac{x-30}{75-30} & , 30 < x < 75 \\ 1 & , x \geq 75 \end{cases}$$

B. Inference and Rule Base

The recommendation database is as follows:

ID	Description
1	Breed the predators to attack empoasca pests
2	Use natural insecticides for empoasca
3	Breed the predators and use natural insecticides for empoasca
4	Use chemical pesticides for empoasca
5	Breed the predators to attack helopeltis pests
6	Releasing the parasitoid fungus from this pest in the form of Beauveria bassiana
7	Breed the predators and use Beauveria bassiana
8	Use chemical pesticides for helopeltis
9	Breed the predators to attack caterpillar pests
10	Biological control by extracting leaves and seeds from plants
11	Breed the predators & Biological control by extracting leaves and seeds from plants
12	Use chemical pesticides for caterpillars
13	Breed the predators to attack Hierodula sp
14	Biological treatment using the Beauveria bassiana fungus
15	Breed the predators & use mushroom extract
16	Use chemical pesticides to attack caterpillars
17	Planting and managing shade trees
18	Providing mulch or litter in the tea garden
19	Use plant-based pesticides
20	Use chemical pesticides to attack fungus
21	Picking early to reduce the risk of decreasing yields.

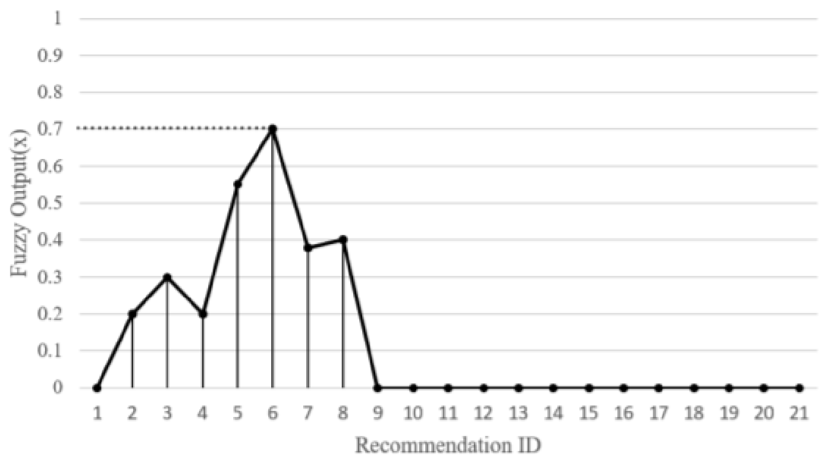
The recommendation data is used to determine the rules for this inference process. Total of rules can be calculated by multiplaying all of linguistic value. In this case total of Rules is 60 rules.

Rule ID	Pests and Diseases	Attack Intensity	Last Pesticide	ET	Recommendation ID
1	Empoasca	Light	Natural	Low	1
2	Empoasca	Light	Natural	High	1
3	Empoasca	Light	Chemical	Low	1
4	Empoasca	Light	Chemical	High	1
5	Empoasca	Medium	Natural	Low	2
6	Empoasca	Medium	Natural	High	3
7	Empoasca	Medium	Chemical	Low	21
8	Empoasca	Medium	Chemical	High	21
9	Empoasca	Heavy	Natural	Low	4
10	Empoasca	Heavy	Natural	High	4
10	Empoasca	Heavy	Natural	High	4
11	Empoasca	Heavy	Chemical	Low	21

