Internet of Things for Aquaculture in Smart Crab Farming

Jumras Pitakphongmetha

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Computer Engineering

Prince of Songkla University

2021

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ชื่อวิทยานิพนธ์ อินเตอร์เน็ตของทุกสรรพสิ่งสำหรับการเพาะเลี้ยงสัตว์น้ำในฟาร์มปู
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บทคัดย่อ

เศรษฐกิจที่สำคัญในภาคใต้ของประเทศไทยคือการเพาะเลี้ยงสัตว์น้ำเช่นการประมงกุ้งมุกหรือฟาร์มปู แนวคิดของเซ็นเซอร์เชื่อมต่อ IoT และรวบรวมข้อมูลที่จำเป็นทั้งหมดไปยังแพลตฟอร์ม IoT เราสามารถคำนวณควบคุมและจัดการฟาร์มได้อย่างมีประสิทธิภาพ ปูนิ่มเป็นที่นิยมมากในร้านอาหารจีนและญี่ปุ่น น่าเสียดายที่ประสิทธิภาพของการผลิตปูนิ่มมีน้อยมากเนื่องจากมีอัตราการรอดชีวิตสูง ปูแต่ละตัว โตแยกกันในกล่องเล็ก ชาวนาจะต้องให้อาหารพวกเขาทีละคนและตรวจสอบพวกเขาทุก 4 ชั่วโมงเพื่อหลีกเลี่ยงการปูนิ่มเปลี่ยนเป็นเปลือกแข็ง ในวิทยานิพนธ์ฉบับนี้เราเสนอให้ใช้ IoT และระบบอัจฉริยะเพื่อปรับปรุงประสิทธิภาพในฟาร์มปูนิ่ม เซ็นเซอร์คุณภาพน้ำเซ็นเซอร์ตรวจจับความเคลื่อนไหวและระบบการให้อาหารได้รับการออกแบบและพัฒนาเพื่อเพิ่มความสามารถของฟาร์มปูนิ่ม ในขณะเดียวกันด้วยแนวคิดเดียวกันระบบของเราสามารถนำไปใช้ในการเพาะเลี้ยงสัตว์น้ำอื่นเพื่อเป็นฟาร์มที่ชาญฉลาดและเป็นระบบการเพาะเลี้ยงที่แม่นยำในอนาคต

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ABSTRACT

Internet of Things (IoT) has been introduced and applied in many applications and become an emerging technology in digital era. The major economic in southern part of Thailand is aquaculture such as fishery, shrimp, pearl or crab farm. The concept of IoT connecting sensors and gathering all necessary data to IoT platform allows us to compute, control and manage farm more efficiently. Soft shell crab is very popular dishes in traditional Chinese and Asian fusion menu. Unfortunately, the productivity of typical soft shell crab farm is very small due to a low survival rate. In order to increase the productivities of soft-shell crab, the smart aquaculture system based on IoT is proposed. Each small crab has been raised separately in a small box. Normally, farmer feeds them one by one and monitors them every 4 hours in order to avoid soft shell crab turn to hard shell. In this thesis, thus, we propose to apply IoT and intelligent system to improve the productivity in soft shell crab farm. Water quality sensors, motion sensors and feeding system are designed and developed to enhance the capability of soft-shell crab farm by less people. The return of investment of our proposed IoT aquaculture is 36 months. Meanwhile, with the same concept, our system can be applied in another aquaculture to be smarter farm and be precision aquaculture in the near future.

Keyword: Internet of Things, Intelligent system, Soft shell crab, Precision aquaculture,

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LIST OF ABBREVIATIONS AND SYMBOLS

IoT	=	Internet of Thing
CO_2	=	Carbon dioxide
O_2	=	Oxygen
°C	=	Degree Celsius
%	=	Percentage
m^{-2}	=	Square Meter
WSN	=	Wireless Sensor Networks
MLR	=	Multiple Linear Regression
Evap	=	Evaporative cooling system
A/D	=	Analog and Digital
AC	=	Alternating current
DC	=	Direct current
mm	=	Millimetre
g	=	Gram
kg	=	Kilogram
mg	=	Megagram
UV	=	Ultraviolet-Visible
V	=	Volt
W	=	Watt
N	=	Nitrogen
P	=	Phosphorus
K	=	Potassium
DO	=	Dissolved Oxygen
pH	=	Potential of Hydrogen ion
EC	=	Electric Conductivity
L	=	liter
Ca	=	Calcium
Mg	=	Magnesium
NM3	=	Ammonia
No2	=	Nitrite

LIST OF PUBLICATIONS

1. J. Pitakphongmetha, W. Suntiamorntut, S. Charoenpanyasak, “Internet of Things for Aquaculture in Smart Crab Farming”, International Conference on Big data, IoT, and Cloud Computing, ICBIC2020, pp. 01-05, 2020.

Chapter 1
Introduction

1.1 Background and rationale

Thailand’s development is based on agriculture production and we are moving forward to the next transition using the concepts of Thailand4.0 according to the fourth world revolution. The national development plan named 20-year Thailand Strategy will focus on technologies development to enhance the competitiveness and value added in agriculture sector. In many countries around us such as China, Viet Nam and Philippines, their government organizations have national policies and regulation for aquaculture farm planning. Licensing is required in order to have a well environment assessment of aquaculture development. Because the young crabs are taken from local mangrove which related to the environment conditions, the farmer and local government agency must work closely. After the world has been affected by Covid-19, everything countries start to plan about food security more seriously. Many countries thus are seeking a good smart or precision aquaculture system solution. This is a great opportunity for Thai technology companies.

In the last ten years, the technology named Wireless Sensor Networks (WSN) has been introduced and adapted to be support the concept of Internet of Things (IoT) which combining several knowledges such as embedded system, low power communication, sensing and cloud system development. The large number of tiny low power devices which can be deployed and gathered data back to cloud system for an analytic is the main purpose of IoT. The applications of IoT [1], [2] are flood detection, fire detection, object tracking and smart farm, etc.

In the past few year, the internet of thing is very popular and widely deployed in many domains, especially agriculture. Precision aquaculture [3] consists of many sensors to monitor farm environment, compute data, make decisions the best fish growth and benefit. With the traditional aquaculture process requires humans and depends on farmer’s experiences for correct decision and action. Thus, IoT has been used in smart or precision aquaculture. Raising crabs with high survival rate requires more experiences and time. Therefore, many research works have been proposed in [4]–[6]. the Internet of thing in crab farm such as feeding using the rotation of by threaded bar scheduled crab feeding system when feeding and controlling food portions using the microcontroller [7], water quality main key of the aquatic animals. Unable to control water quality make causing crabs in the system to die so sensor must be accurate[8]. Most of them proposed some system to monitor environmental conditions, especially water quality. Some proposed feeding system. Not yet, the whole smart or precision crab farm is proposed. Apart from lacking the modern and smart system, the traditional soft shell mud crab farm is grown in pounds. To increase yield and productivity is limited by area and time.

Therefore, this work is proposed the smart closed-aquaculture system for soft-shell mud crab to improve yield and productivities. The young mud crabs are raised in the shelf of box contained varies from 24-36 boxes, we called 'Crab Condo'. The closed-water treatment system is used. Temperature and water quality are monitored using Temperature and EC sensors, respectively. Automatic feeding system is designed and installed on this crab condo together with camera. All devices are connected using in-house IoT connectivity platform. Sensory data is processed and control back to crab condo in order to keep the good condition for raising crab. The image from camera is analyzed to detect molting crab and noticed to farmer via Line.

1.2 Research objectives

1. To enhance the productivity of soft-shell mud crab by 50 %.
2. To develop and implement precision soft shell mud crab farm in order to increase productivity and reduce cost based on IoT and intelligent platform

1.3 Advantages

1. Aquaculture workers will be able to take care of aquatic animals more easily and can also control water supply and feeding.
2. Aquaculture workers aware of the quality of water.
3. Increase the survival rate of mud crab.
4. Developing aquaculture producers to be able to view water quality data.

1.4 Research scope

Monitoring environmental factors that effecting the growth of in the crab condo via the mobile and web application. It can be worked as follows:

(1) The system can control the appropriate conditions for measuring and visualizing the environment.

(2) The system can reduce the labor force for measuring and visualizing the environment.

(3) The system can operate independently without having to control in the model area.

(4) The system can increase the survival rate of aquatic animals.

Chapter 2

Literature Reviews

2.1 Background

2.1.1 Internet of Thing (IoT)

Internet of Things (IoT) is an important player in many applications such as health care, logistic, industry and agriculture. IoT must deploy many devices as much as possible, it is a main concept of IoT technology. Those devices have been connected to the internet. This allows to monitor and control the various devices remotely and supports the smart systems for examples Smart Home, Smart Office, Smart City, Smart Health and Smart Energy and other daily life applications. It is carrying out every activity which relied on the IoT applications and equipment in order to increase the system efficiency and understand the behavior of human[9][10].

Internet of Things composition consists of 3-technology as shown in Figure 2.1

- Sensor & activators are parts of sending and receiving information.

- Connectivity is the part of connecting to communicate with networks such as Zigbee, Wi-Fi, 4G, NB-IoT and LoRaWAN.

- People & Processes are the part of the users and work processes of IoT devices[11]

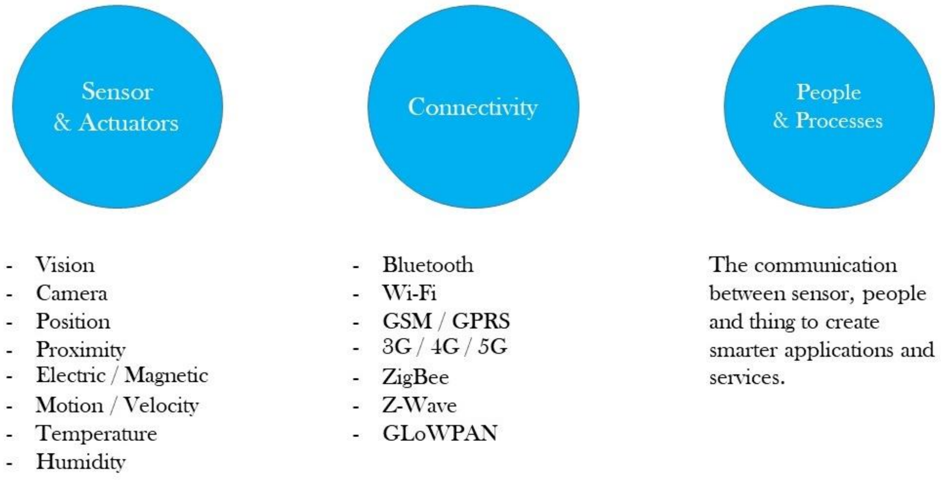


Figure 2.1 Elements of IoT

There are many ways to classify the IoT sectors. In this thesis, we use the networking level divided IoT into 2 groups:

1. IoT required gateway: In this type of IoT, each devices or sensors are connected via non-IP network such as Zigbee or Bluetooth. In this case, user can get data and control devices via gateway which has IP network as shown in Figure 2.2.

2. Individual IoT: Each device in the system can be connected to existing network infrastructure. There are two methods for doing this. One is IP based devices. Another is connected via mobile network such as NB-IoT[12].

