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Construction of micro scale coral propagation media controller system with Arduino Nano and Flutter SDK

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Abstract

Rising sea temperatures due to global warming and human activities in Indonesia threaten coral reef sustainability, leading to bleaching and mass mortality. In 2016, 50% of coral colonies in Gili Matra experienced bleaching, 11% were pale, and 1% faced mortality. To mitigate damage, controlled coral cultivation in isolated media offers an alternative to open-ocean methods, allowing precise water quality management. Coral transplantation, involving fragmentation and placement in controlled environments, enhances rehabilitation efforts. An IoT-based controller enables real-time monitoring and automation of life-support systems, including supplementation pumps, photosynthetic lamps, top-up pumps, cooling fans, and current pumps. System performance shows consistent lamp scheduling, supplementation dosage with a deviation of ±1-2%, precise top-up activation, current pump scheduling with a 1s deviation, and optimal water parameters (alkalinity 8.3 dKH, calcium 420 ppm, magnesium 1050 ppm, salinity 1.025).

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1. Introduction

Indonesia is an archipelago with abundant marine biological resources with great potential for utilization [1]–[3]. One of the abundant marine biological resources spread throughout Indonesia's marine and coastal waters is coral reefs [4]. With a stretch of coral reefs ± 51,000 〖Km〗^2 or 17 percent of the total area of the world's coral reefs makes Indonesia the country with the second largest stretch of coral reefs in the world [5][6]. Human activities and changes in sea water temperature due to global warming create a major threat to the sustainability of coral reefs, pollution and rising sea water temperatures can cause coral bleaching which can cause mass death of coral reefs [7][8]. Seen from the cause of coral reef damage that occurs can be grouped into two main categories, namely damage caused by human activities such as coral mining, coral trade, fish bombing in coral reef areas, fishing activities that use trawling, and others. While damage caused by nature is such as climate change, biological activity, the spread of disease, and the presence of predatory animals [9][10]. Indonesia itself has a high risk in terms of damage to coral reefs, this is caused by overfishing using destructive tools, waste pollution, oil spills, and development close to the coastline, causing smothering [11][12]. This is evidenced by the condition of the coral reef ecosystem in the waters of Gili Matra in 2016, there was an increase in temperature which resulted in 50% of coral colonies experiencing coral bleaching, while

11% of coral colonies were found in pale conditions and there was coral colony mortality of 1% of coral colonies affected by bleaching [13]–[15] The destruction of coral reefs has become a major threat to the survival of marine life and human life, with global warming, ocean acidification and environmental pollution that we cannot control the mass death of coral reefs is very likely to occur. With the threat of massive damage due to environmental damage and global warming, of course, prevention efforts by means of cultivation carried out in a controlled and isolated medium from the open ocean are one alternative. In this research, the author chose the prototyping method, which is one approach in software engineering that directly demonstrates how a software or software components will work in its environment before the actual construction phase is carried out.

The prototype model is used as an indicator of the picture to be created in the future and distinguishes two functions of exploration and demonstration [16][17]. When compared to coral reef cultivation in the open ocean, isolated coral reef cultivation in aquarium culture media has advantages in terms of control because water quality can be carefully controlled [18][19]. Coral reef rehabilitation efforts through aquaculture can be done with coral transplantation methods. Coral transplantation is a method of planting and growing coral colonies by fragmenting coral colonies and then placing colony fragments in cultivation media [20][21].

The internet of things is the linkage of sensory and actuating devices that provide the ability to share data and information between platforms by utilizing internet networks to develop innovative applications [22][23]. Internet of things (IOT) is one of the rapidly growing technologies that provides benefits in monitoring and control of aquarium water parameters [24]–[26]. With an Internet of things-based controller device, users can access water parameter information and control life support instruments wherever the user is [27][28]. One of the utilizations of the Internet of things is remote control. This allows users to control lighting devices anytime and anywhere, provided that the location where the controller device is used has usable and adequate internet access [29][30]. Users will be able to control IOT devices using mobile applications on the android platform to make it easier for users to monitor and control instruments and controllers. The author hopes that the cultivation of coral reefs isolated from the open ocean can help prevent the extinction of coral species due to over-mining and climate change.