12	Empoasca	Heavy	Chemical	High	21
13	Helopeltis	Light	Natural	Low	5
14	Helopeltis	Light	Natural	High	5
15	Helopeltis	Light	Chemical	Low	5
16	Helopeltis	Light	Chemical	High	5
17	Helopeltis	Medium	Natural	Low	6
18	Helopeltis	Medium	Natural	High	7
19	Helopeltis	Medium	Chemical	Low	21
20	Helopeltis	Medium	Chemical	High	21
21	Helopeltis	Heavy	Natural	Low	8
22	Helopeltis	Heavy	Natural	High	8
23	Helopeltis	Heavy	Chemical	Low	21
24	Helopeltis	Heavy	Chemical	High	21
25	Ulat Jengkal	Light	Natural	Low	9
26	Ulat Jengkal	Light	Natural	High	9
27	Ulat Jengkal	Light	Chemical	Low	9
28	Ulat Jengkal	Light	Chemical	High	9
29	Ulat Jengkal	Medium	Natural	Low	10
30	Ulat Jengkal	Medium	Natural	High	11
31	Ulat Jengkal	Medium	Chemical	Low	21
32	Ulat Jengkal	Medium	Chemical	High	21
33	Ulat Jengkal	Heavy	Natural	Low	12
34	Ulat Jengkal	Heavy	Natural	High	12
35	Ulat Jengkal	Heavy	Chemical	Low	21
36	Ulat Jengkal	Heavy	Chemical	High	21
37	Ulat Pucuk	Light	Natural	Low	13
38	Ulat Pucuk	Light	Natural	High	13
39	Ulat Pucuk	Light	Chemical	Low	13
40	Ulat Pucuk	Light	Chemical	High	13
41	Ulat Pucuk	Medium	Natural	Low	14
42	Ulat Pucuk	Medium	Natural	High	15
43	Ulat Pucuk	Medium	Chemical	Low	21
44	Ulat Pucuk	Medium	Chemical	High	21
45	Ulat Pucuk	Heavy	Natural	Low	16
46	Ulat Pucuk	Heavy	Natural	High	16
47	Ulat Pucuk	Heavy	Chemical	Low	21
48	Ulat Pucuk	Heavy	Chemical	High	21
49	Cacar Daun	Light	Natural	Low	17
50	Cacar Daun	Light	Natural	High	17
51	Cacar Daun	Light	Chemical	Low	17
52	Cacar Daun	Light	Chemical	High	17
53	Cacar Daun	Medium	Natural	Low	18
54	Cacar Daun	Medium	Natural	High	19
55	Cacar Daun	Medium	Chemical	Low	21
56	Cacar Daun	Medium	Chemical	High	21
57	Cacar Daun	Heavy	Natural	Low	20
58	Cacar Daun	Heavy	Natural	High	20
59	Cacar Daun	Heavy	Chemical	Low	21
60	Cacar Daun	Heavy	Chemical	High	21

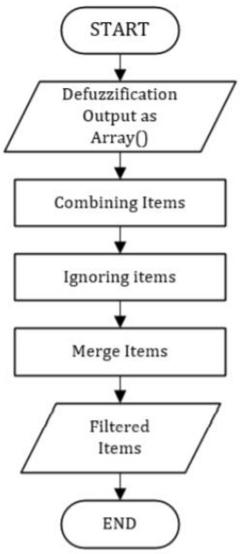
C. Defuzzification

Defuzzification is the final process of the fuzzy logic algorithm. This process will produce a decision value using the Maxima method. The maxima method will choose the largest value from the members of the output set. The output set member consists of the Recommendation ID that has been stored in the database.



D. Filtering of Recommendation Result

To produce higher accuracy, an algorithm is needed to determine the best recommendations, so that the results of the recommendations obtained are in accordance with the real conditions in the field. In this study an algorithm was designed to filter the results of the defuzzification process through the stages of combining items, ignoring items, and merge items.



4. Prototype Result

From the design of the proposed early warning system the following prototype results are in the form of hardware, web applications, and mobile applications:

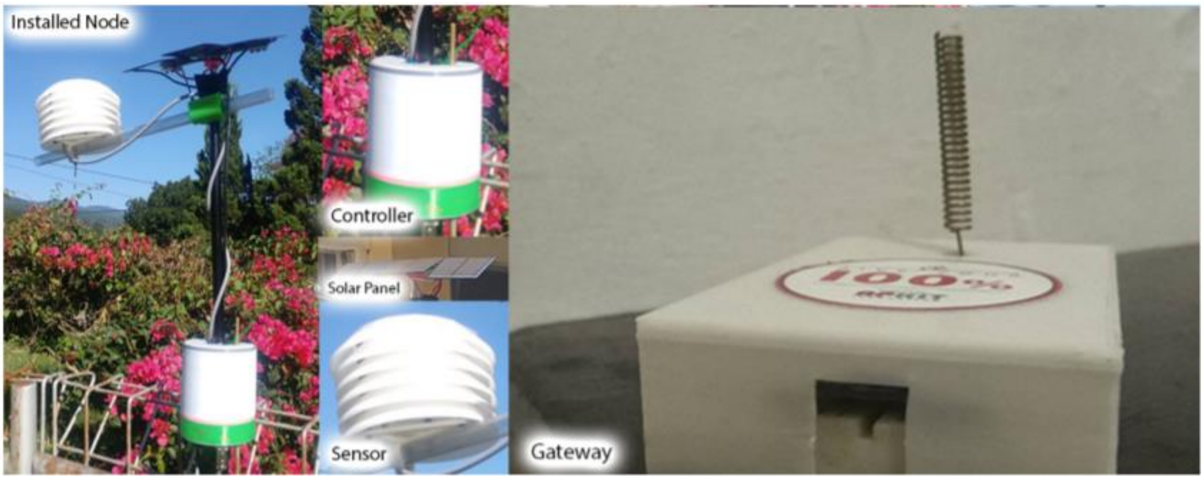


Figure. 11 Prototype (Hardware)