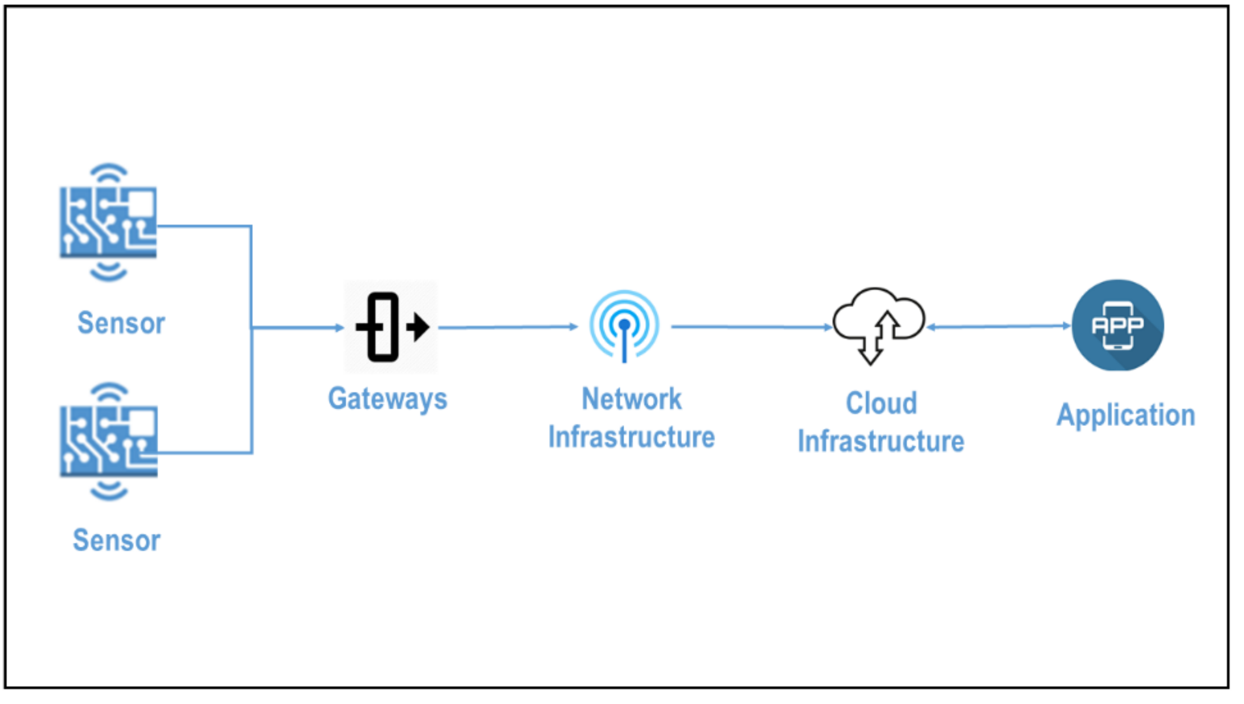


Figure 2.2 Network of Internet of Things.

These sensors are defined as uniquely identifiable nodes, primarily sensors that communicate without human interaction using different connectivity methods.

- Gateways These acts as intermediaries between things and the cloud to provide the needed connectivity, security, and manageability.
- Network Infrastructure This is comprised of routers, aggregators, gateways, repeaters, and other devices that control and secure data flow.

- Cloud Infrastructure Cloud infrastructure contains large pools of virtualized servers and storage that are networked together with computing and analytical capabilities.
- Application software created for user including connected things together.

2.1.2 Mud crab

Mud crab (Scylla serrata) is popular used to make soft shell crab for cooking as well as delicious taste. Unfortunately, raising mud crabs are required high experience farmer because of their survival rate. Mud crabs respond to environmental factors such as temperature and salinity. Their molt cycle is an important drive of internal metabolic processes. Thus, water quality is one parameter to increase the chances of survival. Table1 shows the important parameters for mud crab. Farmer who raise mud crab in pound or crab condo must to control the environmental parameter like these[13].

Table 2.1 The near optimal environmental for Mud Crab to soft-shell crab.

Parameter	Standard value
Salinity	25 g/kg to 30 g/kg
Suspended Solids (SS)	<70mg/L
Temperature	28 °C to 30 °C
Dissolved Oxygen	>4 mg/L
Biochemical Oxygen Demand (BOD)	≈2mg/L
Total Ammonia (NM3)	<4mg/L
Nitrite (No2)	<0.1 mg/L
Hydrogen Sulfide (H2F)	<0.02 mg/L
pH	7.0 to 8.5
Phosphorus	<0.4 mg/L

In this thesis, we bring young crabs (10 cm.) from mangrove and feed them in our crab condo. We study and observe the behavior of molting of the crab. From young crabs, it takes 90 days for raising to be fully-grown mud crab which is ready for molting. Water quality sensor has been installed and record continuously to observe the relation between growth rate and quality of water. The sensors to monitor water quality will be explained in section 4.1. In section 4.1, feeding is described. We prepare their food by using fresh, coarse spinning fish, rolled into cubes. The auto feeder is invented as well.

2.1.3 Fertilizer

A fertilizer is material of synthetic origin used mix the water for mud crab to soft-shell crab obtain mud crab nutrients that are essential for mud crab growth. In general, the main nutrients that are important mud crab to soft-shell crab must be in sufficient quantities to meet the needs of soft-shell crab. The main nutrients include Oxygen (o_2), The potential for hydrogen of water(pH), Calcium (Ca), Magnesium (Mg), Nitrate and Nitrite. The crab use Ca and Mg for growth to soft-shell crab. In the same way, the crab use pH and o_2 help to the survive crab breathes underwater by pulling water. Above the gums using an organ called scaphognathite Which is located at the bottom of the crab near the base of the claws the water flows through the gums which extract oxygen. The oxygen in the water must not be lower than 8 and the pH value is determined by the level requiring similar temperatures. This means that the water's pH is not a physical parameter that can be measured at concentration or volume between 0 and 14. The optimum pH of mud crab between 8.0 to 8.5. Finally, Salinity is most important for better survival and growth of mud crabs, so mud crabs are resistant to a variety of salinity conditions, from a salinity between 15 to 30 parts per thousand (PPT)[14].

2.1.4 Object Detection

Object Detection [15] is major feature in computer vision. Object detection has been used in many applications such as video surveillance [16], medical imaging [17] and self-drive car[18]. Previously, there are many processes have to be done for doing object detection. Firstly, we do need background subtraction [19], temporal differencing [20], Kalman filtering [21], Support Vector Machine (SVM) [22], and contour matching [23]. Object detection can be implemented two possible methods. One is using traditional machine learning based on several computer vision techniques. The other is deep learning methods, R-CNN [24] and YOLO [25].

This research use darknet function on YOLO-based real-time object detection system. On a Pascal Titan X YOLO can process images at 30 FPS by use classify reflect infrared light, so reflection of crab and soft-shell crab are completely different. Also, YOLO makes predictions with a single network evaluation systems R-CNN which require thousands for a single image. This makes it extremely fast, more than 1000x faster than R-CNN and 100x faster than Fast R-CNN[26]. And YOLO instead of guessing boxes and then passing on to classify, YOLO guesses both the box and the probability of different classes simultaneously and 2. Instead of guessing the values from the whole image, we divide the image into parts. For each part, we guess both box and class, which we can combine to select a class / box pair. That the highest score is the answer

2.2 Related work

This section describes the use of IoT in aquaculture for system management. there are reported on the technological control of environment, by applying IoT and Wireless Sensor Networks (WSN) in aquaculture to influence mud crab growth molting to soft-shell crab for improved efficiency (Kodali et al., 2014; Ojha et al., 2015; Muangprathub et al., 2019). Hashim et al. (2015) reviewed control with an electronic device (Arduino) of temperature, pH, EC, and D.O. using LINE application to status of crab farm. Management of aquaculture, as the soft-shell crab farmers do not know when mud crab is molting and the survival. Using the water quality sensor and using the camera to alert the crab when molting Water quality will affect the survival rate of mud crabs following the effect of physic chemical properties of water such as Salinity, Temperature, pH, DO, Ammonia, Nitrate and Nitrite on growth and survivability of mud crab, but 3 main parameters are temperature, salinity, and pH. presented (S. Pedapoli and K. R. Ramud, 2014).

A. Water Temperature

Water temperature is an important factor to consider when evaluating water quality. Aside from that, its effects on temperature also influence many other parameters and can change the physical and chemical properties of water. In this regard, the water temperature should be considered when considering. The optimum temperature of mud crab values between 23 C to 30 C.

B. Salinity

Salinity is most important for better survival and growth of mud crabs, so mud crabs are resistant to a variety of salinity conditions, from a salinity between 10 to 34 parts per thousand (PPT).

C. power of hydrogen or potential for hydrogen(pH)

The pH value is determined by the level requiring similar temperatures. This means that the water's pH is not a physical parameter that can be measured at concentration or volume between 0 and 14. The optimum pH of mud crab between 8.0 to 8.5

D. Oxygen in water

Crab breathes underwater by pulling water. Above the gums using an organ called scaphognathite Which is located at the bottom of the crab near the base of the claws the water flows through the gums which extract oxygen. The oxygen in the water must not be lower than 8

There was reported many studies on the IoT base water quality technological. Muhammad Niswar et al., (2018) presented an IoT environmental monitoring system and IoT wireless platform. The system for monitoring environmental factors in water and platform management of sensor node shown as in Figure 2.3. and flow Diagram for monitoring pH as in Figure 2.4.

Figure 2.3 Sensor Node on water (Muhammad Niswar et al., 2018)

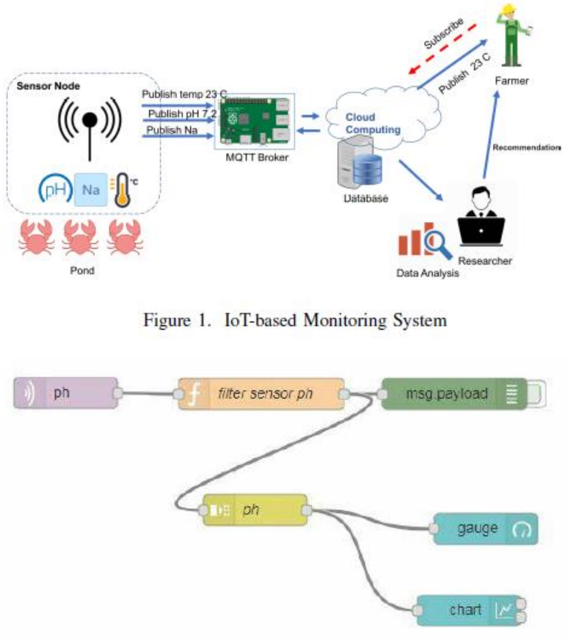


Figure 2.4 Flow Diagram for monitoring pH (Muhammad Niswar et al., 2018)

Ing-Jer Huang et al. (2018) developed system for shrimp farming in pond. They used WSN is used to monitor feed auto and camera for classification shrimp and food, the auto feeding machine is based on the AI image recognition system[27] (Figure 2.5).

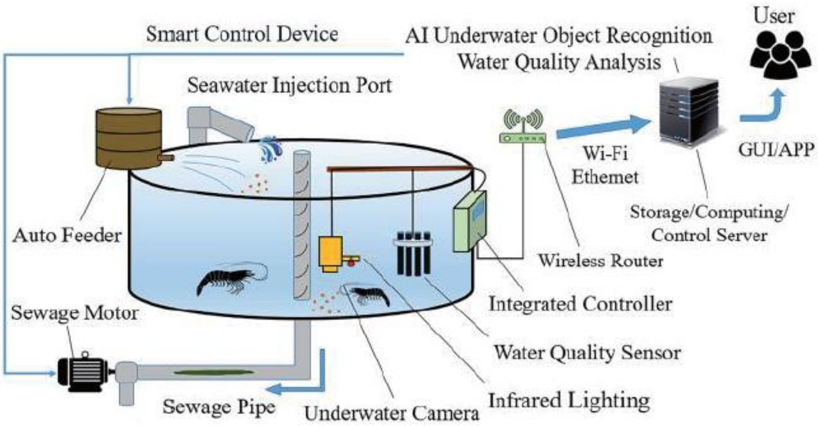


Figure 2.5 Control system on smart shrimp (Ing-Jer Huang et al. 2018)

AI system image process Ing-Jer Huang et al. (2018) proposed the model for object recognition for shrimp and food by used yolo model for our AI image processing technology, we describe the underwater image enhancement, feed recognition and shrimp recognition shown as Figure 2.6.