2. Research Methodolgy

a. Reasearch Object and Subject

The object of research is the point of attention of a study. The point of attention of this research is the design of a controller device with Arduino Nano and interface applications using Flutter SDK and Firebase that able to maintain certain levels of water conditions through several life support instrument. While the research subject is a group of coral reef specimens that will be studied for the living conditions an requirement. In this study, the subject to be observed is a group of coral colony specimens of the species Montipora Capricornis, Acropora Selago, Seriatopora Hystrix, and Dragon Eyes Zoanthids of the genus Zoanthus which all of the specimen is native to indonesian coral reefs, with that we can use the average seawater condition in indonesian coral reefs as the foundation for device calibration and media preparation. While there's many complex seawater parameters this research focused to maintain and adjust on 4 essential seawater parameters in order to maintain good coral health and growth which are calcium ion levels, magnesium ion levels, salinity levels, and alkalinity levels. From previous attempt to cultivate coral and literature study the system needs to maintain parameter levels of calcium level range is 420ppm – 440ppm, magnesium level range is 1300ppm – 1500ppm, alkalinity level range is 8Dkh – 9Dkh, and salinity level range is 1.025 – 1.026 spesific gravity.

b. Research Method

This research was conducted by the author using the Prototyping method, the selection of this method is intended to assist the author in making and compiling this research report. Then the flow of the prototyping research method used is as follows:

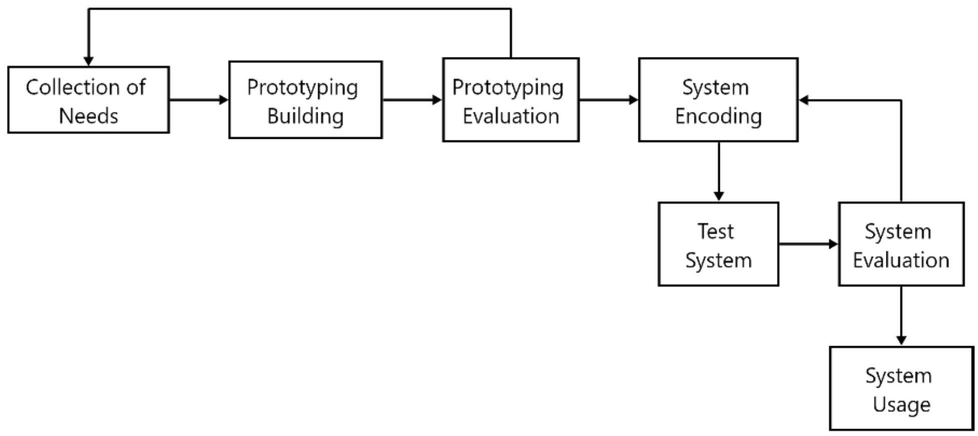


Figure 1. Prototype method structure

c. Hardware System Design

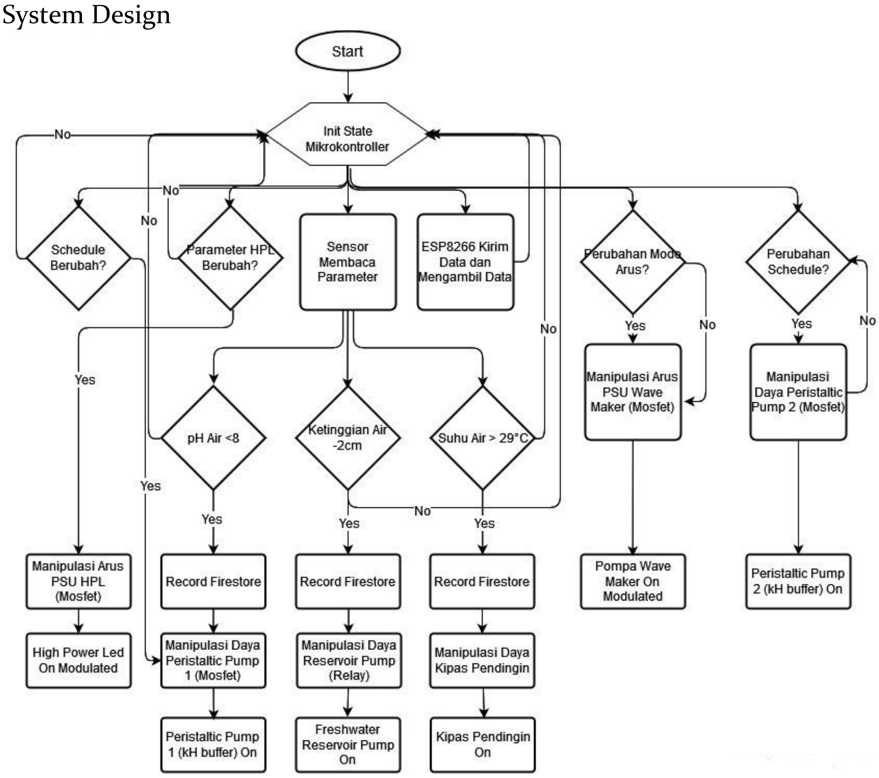


Figure 2. Flowchart System

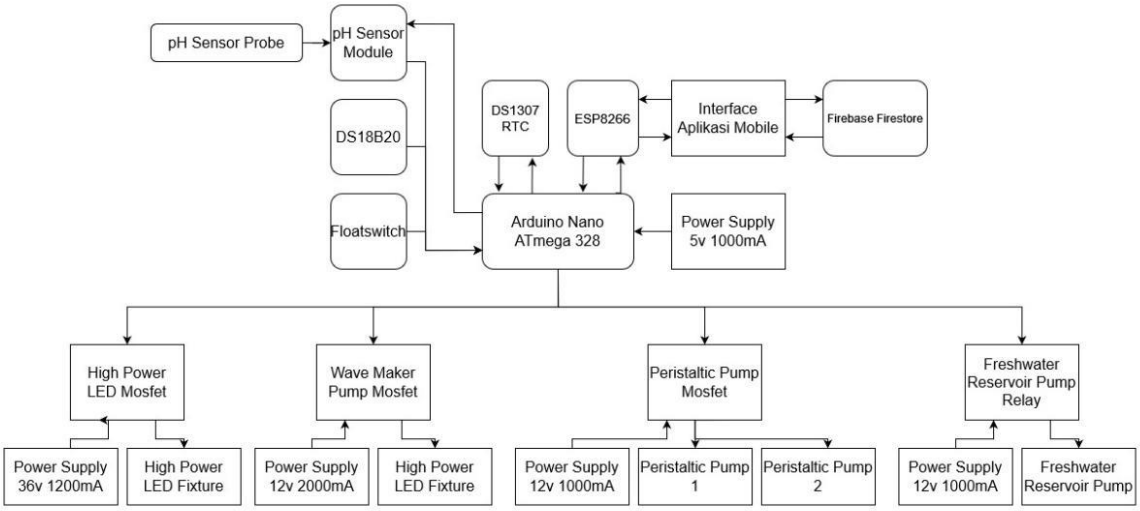


Figure 3. Block Diagram of Controller Device System Schematic Design

1. Tools

The hardware used is:

1. Acer Aspire V3-372T laptop with specifications:
    a. Processor: Intel i5 6200U
    b. Memory: 8 GB DDR3 RAM
    c. Graphic Card: Intel HD graphics 520
    d. SSD: 256 GB
2. Samsung S21 FE cellphone with specifications:
    a. Chipset: Exynos 2100
    b. Memory: 8 GB RAM LPDDR4
    c. Storage: 356GB
    d. Network: 4G LTE
3. Visual Studio Code with specifications version: 1.74.2
4. Windows 10 Pro with specifications architecture: 64 bit
5. One UI 5.0 with specifications android version : Android 13
6. Arduino IDE with specifications version: 1.8.17.0
7. Adobe XD with specifications version: 39.0.12.12
8. Fritzing with specifications version: 0.9.2.b
9. AutoCAD 2021 English with specifications version: AC1032

2. Materials

The materials used are:

1) Microcontroller Arduino Nano v3 with specifications Microcontroller ATmega 3282) Memory: 2KB SRAM3) Storage: 32KB Flash Memory4) Operating Voltage: 5v5) PWM pins:6 pinsb) Coral Reef Cultivation Media with specifications.
2) Aquarium: Dimensions 130 cm x 45 cm x 45 cm
3) Water Source: Natural Sea Water3) Filtration System: Multi Chamber Sump Filter
4) Return Pump: Armada AM-105B 4000LPH5) Anaerobic Nitrate Reactor
5) Espressif ESP8266 Network Module with specifications: Network: 2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2)2)CPU:Tensilica Xtensa L1063) Operating Voltage: 3.3v d) Kamoer Peristaltic Pump NKP-DC-S06D with specifications:1) c) Espressif ESP8266E Network Module with specifications:1) Network:2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2)2)CPU:Tensilica Xtensa L1063) Operating Voltage:3.3vd) Kamoer Peristaltic