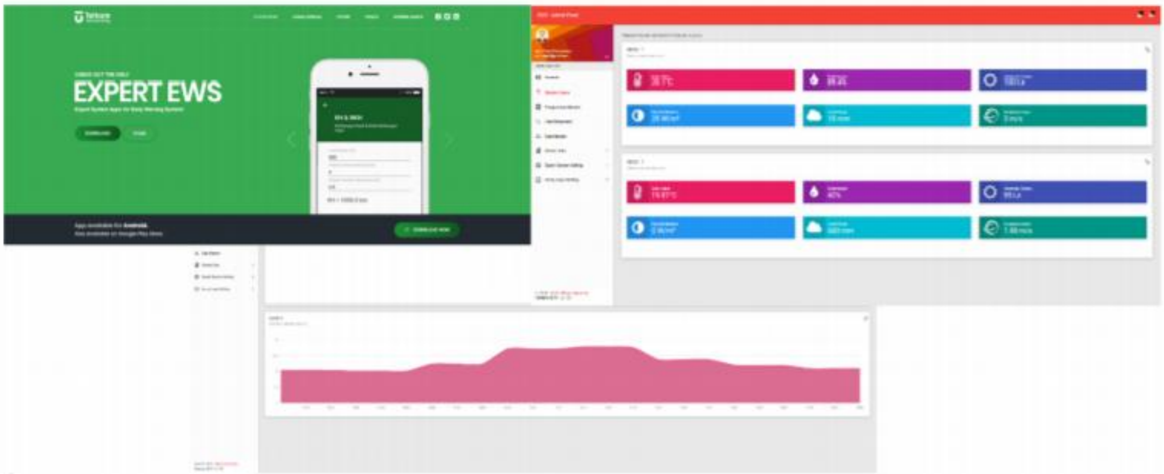


Figure.12 Prototype (Web Application)

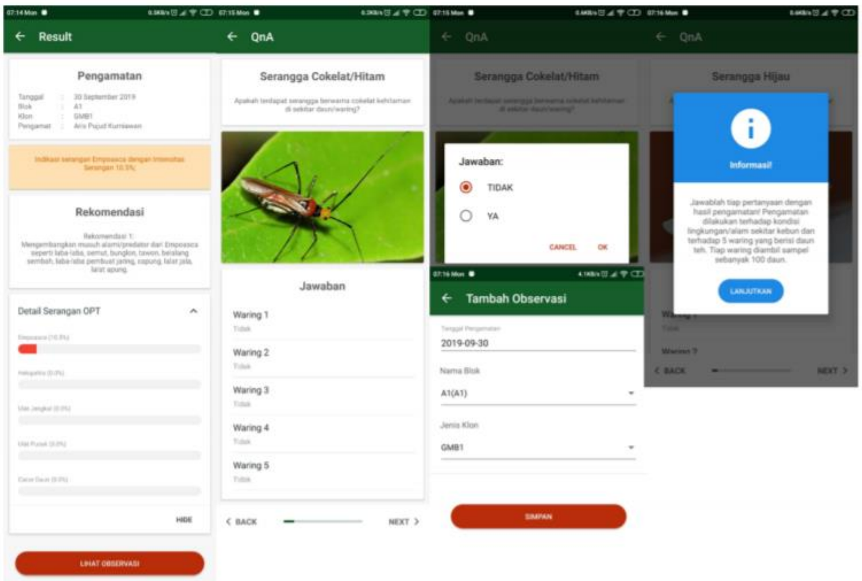
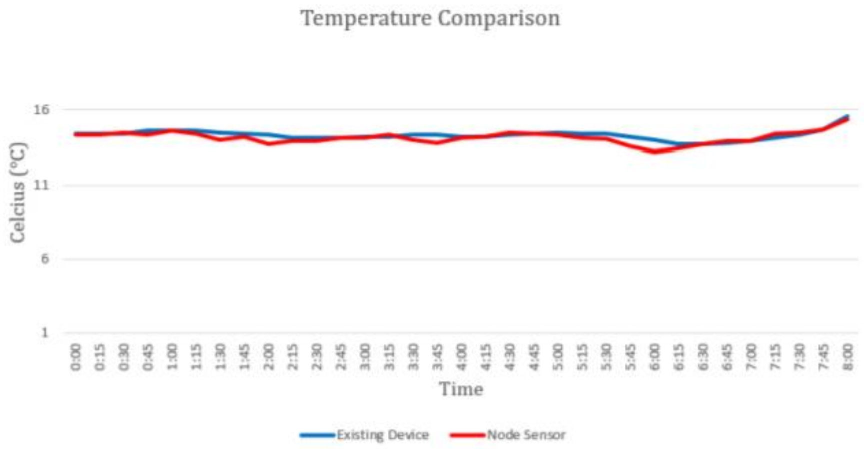
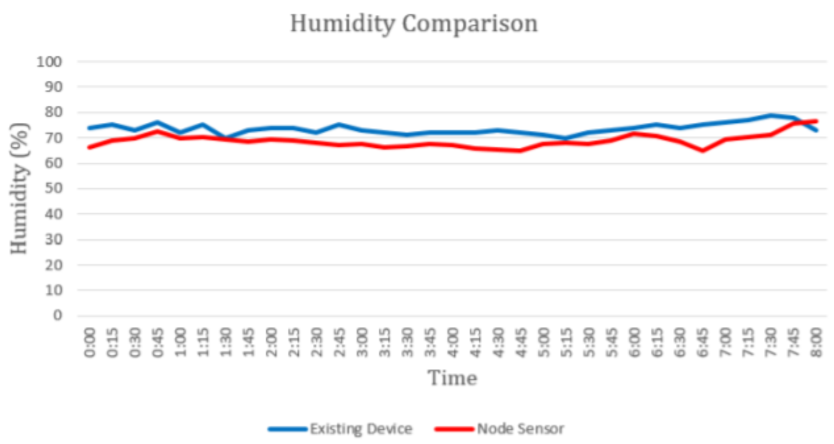