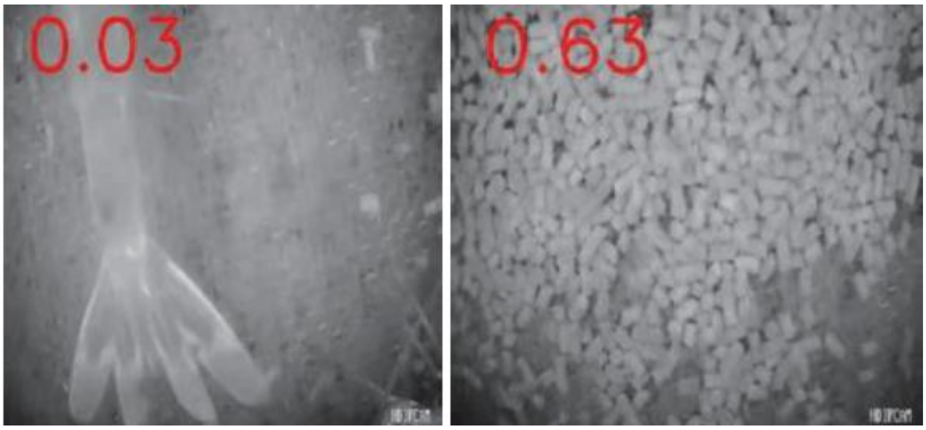


Figure 2.6 Food recognition results, the red number in the upper left corner of the figure is the estimated percentage of food in the image. (Ing-Jer Huang et al. (2018)

Machine learning is the classification of things. (classification) it learns to create. A classifier, such as Neural Network or SVM, that can tell what character the visible image any kind of animal such as dog, cat, bird, etc. or any kind of place such as forest, sea, mountain, etc. The concept of predicting the position + the size of the box and the probability that it will be Frame This was used in another work called YOLO (You Only Look Once). However, YOLO has a different concept from Faster R-CNN, that is, 1) instead of guessing boxes and then passing on to classify, YOLO guesses both the box and the probability of different classes simultaneously and 2. Instead of guessing the values from the whole image, we divide the image into parts. For each part, we guess both box and class, which we can combine to select a class / box pair. That the highest score is the answer shown as Figure2.7.

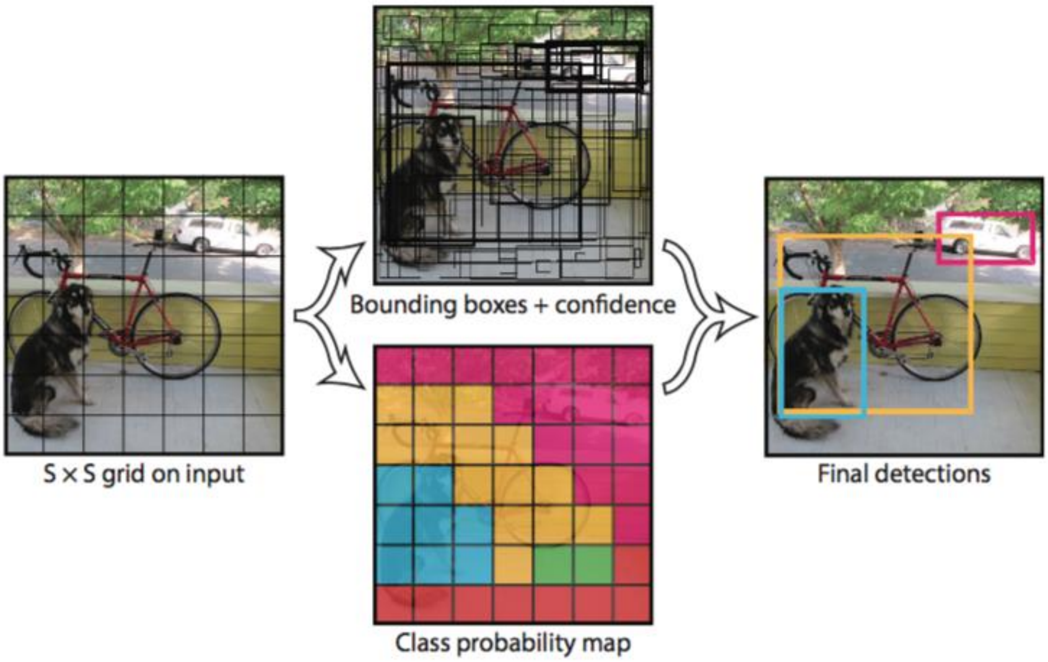


Figure 2.7 YOLO header (J. Redmon et al., 2016)

W. Liu et al. (2016) presented another structure that can be seen as an extension of the YOLO is the SSD (Single Shot multi-Box Detector) that offers to predict boxes from multiple scales instead of guessing at a single YOLO scale. scale can be very different shown as Figure 2.8.

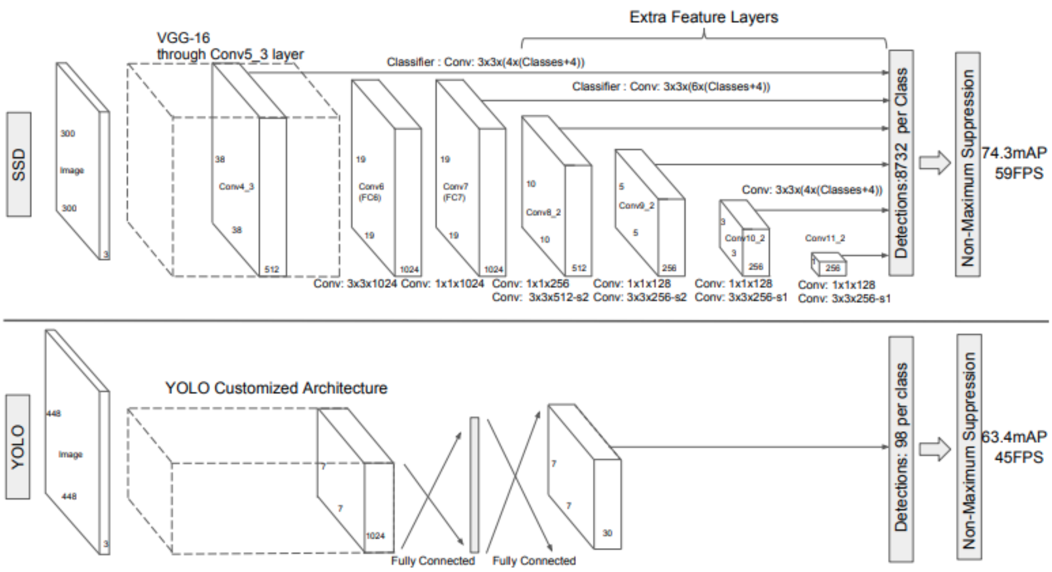


Figure 2.8 SSD and YOLO structure (W. Liu et al., 2016)

YOLO is a state-of-the-art real-time system built on deep learning to solve image sensing problems. As you can see in the image below, it will first split the image into defined boundary frames, and then run a concurrent recognition algorithm for all of these boxes to identify the object classes belonging to the class. After this class has been identified, it will intelligently combine them to create the best bounding boxes around objects. use darknet function on YOLO-based real-time object detection system. On a Pascal Titan X YOLO can process images at 30 FPS by use classify reflect infrared light, so reflection of crab and soft-shell crab are completely different.

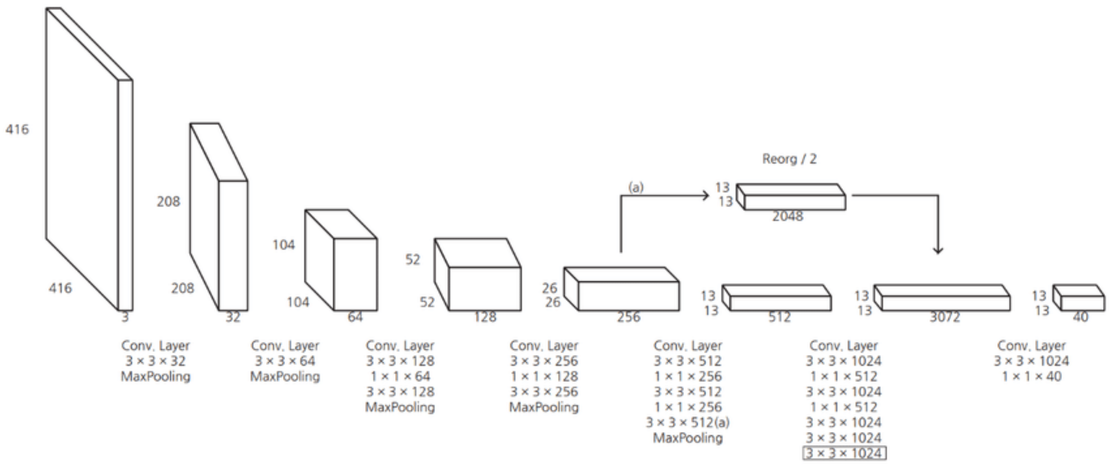


Figure 2.9 The working principle of yolo (J. Redmon et al., 2016)

2.3 Materials and equipment

This research requires different equipment’s and tools. In general, materials and equipment were specified in groups as follows.

2.3.1 Software

1) Arduino IDE: it was used compiling, uploading and debug programs to an Arduino board, such as Node MCU ESP8266, Arduino UNO.

2) Visual Studio Code: it was used developed code and It offers support for debugging, built-in Git controls, syntax highlighting, intelligent code addition, and code refactoring.

2.3.2 Hardware

1) Arduino UNO R3 & CNC shield

2) Raspberry pi 3

3) ENV-50-pH sensor

4) ENV-50-EC-1.0 sensor

5) ENV-40-DOX sensor

6) Water pump

7) Camera

2.3.3 Agricultural equipment

1) Aluminum profile

2) Equal Angle

3) Other

Chapter 3
Research Methodology

This chapter will explain the research methodology in each step. We have set a planning, getting the requirements from farmer, doing analysis and start to design the proposed system. After that we have developed and implemented each part of the system and then integrated them together. The system has been tested and observed the experimental results.

3.1 Planning

This work is planned to study, examine, and collect data from literature reviews and related works. Tools and possible technology are studies and explored in order to improve the environmental factors affecting molting of mud crabs. There are five parts to achieving the proposed system as follows:

(1) Crab indoor farming system: The main goal of building a controlled crab indoor farming system was to determine the important factor of controlling which is the movement of the camera to process images.

(2) System aquaculture: study of design architecture, considering the structure of IoT systems, it is important to define the functions within the system. Architecture designed as a template to design other parts of the system.

(3) Hardware: This work plans to design IoT Devices which are suitable for locally use and eco-budget. The family of Arduino and Raspberry Pi are planned to manage and control devices for IoT systems for measuring and controlling various factors. This work planned to design the IoT devices that was considered for appropriate use according to usage and cost. The microcontroller board in the Arduino family was planned to use to manage and control the device for IoT system of measurement and control environmental factors. Moreover, the hardware need was tested for performance to find shortcomings in real work.

(4) Software: The core of the system internal communication was designed and developed in software component with web applications that was divided into two parts namely server and user applications. The server application was used to manage the

data in the system while user application was developed to provide the information of environmental factor for monitoring and control of system. This research developed using connexthing.io for database management.

(5) Prediction models: This study was planned to apply analyze relationships and predict the possibilities of molting. This work then used the analysis of the environmental factors together with the data from IoT system to find the relationship and forecast the temperature by the method of data science.

3.2 Systems analysis and requirements

System requirements this step derived from an expert in aquaculture, literature view, and prior research to achieve the objectives of this work. The system requirements were covered scope of the research, which was as follows: (i) to enhance the productivity of soft-shell crab 50%, (ii) to develop and implement precision soft shell crab in order to increase productivity and cost, (iii) to design and develop intelligent system for crab farm.

3.3 Systems design

3.3.1 Crab indoor farming system

Crab indoor farming system, device for the measurement and control of IoT systems were designed in Figure 3.1.