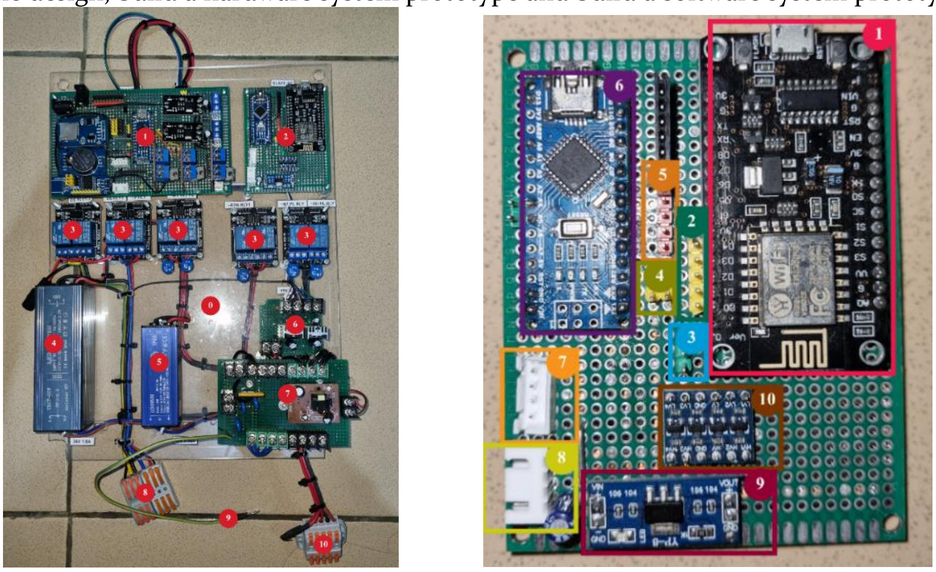
Pump NKP-DC-S06D with specifications:1)Working Voltage: 12 Volts 2)Flow Range: 5.2ml/min to 90ml/min e) Artificial Lighting Device with specifications:

a. Working Voltage: 12 Volt - 36 Volt
b. Light Emitter: Light Emmiting Diode
c. Light Spectrum Range: 450nm - 660nm

6) Optical Lens Angle: 45º - 120º
7) Power consumption: 80 Watts
8) Heat Dissipation: Aluminum Heatsink Single fan
9) DCP002 Current Making Pump with specifications: Working Voltage: 12 Volts
10) Flow Range: 400LPH - 1000LPH
11) Tiny RTC DS1307 Time Module with specifications: Working Voltage: 5 Volts Communication Protocol: I2C Protocol.

3. Results and Discussion

This chapter is a continuation of the design, namely implementation, testing, and discussion of evaluations of prototype tools that have been assembled and coded. At this stage the author will evaluate the design, build a hardware system prototype and build a software system prototype.



Figur 4. Controller device and Controller slave device

The master controller board is built with a common ground star topology to minimize the occurrence of noise and EMI from each connected work component. While the power lines (5v and GND) for relay control power have been isolated from the main power lines shown at points 2 and 6 in Figure 2, this is intended to avoid unwanted interference from the effect of the relay induction load itself.

In the slave controller there is a Node MCU development module, based on the ESP8266EX microcontroller which is a development version of the ESP8266, this microcontroller is used as a network endpoint and relay control of network status indicator lights. arduino nano sensor side microcontroller which has a function to read the sensor and control the activation of the top up pump relay and aquarium cooling fan.

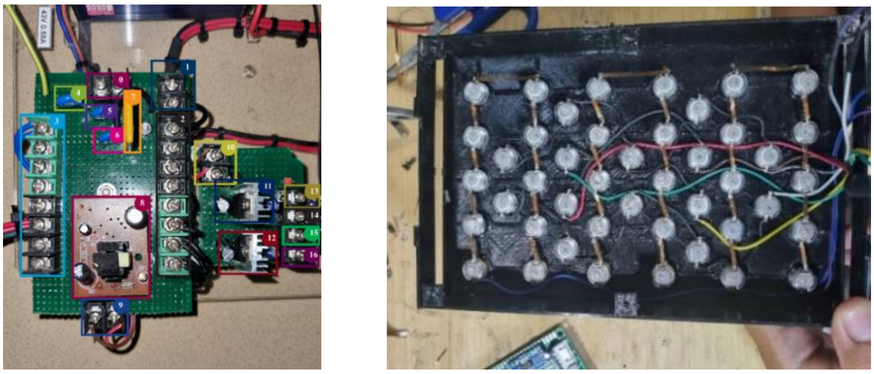


Figure 5. Power delivery board and Photosythetic lamp

1) Board for power delivery with overcurrent protection and overvoltage protection using PPTC and MOV, it provides the system a working current 230v, 12v, and 5v dc. The photosynthesis lamp uses PETG plastic for the casing made using 3D printing technology, 2 6cm x 6cm cooling fans, an aluminum heatsink, and 44 HPL LED emitters.

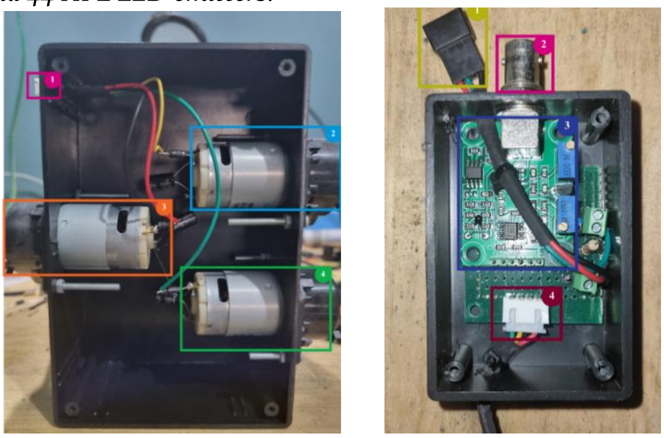


Figure 6. Dosing pump and Sensor Sub board

The peristaltic pump circuit is protected by using a plastic casing, rectification diodes, voltage stabilizing capacitors, and using an XH 2.54 connector as a power connection. The secondary board circuit houses the PH 4502C board and a pull-up resistor for the DS18B20 temperature sensor output.