Figure.13 Prototype (Mobile

4.1. 1 Temperature Sensor & Humidity Sensor Test Result

Temperature and humidity sensor test results show that this sensor has high accuracy and precision. The graph of the temperature sensor test results is as follows:

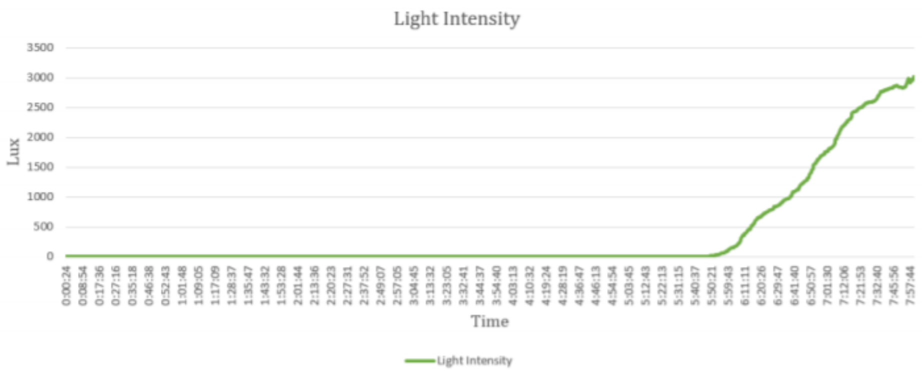




Where, for the blue line is the value of an existing sensor at PPTK Gambung, while for the red line is the value of the sensor used in this study. Measurement result of the temperature sensor has an accuracy of 99.7 % and a precision of 99.36 % compared to the pre-existing AWS Station. While, the humidity sensor has an accuracy of 96.3 % and a precision of 98.93 %.

4.1. 2 Light Intensity Sensor Test Result

In this test the light sensor is used to determine the length of time during the day by comparing the time of day (calculated from sunrise to sunset) based on this sensor with the results of weather calculations from timeanddate.com. The following is a graph of changes in the value of light sensors to changes from night to day.



5. Conclusions and Future Work

5. 1 Conclusions

The conclusion of this research based on the testing are follows:

1. The node system built has 3 types of sensors, where each sensor has an accuracy of 99.7% and a precision of 99.36% for the temperature sensor, an accuracy of 96.3% and a precision of 98.93% for the humidity sensor. While the light intensity sensor is used to determine the length of daylight. In determining the length of the day, this sensor has an accuracy of 99.76%. In this study it was also known that the length of daylight hours in PPTK Gambung ranged 52% per month or around 386 hours 59 minutes 18 seconds.

2. The Expert System and Fuzzy Logic can provide attack information and treatment recommendations for tea plants. The combination of these algorithms has 100% accuracy and 100% precision.

3. The Design of Early Warning System can implemented at Research Institute for Tea and Cinchona, Gambung, Ciwidey, Indonesia.

5. 2 Future Work

The future work in this field are follows:

1. Add new Pests and Diseases database and also recommendation database.

2. Build the mobile application on another platform or Operating system.

3. Commercialize the Early Warning System features as SaaS (Software as a Service) on behalf of Telkom University. 4. Building a more efficient inter-node communication system

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