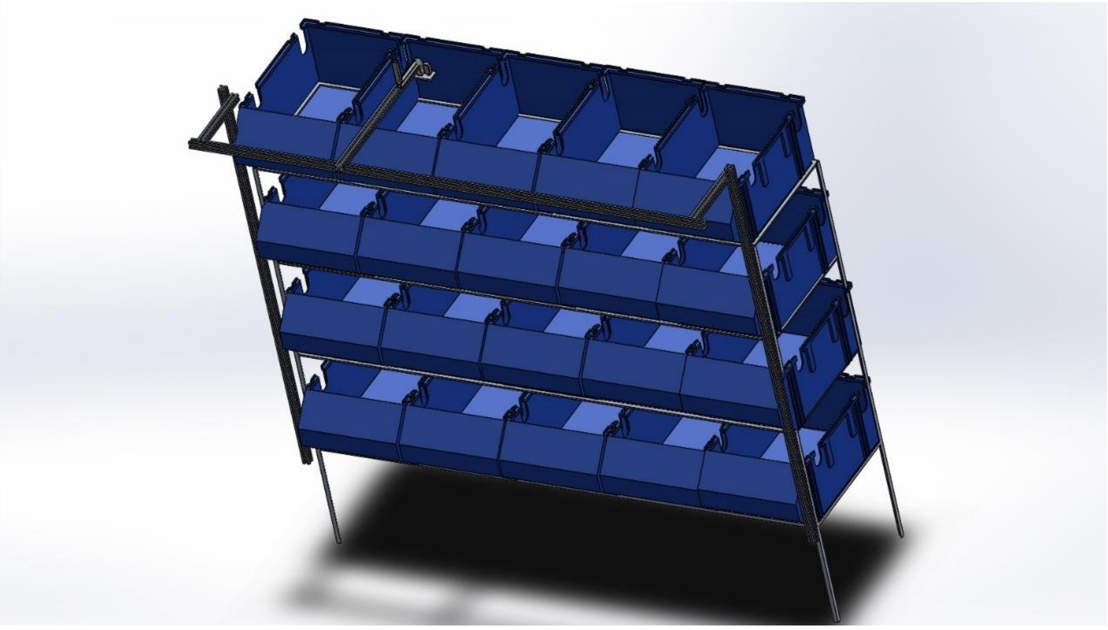


Figure 3.1 Crab indoor farming system

Area: water crab indoor size 20 box 15 box of crab of 0.25*1.5*1.8 (length * width * height: m) in system 290L each layer is 34 cm 4 apart and 4 filter tank the first filter tank filter waste from crab second ceramic material show third oyster shell and sea plants fourth bio ball show in figure.3. One 1 condo box to 1 crab with camera to capture photos and feed every midnight.

.

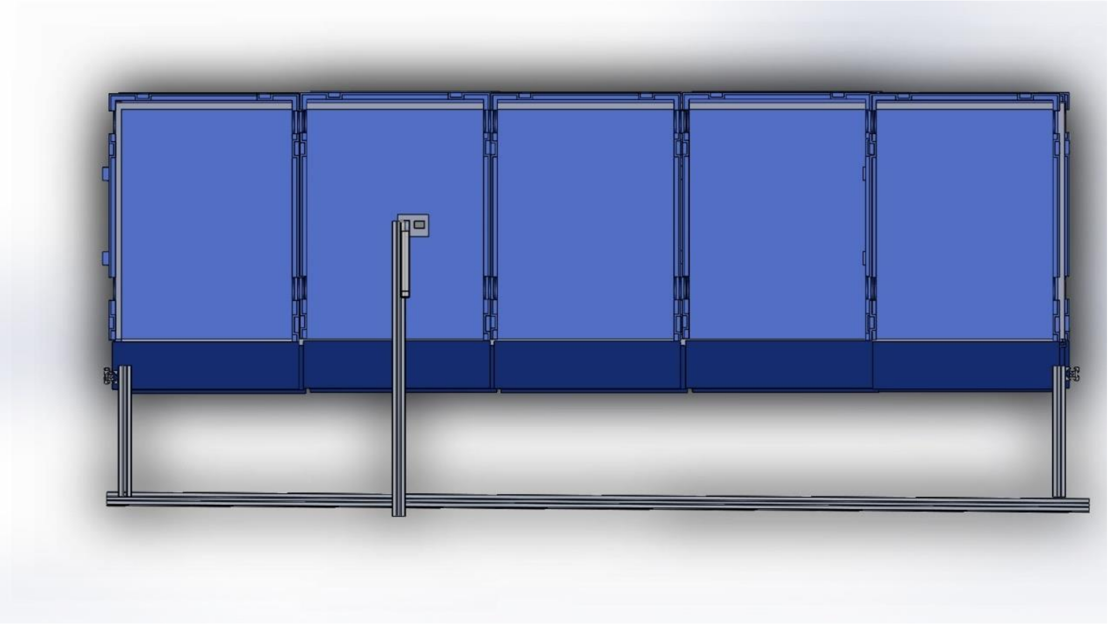


Figure 3.2 One box for one crab had sensor each layer.

3.3.2 System architecture design

This study was analyzed and designed to experiment and control molting of crab. There are components of the proposed system as showed with the novelty system architecture design overview in Figure 3.3.

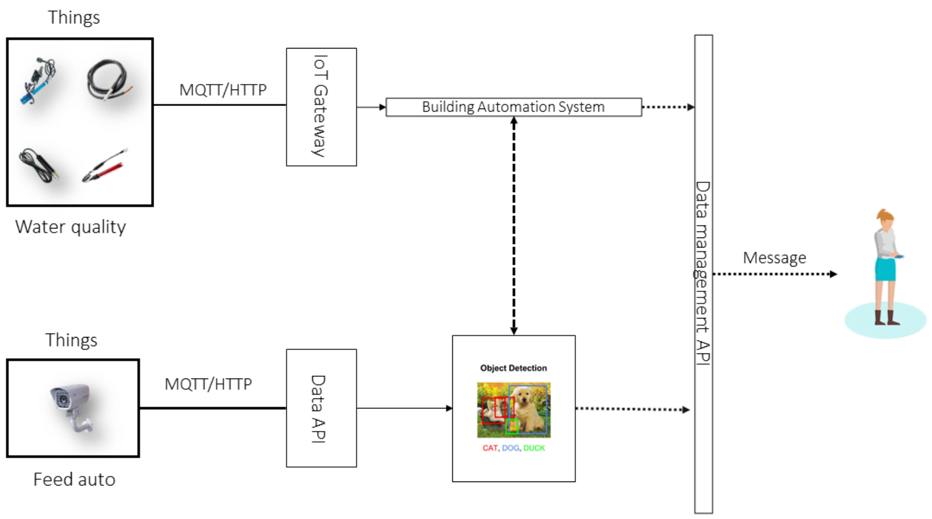


Figure 3.3 The system overview

From Figure 3.3, the system overview consisted of three components represents physical, communication, and application layer. The physical layer was designed in hardware communication with application layer realizably developed in software form. The hardware l and application layer related to communication layer where hardware layer. IoT was applied to the design of the overview and architecture of the system for measurement, monitoring and control environmental factors, then the architecture of the system was proposed in determining model communication of the system which is shown in Figure 3.4.

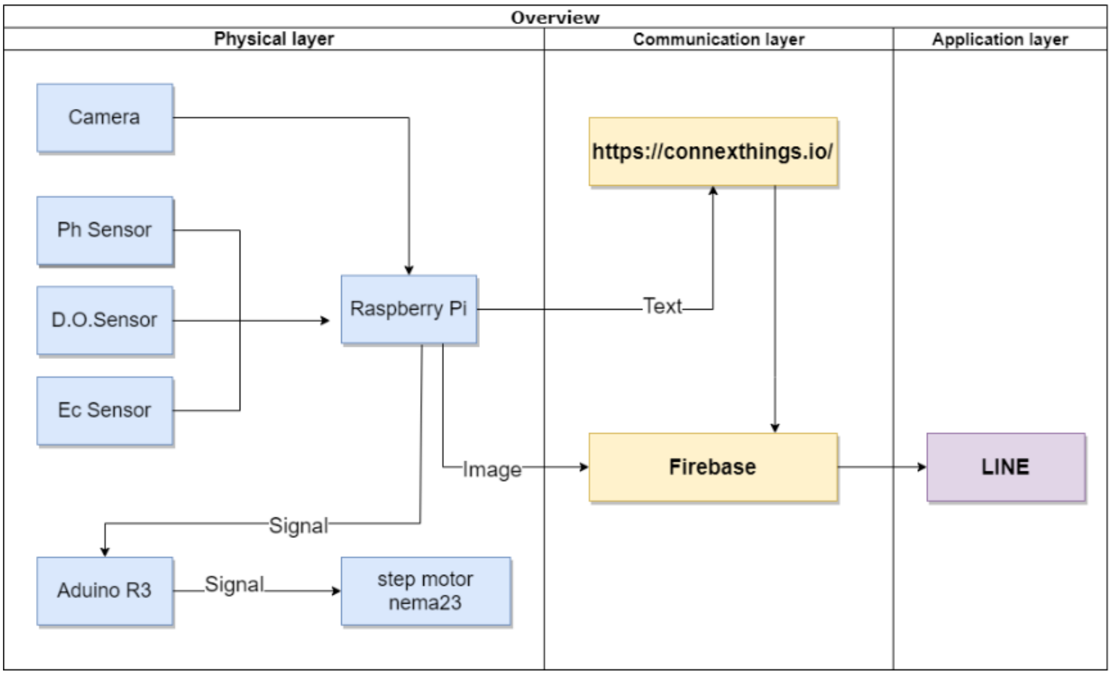


Figure 3.4 The architecture system

Figure 3.4 shows the designed architecture for the proposed crab farm system consists 3 main parts: the physical, communication, and application layer as follows:

The physical layer for measurement data from sensors and control of the environment in the controlled Crab indoor farming. involved environmental data acquisition from sensors. These were temperature, pH, D.O. and EC. The user-activated environmental control function through the LINE application.

The communication layer, the data from the sensors were collected into https://connexthings.io/ by via Raspberry to contact the Internet with the router Wi-Fi (3G/4G) and communicates for sent data to sever connexthing. And then easier to manage data and add information to environmental factors in each area.

The application layer was the interface for user. By the system was managed and notifications data from a user via LINE application.

Firebase is tools to compose or create message requests. The notification compiler has a GUI-based option for generating notification requests. For full automation and support for all types of messages, you need to create a message request in Server environment at Reliable, which supports Firebase Admin SDK or FCM server protocol. This environment can be cloud functionality for Firebase, Google App Engine, or your own app server.

3.3.3 Hardware design

The hardware was designed to support the operation of the software. It requires a sub-processor that was used to manage the operation of other devices. Arduino UNO R3 and Raspberry were used as the core processing system. The main wireless communication was designed to connect among sensors devices by using Wi-Fi. The sensors for measuring the environmental factors were consisted of Industrial pH Probe

Dissolved Oxygen Probe, Industrial Conductivity Probe K 1.0, Industrial Conductivity Probe K 1.0. The details of sensors are showed in Table 3.1.

Table 3.1 Sensor specifications based on environmental factors

Parameter	Value	Range	Accuracy
pH	Industrial pH Probe	0 – 14	± 0.002
Dissolved Oxygen	Dissolved Oxygen Probe	0 − 100 mg/L	±0.05 mg/L
Temperature	Industrial Conductivity Probe K 1.0	0 − 110 °C	± 1 °C
Conductivity	Industrial Conductivity Probe K 1.0	5 − 200,000 μS/cm	±0.1 μS/cm

From the system architecture design in Section 3.3.2, the physical and communication layers were very important in the measurement of environmental factors in the crab indoor farming system using IoT devices provided above. The IoT devices were designed to connect inside the wireless sensor network and then transfer data into server

3.3.4 Prediction models

This study was related to the design of classification between crab and soft-shell crab by Parenting in the system for measurement, monitoring, and in the previous section. Also collected pictures of crabs to process to crab model, it was divided into 4 steps of the analysis process as follows:

1. image collection: In this first part, capture images every 1 hour by cameras installed in each box and factors data was measured and collected by IoT systems for measurement. It was measured and stored every 2 minutes from 20th April to 29th June 2020 for 90 days.

2. Data preparation: This step was involved clean to ensure the quality of the image for make model to classification. Then the data was divided into 2 sets for data for learning for classification and test data for test accuracy of model

3. Create model: At this stage, this can also be done with LabelImg, locate the crab in the picture by LabelImg program shown in Figure.3.5. and then a graphical annotation tool that creates .txt for images in YOLO format and Figure.3.6 Train and Test sets can then randomly split the images for train and test sets in the ratio of 80:20 and then each row in the file should have the location of train dataset and test dataset.