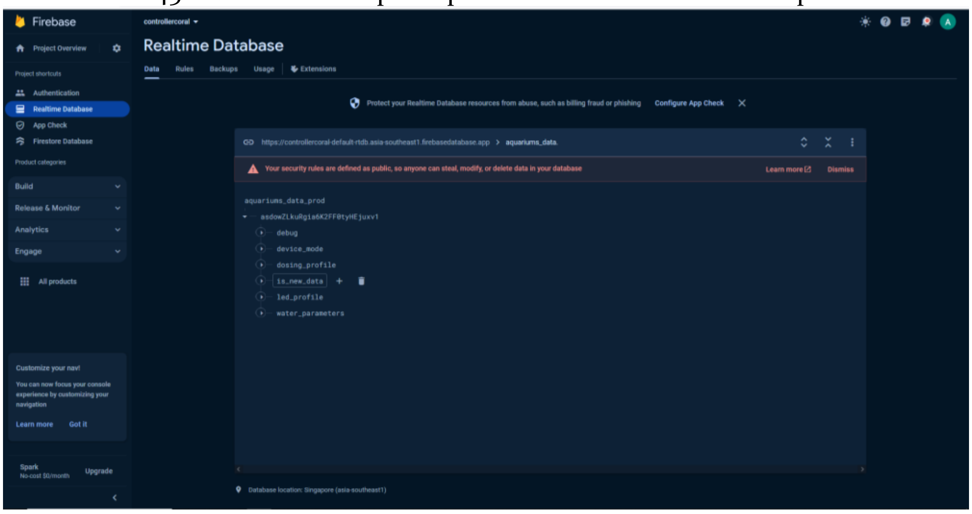


Figure 7. Database system using the Firebase realtime database service

The firebase firestore system is used as a data logger that records sensor readings, water parameter readings from user input, and records the amount of supplementation that has been given. The Android-based monitoring and control application was created using the Flutter Software Development Kit using the Visual Studio code IDE. The application is built with MVVM architecture or Model, View, View Model and Provider as state management.

2) The embedded software is created using the c++ language with the Arduino IDE, there are 3 source codes created for each microcontroller. At this stage the prototype product that has been made will be tested using the blackbox testing method which will test several aspects of the entire controller system. Application testing was carried out using the One UI operating system based on Android 13 on a device with the Samsung S21 FE model and an indihome internet network with a speed of 25Mbps - 40Mbps. Connect the ESP8266 Node MCU network endpoint slave controller with a wifi network and firebase server. Communication between the NodeMCU network endpoint and the Arduino nano v3 master controller via serial communication protocol.

Figure 8. Testing power delivery

Tests were carried out using avometer and testpen voltage test equipment to test the voltage magnitude and orientation of the power line on the part of the power provider and the input voltage of the 1 phase 220v - 250v PLN voltage.

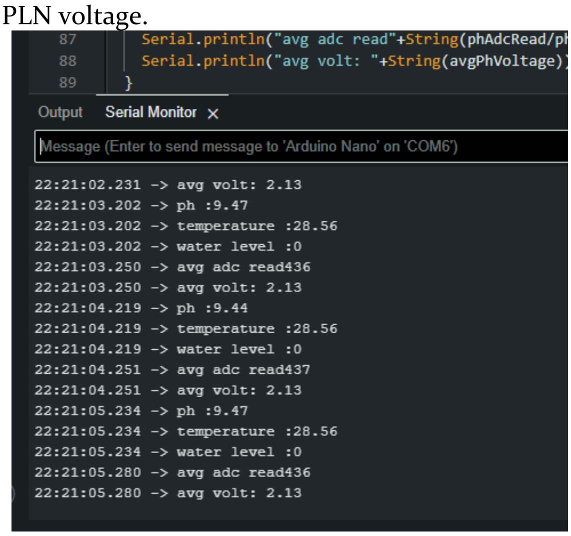


Figure 9. Testing sensor reading

Testing of sensor devices is done by testing each sensor with test media that is already known to the test magnitude.