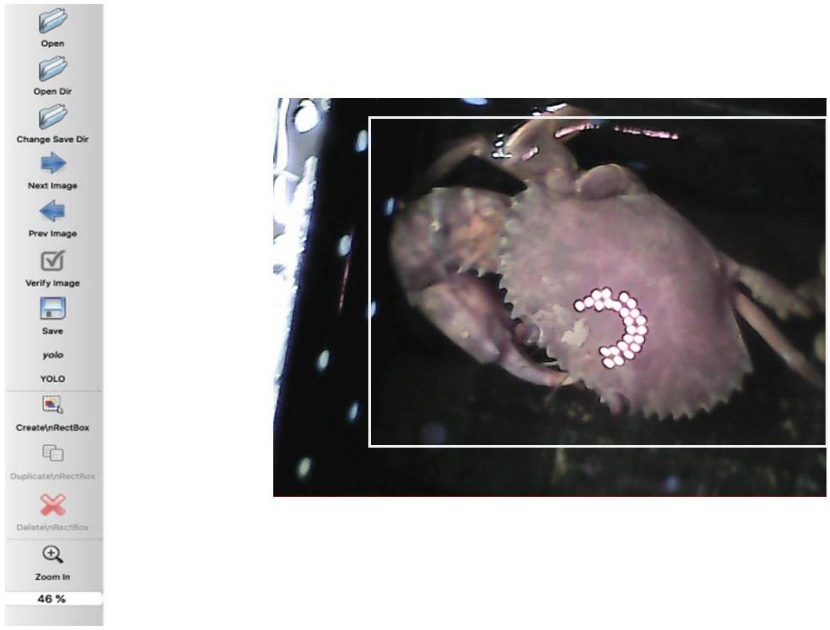


Figure 3.5 locate the crab in the picture by LabelImg program

And then LabelImg program show number position identification number of images .txt for images in YOLO format as follows

height, width - Actual height and width of the image

x, y - center coordinates of the bounding box h, w - height and width of the bounding box

<x-center>: x / width

<y-center>: y / height

<width>: w / width

<height>: h / height

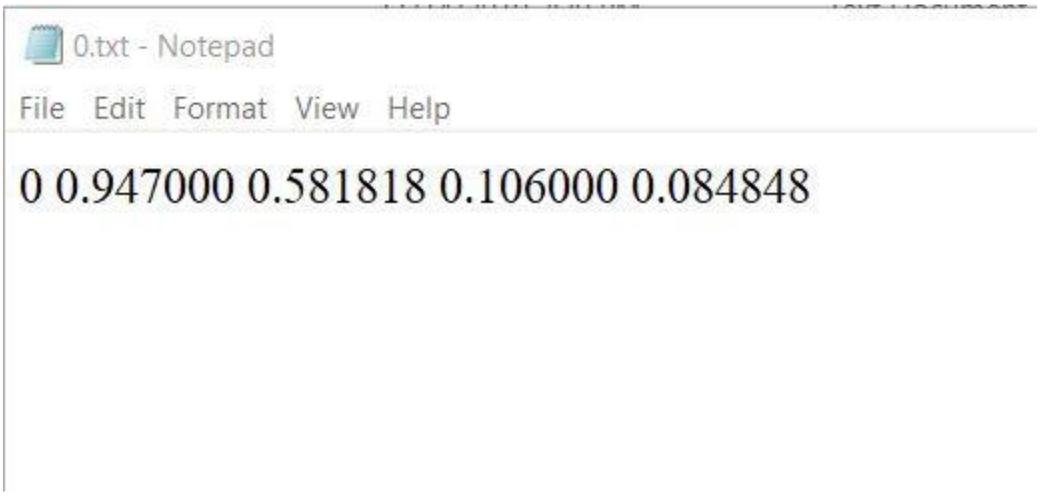


Figure 3.6 *.txt for images in YOLO format*

After receiving the yolo format, Training is taken by random images to make the model by used colab by google. Image is divided into 2 sets: 1,000 for training dataset and 500 for test dataset without duplication use labelimg to create model classification crab and soft-shell crab use yolov2 for detect 3 type crab, soft-shell crab and unknown. When camera detect meet soft-shell crab and unknown sent message to line Shell of crab reflective infrared and soft-shell crab do not infrared reflection

3.4 Development

3.4.1 Hardware development

The hardware was developed with using IoT devices. For measuring stations were developed for use in measurements environmental factors water quality. all data send https://connexthings.io/. The measuring station outside electricity to the device, as shown in Figure 3.8. It used AC 220V for water pump and Raspberry pi , and had DC voltage: for distributing electricity to the current/pressure converter module (DC-DC) was thus used to adjust voltage from 12V to 3.3V. follow as 5V for Arduino duo ,DC 12V for CNC shield and 3.3V for infrared light , it was used continuously for a long time and easy to maintain. However, microcontrollers and sensor devices use an only 3.3-5V voltage.

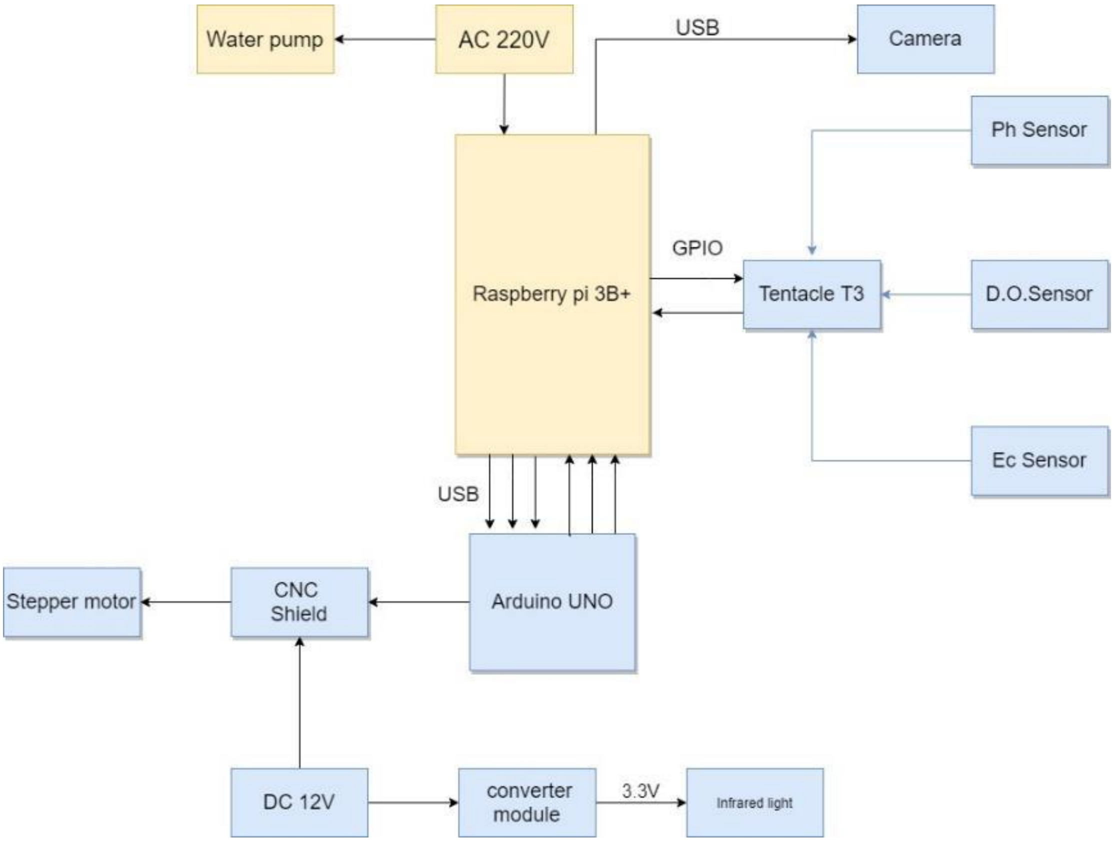


Figure 3.7 Hardware detailed block diagram

The control station was used as the center for control the communication of sending data to cloud. It was used as a core processor of WSN, then the instruction set was installed in the main process receiving data from sensors, process data and sending data to the https://connexthings.io. The process was summarized in the flowchart in Figure 3.9.

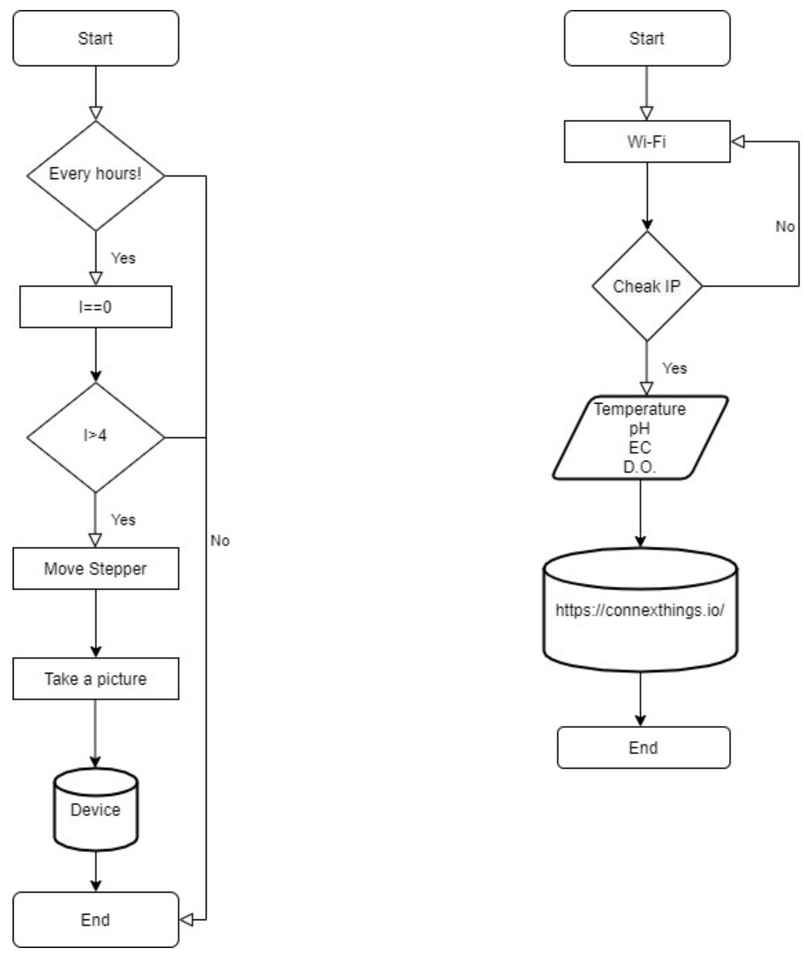


Figure 3.8 The main flowchart of the device Arduino side (left) and Raspberry pi 3(right)

Arduino check every hour for collage image about mud crab and save in device and then sent image to google drive and sent data to https://connexthings.io/ for create API to notification on LINE application via firebase cloud to user

3.4.2 Software development

อธิบาย line The software divided into 2 group is object model and data cloud the first was developed in the form of an object classification by yolo algorithm used detect object. The second data cloud sever to storage data of sensor. From topic crab model training with all the necessary files and illustrations shown as Figure 3.10. and testing will explain at unit 4 result and discussion

```
layer     filters    size              input                output
    0 conv     32  3 x 3 / 1   608 x 608 x   3   ->   608 x 608 x  32  0.639 BFLOPs
    1 conv     64  3 x 3 / 2   608 x 608 x  32   ->   304 x 304 x  64  3.407 BFLOPs
    2 conv     32  1 x 1 / 1   304 x 304 x  64   ->   304 x 304 x  32  0.379 BFLOPs
    3 conv     64  3 x 3 / 1   304 x 304 x  32   ->   304 x 304 x  64  3.407 BFLOPs
    4 res    1                 304 x 304 x  64   ->   304 x 304 x  64
    5 conv    128  3 x 3 / 2   304 x 304 x  64   ->   152 x 152 x 128  3.407 BFLOPs
    6 conv     64  1 x 1 / 1   152 x 152 x 128   ->   152 x 152 x  64  0.379 BFLOPs
    7 conv    128  3 x 3 / 1   152 x 152 x  64   ->   152 x 152 x 128  3.407 BFLOPs
    8 res    5                 152 x 152 x 128   ->   152 x 152 x 128
    9 conv     64  1 x 1 / 1   152 x 152 x 128   ->   152 x 152 x  64  0.379 BFLOPs
   10 conv    128  3 x 3 / 1   152 x 152 x  64   ->   152 x 152 x 128  3.407 BFLOPs
   11 res    8                 152 x 152 x 128   ->   152 x 152 x 128
   12 conv    256  3 x 3 / 2   152 x 152 x 128   ->    76 x  76 x 256  3.407 BFLOPs
   13 conv    128  1 x 1 / 1    76 x  76 x 256   ->    76 x  76 x 128  0.379 BFLOPs
   14 conv    256  3 x 3 / 1    76 x  76 x 128   ->    76 x  76 x 256  3.407 BFLOPs
   15 res   12                  76 x  76 x 256   ->    76 x  76 x 256
   16 conv    128  1 x 1 / 1    76 x  76 x 256   ->    76 x  76 x 128  0.379 BFLOPs
   17 conv    256  3 x 3 / 1    76 x  76 x 128   ->    76 x  76 x 256  3.407 BFLOPs
   18 res   15                  76 x  76 x 256   ->    76 x  76 x 256
   19 conv    128  1 x 1 / 1    76 x  76 x 256   ->    76 x  76 x 128  0.379 BFLOPs
   20 conv    256  3 x 3 / 1    76 x  76 x 128   ->    76 x  76 x 256  3.407 BFLOPs
   21 res   18                  76 x  76 x 256   ->    76 x  76 x 256
```

Figure 3.9 Random image to training crab model

The second data cloud storage in https://connexthings.io/ every second and firebase get HTTP data then sent data to LINE application shown as in Figure 3.10.