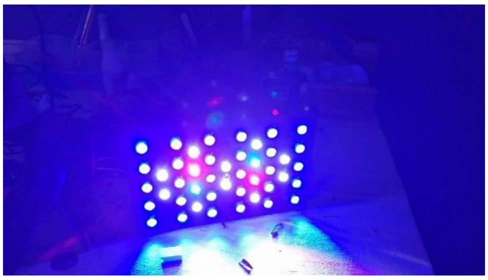


Figure 10. Testing photosynthetic lamp

Testing is done by applying working voltage to each channel of the photosynthesis lamp circuit and ensuring the cooling fan is working properly.

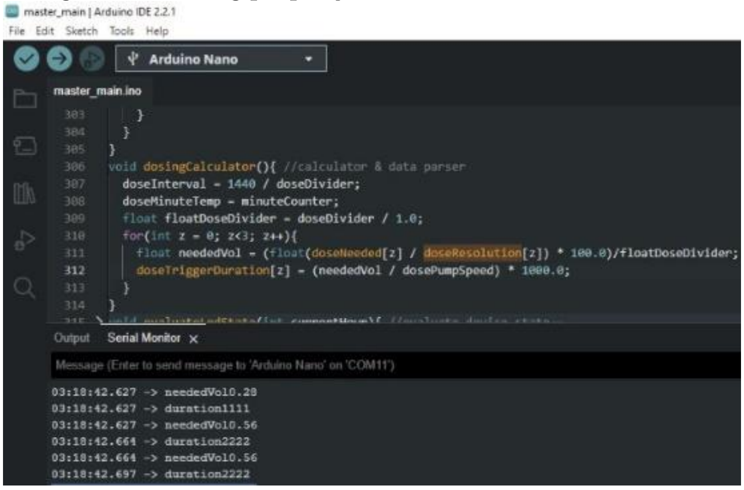


Figure 11. Testing dosing system

The test was conducted by looking at the active duration in milliseconds of each pump channel with an offset as a pause between channels, the active duration dT was determined using the formula: With: dT = active duration (s), a = dose (solution concentration), b = concentration of supplement solution (concentration/volume), c = divisor , Q = pump speed (ml/s), $dT=((a/b)x\ (100/c))/Q\ x\ 1000$

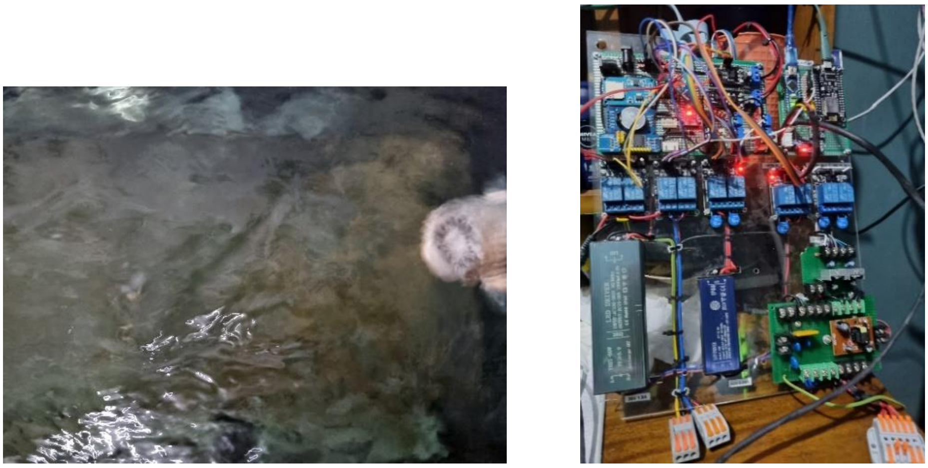


Figure 12. Testing wavemaker system and testing auto top up system

Testing wavemaker system is done by looking at the schedule and duration of current pump activation. Testing auto top up system is done by looking at the response of the top up pump relay to changes in the state of the height sensor.