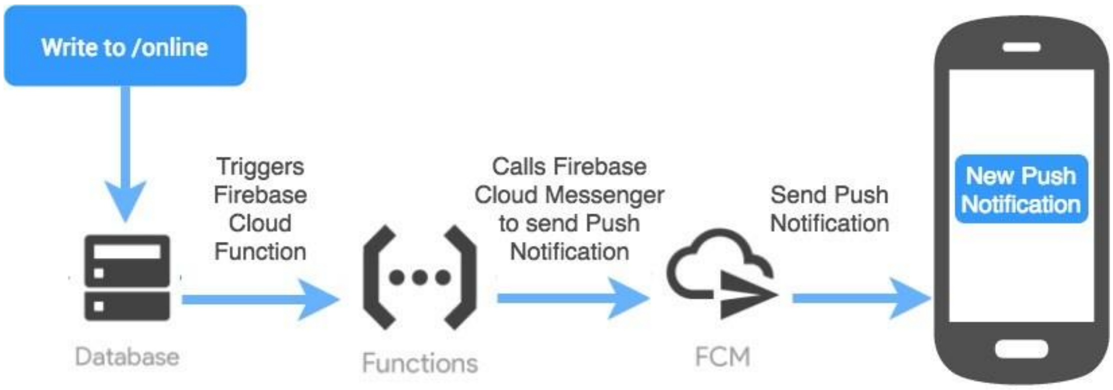


Figure 3.10 Firebase cloud function.

3.5 Implementation and maintenance

The systems as explained in the previous section are implemented and installed in Learning Space at Prince of Songkla University, Aquatic Science, and local communities. Then the results of the operation have been collected and showed in Chapter 4 Results and Discussion.

The final step of any maintenance related hardware or equipment is inspected and maintained on a regular basis. It is important to keep the system running efficiently, additional requirements have been developed, while the addition of hardware devices can still be supported.

Chapter 4

Results and Discussion

4.1 Crab indoor farming system and construction

The crab indoor farming system was designed to insert the sensor and camera. It consisted of structure, water treatment, feeder, and sensor. The structure of 0.25*1.5*1.8 (Width * Length * Height: m) in system 290L each layer is 34 cm 4 apart and 4 filter tanks. consist me, of fitter waste tank, ceramic material, oyster shell and sea plants, bio-ball for each part. and water pump with (220V, 50Hz, 60W) were used to send water to system as shown in Figure 4.1.

Figure 4.1 The overview of feeder and camera

The crab indoor farming system was developed and improved to suit the actual usage by realizing the effectiveness of it was necessaries to have a good management system to reduce temperatures in water and control water quality. IoT system for measurement, monitoring and environmental factors were used to manage the temperature in the crab indoor farming system and support growth of crab. The main factors that used for water and light as shown in Figure 4.2.

Figure 4.2 The overview of feeder and camera

Stepper motor controls 5 position in each row for feed the crabs and the camera captures each box to capture images to model classification objects by used Arduino UNO control signals through USB sent by RASPBERRY PI 3. Figure 4.3.

Figure 4.3 Box controller stepper motor and sensor

The system water quality control is main key of the aquatic animals. Unable to control water quality make causing crabs in the system to die So sensor must be accurate. Water quality control the water quality of crab's livelihood and control nutrients in the water. In terms of data, data was sent to process the survival of soft-shell crab. The sensors used are as follows pH, Dissolved Oxygen, Temperature, Conductivity. Sensor placed at the bottom of the last pond that sends water before up to the system as shown in Figure 4.4.

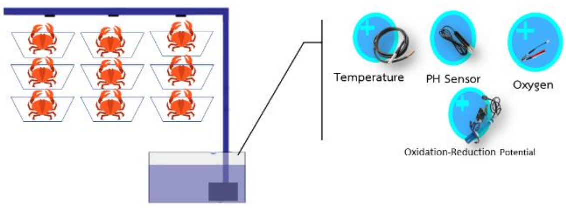


Figure 4.4 System water quality.

Finally, water quality is sent data from sensor into cloud at https://connexthings.io/ for data storage and then firebase request http for sent message to LINE application process with image also sent data to user on web and line application as shown in Figure 4.5.

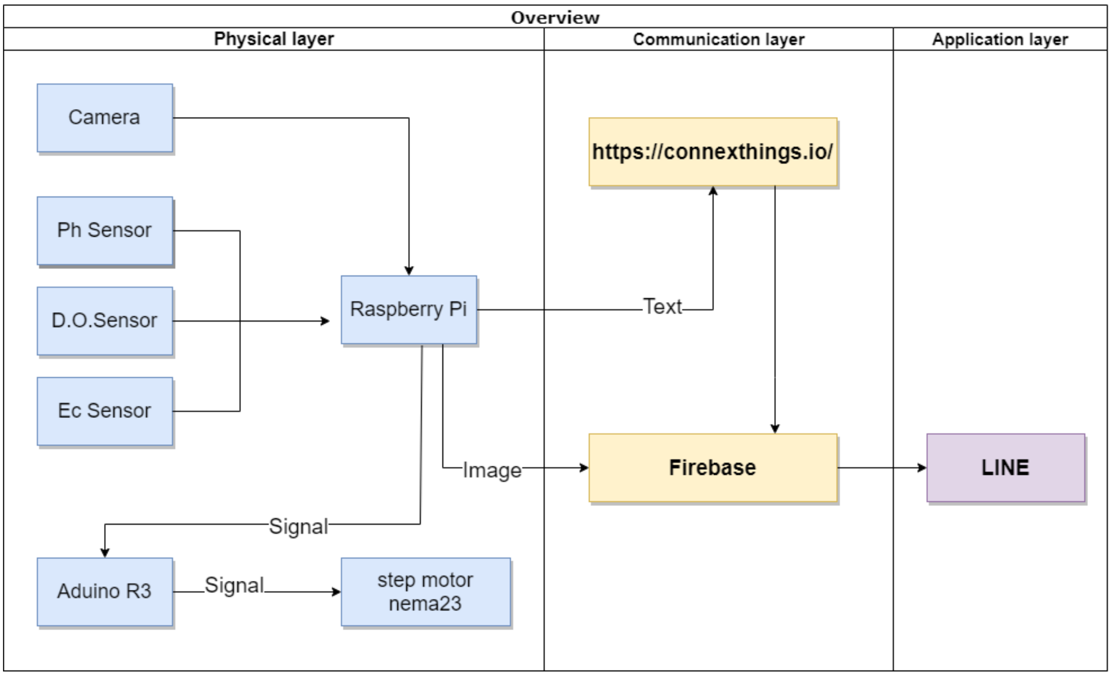
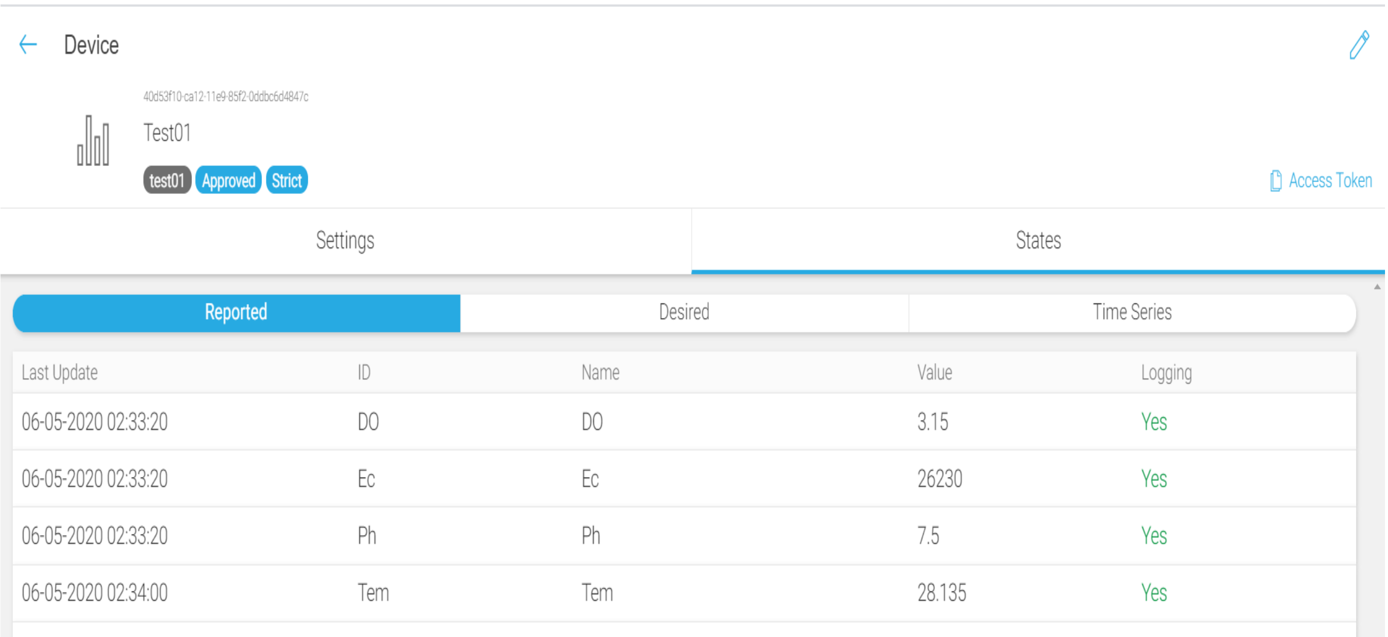
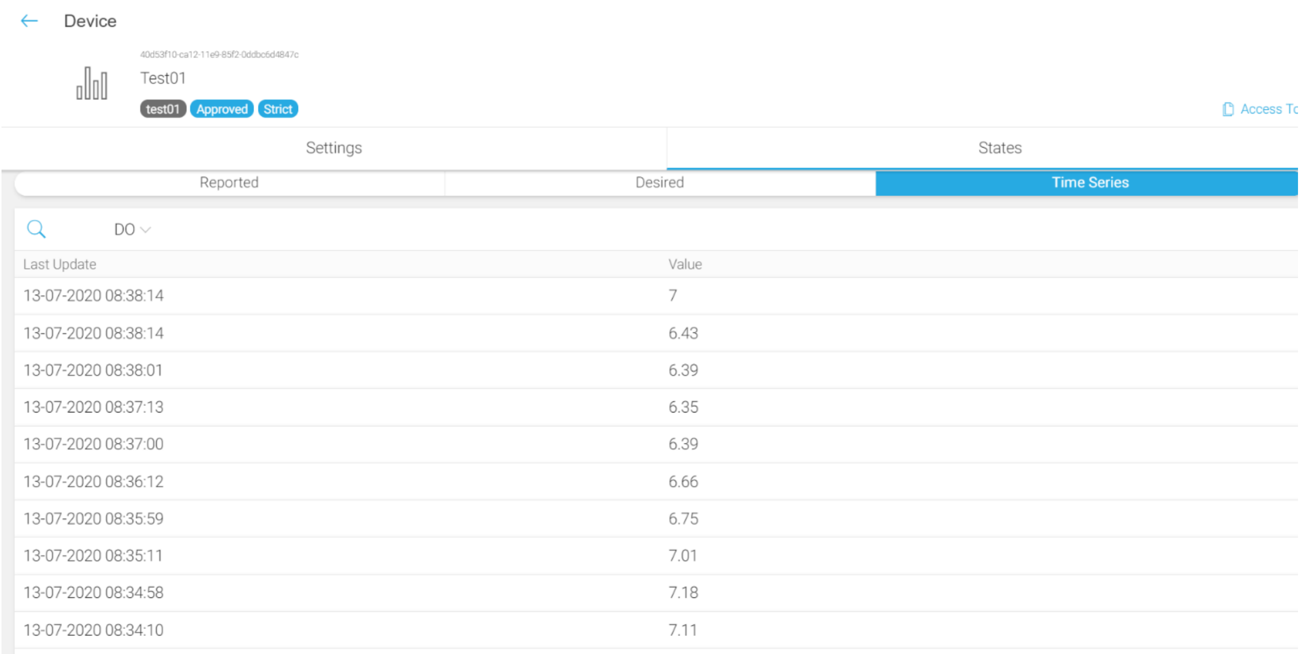


Figure 4.5 Data LINE application.

When the value is lower than the standard value background was changed orange to blank for users to recognize and check your equipment. Connexthings (In-house PSU IoT Platform) have 2 functions to the record the first function which is presented value for real-time. The second record data to time series can be covert to .json for get HTTP data and then send data to LINE application as shown in Figure.4.6.



(A)



(B)

Figure 4.6 Report record data from sensor(A). Data record time series(B)

And then have notifications on LINE chat every hour or when request status in LINE message status detail water quality with D.O., EC, Ph, temperature. User can know status about water quality via Firebase get data to Connexthings and send message to LINE application as shown in Figure 4.7.

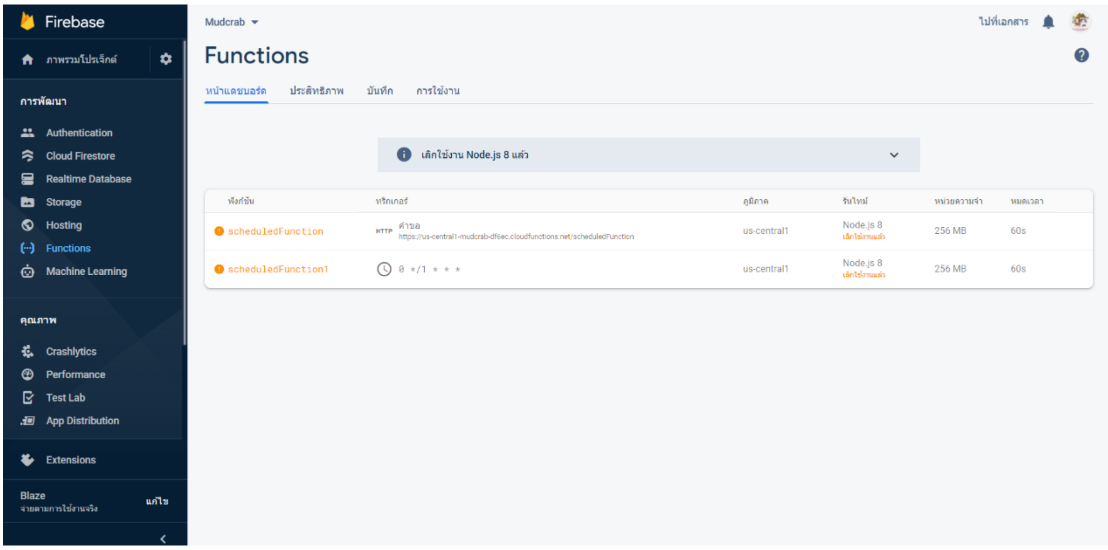


Figure 4.7 Firebase functions

Finally, water quality is sent data from sensor into cloud at https://connexthings.io/ for data storage to process with image also sent data to user on web and line application as shown in Figure 4.8.

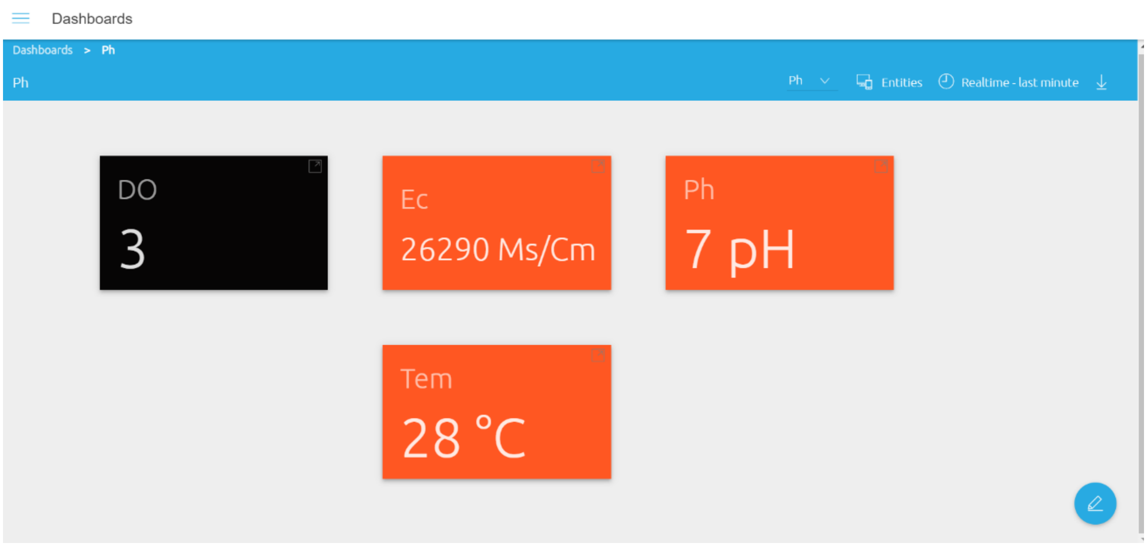


Figure 4.8 Dashboards of connexthings.io

4.2 Hardware results

4.2.1 The device of IoT system

In the originality of prototype system development, IoT by wireless 2.4G was used as a communication network between the microcontroller and server. The control system send data to https://connexthings.io/ communication via user by LINE application.

The device of IoT system was developed and improved for real situation. It was divided into 2 stations: measuring water quality and control position as shown in station of inside Figure 4.8

Figure 4.9 measuring water quality station

Feed auto system control by stepper motor in spiral inside pipe for conveyor food on slide rail length 150 cm. and plant to side left and right feed system to feed every day at time 00.00 AM show as Figure 4.9

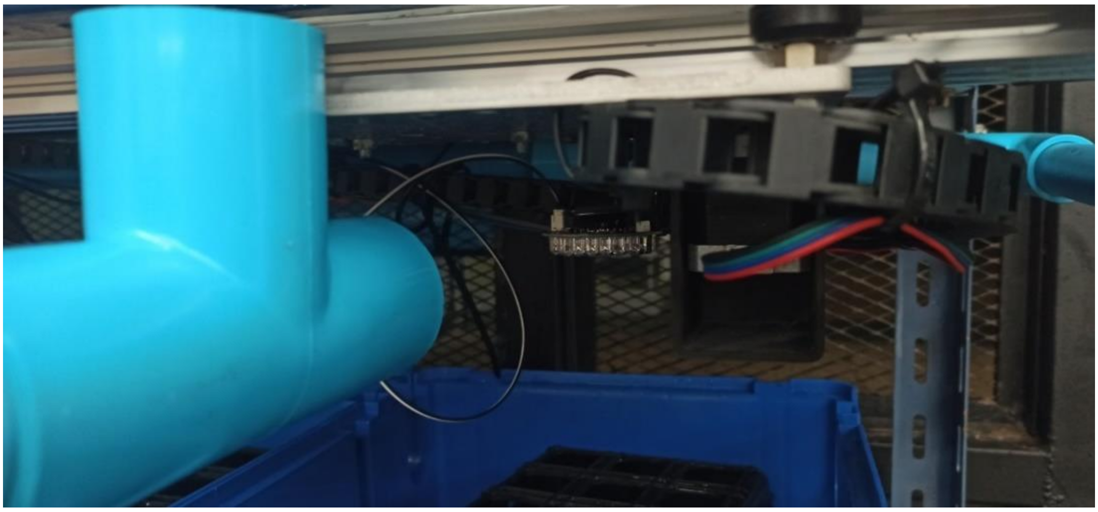


Figure 4.10 control position station

4.2.2 The efficiency of crab indoor farming system

The results from using the system will be described in this section. the results from system will be illustrated with the comparison result from 2 types: (i) the result from without using automatic control system for a day, (ii) using an automatic control system for a day. These types of system were used to validate the nature of environmental factors with feeder and camera. The obtained data of these factors will be used to adjust the suitable environmental factors for Soft-shell crab in next step.

The data from IoT devices of each type of above system were collected every 1-minute water status. The temperature was focused on since 06.00 A.M. to 06.00 P.M. Test results were shown as follows in Table 4.1.

Table 4.1 The value of environmental factors in the controlled crab indoor farming system

Data	Average	Maximum	Minimum
	Using automatic	**Using automatic**	**Using automatic**
	90 days	**90 days**	**90 days**
Temperature (°C)	27.45	29.25	26
D.O. (%)	8.9	9.2	6.95
pH	8.5	8.7	7.7
E.C.	21.18	26	15
Alkaline	138.45	153	119
Calcium	472.4	500	450
Magnesium	960.5	1000	940
Nitrates	4.723	5	3

As shown in Table 4.1, the data of environment data is in terms of values of maximum, minimum, and average for both parts using an automatic control system for 90 days. Demonstrates water quality from prolonged use resulting in higher ammonia values in the water. Causing the need to change the water and the standard values of the crab.

In summary, we found that the proposed system by using IoT can notifications and feeding efficiency and accuracy by reducing the need for labor.

4.3 Software results

This section describes the results from the software object detection in this work and process to LINE application. There is web application to serve user in online format and the obtained environmental factors data from the developed software of https://connexthings.io/ service.

4.3.1 Application

An application divided into 2 application 1. dashboard https://connexthings.io/ is web application the developed web application provided the environmental factor data effecting on water quality as online and real time format to user. Their support both personal computer (PC) and mobile phone. Moreover, the IoT another status was showed to display data and control the operation of the device in an online through web application. 2. LINE application had massage report status of water quality and when detected soft-shell crab.

Data was easy to use and access, the web application was used to display the latest water quality along the day of each factor as shown in Figure 4.14.

The web application was used to display When the value is lower than the standard value background was changed orange to blank for users to recognize and check your equipment. https://connexthings.io/ to the record the first function which is presented value for real-time as showed in Figure 4.15 and 4.16, second record data to time series can be covert to .json for get HTTP data and then send data to LINE application as shown in Figure 4.17 and Figure 4.18. Also, notifications on LINE chat every hour or when request status in LINE message status detail water quality with D.O., EC, Ph, temperature. User can know status about water quality via Firebase as shown in Figure 4.18. Shell of crab reflected infrared and soft-shell crab do not infrared reflect as shown in figure 4.19.