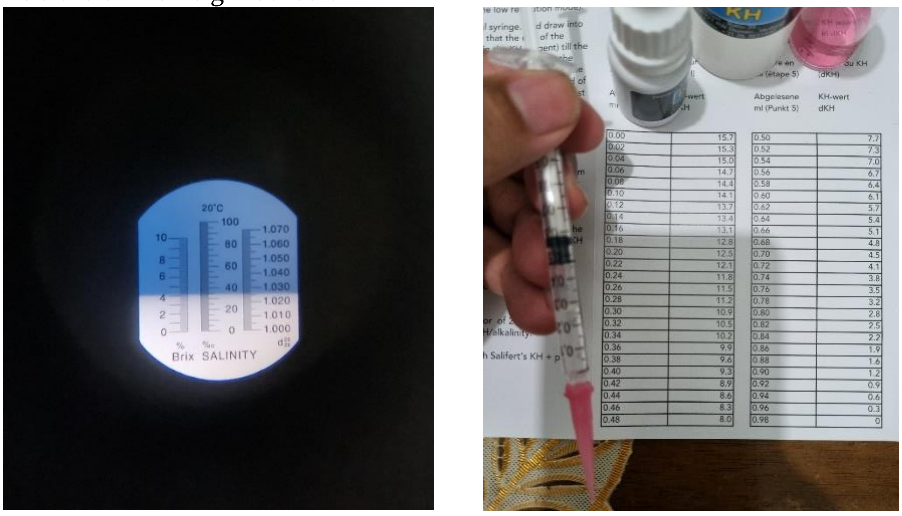


Figure 13. Testing salinity and Testing water chemistry

The test is carried out by taking a sample of media water and using a refractometer to find the salinity value of the water sample.

Testing water chemistry is done through the titration test method using salifert test kit products. By reviewing 12 prototype product test results, 11 tests met the problem limits and deviation limits with a note that the magnesium content of the media water needs to be increased by increasing the dose of magnesium supplementation in the media water.

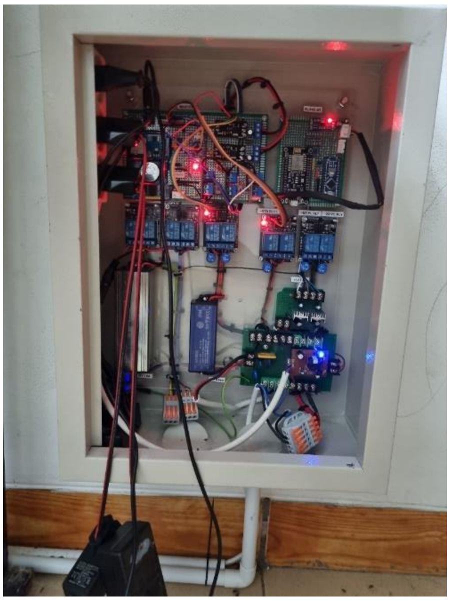


Figure 14. Implementation and Testing

The final display of the Android application displays values in the form of graphs of water PH, water temperature, water usage, water chemistry (Alkalinity, Calcium, Magnesium, Salinity) and supplementation utility (dosing utility).

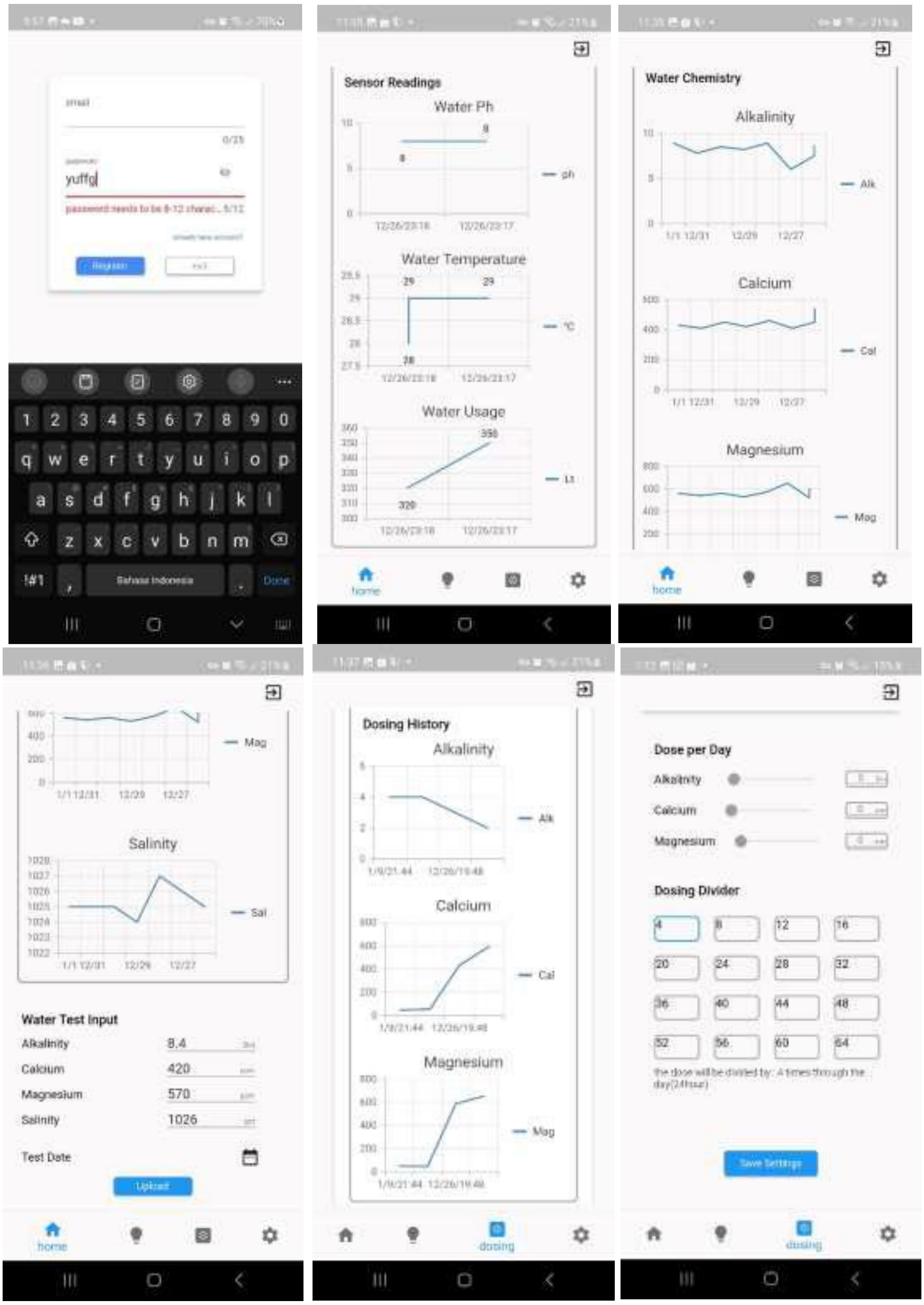


Figure 15. System interface display

The following is a table of the final test results of the tool :

Table 1. The Results of Testing

No	Testing	Expected results	Test result	Dev
1.	Android application functionality testing.	All functions of the Android application run well as designed	The Android application runs well as designed	0
2.	Testing network endpoint connectivity of NodeMCU ESP8266EX slave controller	All functions in the Node MCU embedded program run well as designed	The embedded program is capable of carrying out internet network connection functions, connection functions with the Firebase server, and serial communication well	0
3.	Microcontroller serial communication testing	Serial communication is carried out using a transmission code that gives instructions to the destination microcontroller, and shares data via a serial communication line	2 Android nano v3 microcontrollers are able to communicate with each other with the Node MCU slave network endpoint controller	0
4.	Power supply system testing	All power board terminals must provide voltage within the design range of ±5%	All terminals on the power board provide power voltages within the design range limits	0.1% - 2.6%
5.	Sensor device testing	All sensors must provide readings with a maximum deviation limit of 5%	All sensors fall within the maximum deviation limits	2% - 3%
6.	Photosynthetic lamp control testing	Each series of lights must light up when powered within the working voltage set by the scheduling program	Each set of lights lights up according to the power input from the scheduling program.	0
7.	Supplementation pump testing	Each supplementation pump channel is activated according to program scheduling for a predetermined duration with a maximum deviation of 5%	The program is able to schedule pump activation with a duration within the deviation limits	1.4% - 2.4%
8.	Flow pump testing	Pump activation scheduling is regulated by the program in accordance with the provisions of the wavemakerScheduler function	Pump scheduling runs according to the mode and activation conditions in the program	0
9.	Top up pump activation testing	Activation of the top up pump is regulated by a signal from the water level sensor	The top up pump relay is active when the water level sensor gives a signal and will be deactivated when the sensor no longer gives a signal	0
10.	Testing the return pump water discharge	The pump water discharge at a height of ±90cm reaches a speed in the range of 2000LPH – 4000LPH	The pump provides water flow at a speed of 2067LPH	0
11.	testing media water salinity levels	Media water must have a salinity level in the range of 1.025 – 1.026	The salinity reading was 1.026	0

12.	Testing the levels of media building elements	All building elements are in a range close to the normal limit of natural sea water ±5%	Alkalinity and calcium are close to normal values for natural sea water, but magnesium readings have deviations that exceed the deviation limits	±19%

4. Conclusion

This research successfully developed a coral reef aquaculture media control system based on Arduino Nano V3 and Flutter SDK, which integrates hardware and software architecture with a multi-microcontroller approach as well as ESP8266 and Firebase-based communication. Key findings show that the system is capable of maintaining critical environmental parameters for coral reef biota with less than 5% deviation from reference values, confirming its accuracy and reliability in supporting aquaculture ecosystems. The implications of this research include increased efficiency and automation in coral reef rearing systems, which can be applied in laboratory scale as well as technology-based conservation. However, the limitation of this research lies in that the testing is still limited in a controlled laboratory environment, so it does not fully reflect the dynamics of a more complex marine ecosystem. For future research, it is recommended that the system be tested in natural water conditions to evaluate its performance in a more dynamic environment, as well as optimizing artificial intelligence-based control algorithms for automatic adaptation to environmental variations.

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