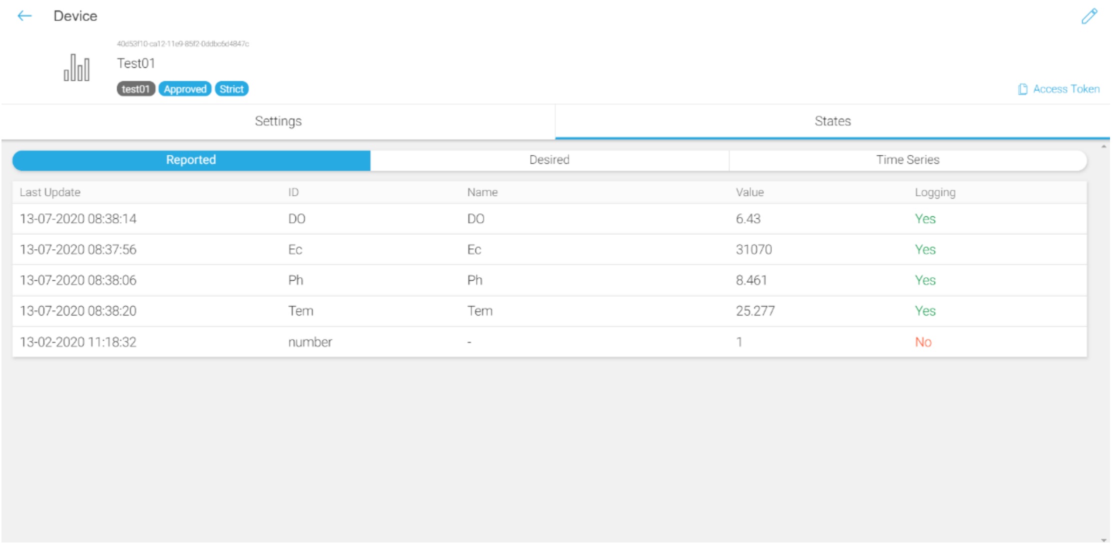


Figure 4.11 Web application was used to display the latest water quality.

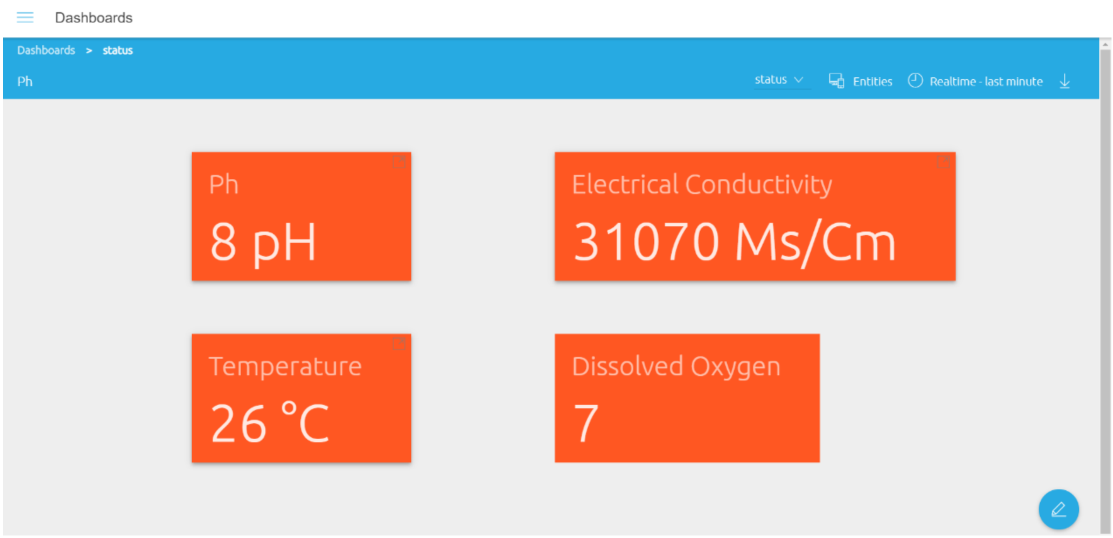


Figure 4.12 Dashboard https://connexthings.io/.

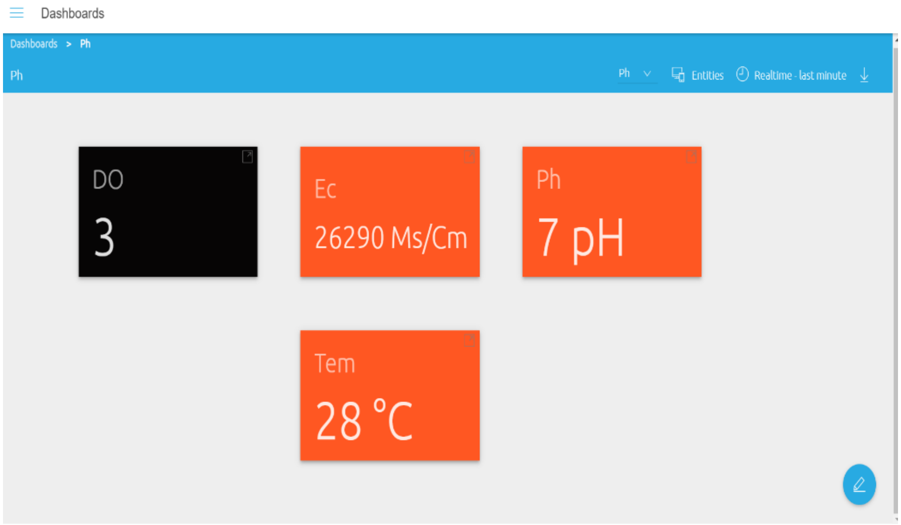


Figure 4.13 The value is lower than the standard background changed orange to blank.

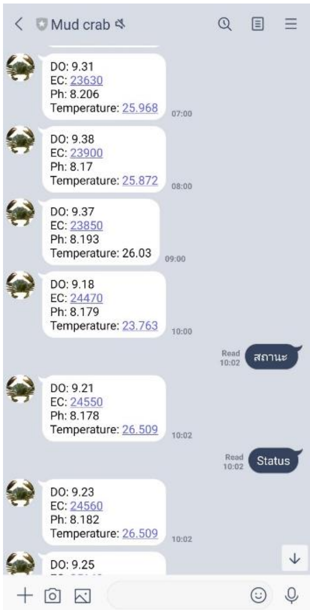


Figure 4.14 Status notifications show on LINE application

Figure 4.15 Detected soft-shell crab and notification

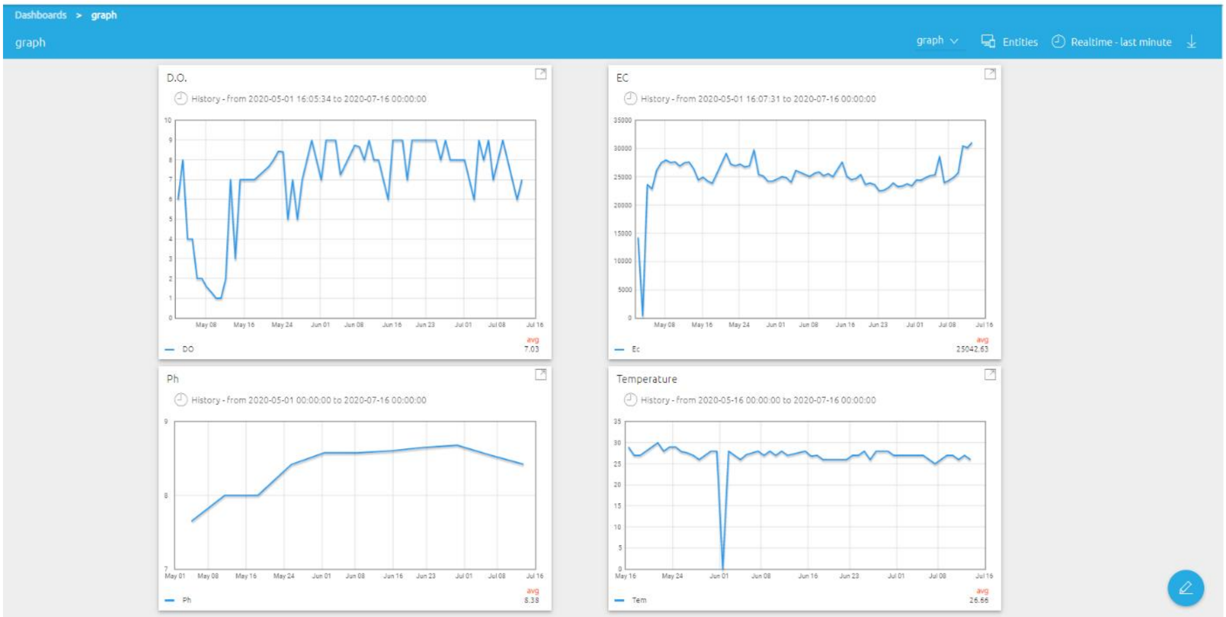


Figure 4.16 Graph data sensor

From Fig. 4.16, it is shown that the graph is significant and the optimum values for molting from crab to soft crab are shown in Table 4.2

Table 4.2 The value of environmental factors appropriate value for molting from carb to soft-shell crab

Parameter	Value
D.O.	7.03
E.C.	25.63
Ph	8.38
Temperature	26.66

From Table 4.2, environmental factors appropriate value for molting from carb to soft-shell crab collection from May to July the appropriate values as follows Dissolved Oxygen is 7.03, Electrical Conductivity is 25.63, Ph is 8.38 and Temperature is 26.66

4.3.2 Data average precision

Data average precision is assessment of the precision of the model that was created by assessment the following

True Positive (TP) is an outcome where the model correctly predicts the positive class.

True Negative (TN) is an outcome where the model correctly predicts the negative class.

False Positive (FP) is an outcome where the model incorrectly predicts the positive class.

False Negative (FN) is an outcome where the model incorrectly predicts the negative class.

$$\text{Average precision} = \frac{TP + TN}{TP + TN + FP + FN}$$

all for data analysis was demonstrated showing in Table 4.2.

Image model classification crab by reflection infrared of shell this system is most effective at night because infrared light easily disturbed by sunlight. Therefore, it decreases confidence in image process from average precision. When an object is greater than or equal to 0.5 mean positive sample, while lower is a negative sample. Testing 30 images for each type, each set is repeated. average precision (AP) of the object detection as shown in table.4.3.

Table 4.3 The value of environmental factors inside building and the crab box system for all day for data analysis

Category	Average Precision (AP)	
	Daytime	Nighttime
Crab	0.62	0.72
Soft-shell crab	0.25	0.81
Unknown	0.83	0.83
Mean	0.553	0.786

From Table 4.2., the use of a camera for classification soft crab at night is more effective using infrared light. This model work in nighttime is better than daytime. From the results, the system was reduced the time of human action to look for crab approaching to soft-shell crab. This means that we can change the traditional aquaculture which has to take care for many times per week, for instead of the waste time, the proposed system just spends only 2 hours per week.

4.6 Crab growth results

To improve the growth of crab, this research used mud crab 20 carbs to molting and increase the survival rate. Moreover, this work improves to change the open area into water filter tank. were observed on week 5^{th} and 6^{th} ± 3.622 cm/week, respectively. The summary of growth for mud crab in Table.4.11. As a result of total soft-shell crab 5 crabs and dead early 7 crabs and then shutdown the system on 13^{th} July 2020 and had notification precision.

Table 4.4 The summary of growth for mud crab.

Box number	**Sex**	**Width**	**Width after 5 weeks**	**Dead**	**Molting**
1	Female	24	30	13/7/2020	2/5/2020
2	Male	16	20	13/7/2020	
3	Male	15	19	13/7/2020	
4	Male	20	24	13/7/2020	
5	Male	15	19.5	13/7/2020	10/5/2020
6	Male	13	16.25	13/7/2020	
7	Male	15	19.25	25/4/2020	20/4/2020
8	Male	18	21.25	13/7/2020	
9	Male	16	19.5	30/4/2020	30/4/2020
10	Male	20	24.25	13/7/2020	
11	Male	17	21	1/5/2020	
12	Male	8	13	29/4/2020	20/4/2020
13	Male	16	18	13/7/2020	
14	Male	13	16.5	1/5/2020	
15	Male	12	15	29/4/2020	
16	Male	13	16	1/5/2020	
17	Male	15	18	30/4/2020	
18	Male	19	23	25/4/2020	
19	Male	17	20	30/4/2020	
20	Male	16	19	1/5/2020	

Chapter 5
Conclusion and Recommendations

5.1 Conclusion

Mud crab (*Scylla serrata*.) depression patients. The cultivation of most to mud crab is popular in Asia. Therefore, an attempt to soft-shell crab raising has been developed, but determine the appropriate area. Therefore, an attempt to cultivate mud crab in a farm box inside building has been developed, but there are environmental limitations in the tropical region. This research proposed the molting soft-shell crab with the designed farm box in closed-loop system by using IoT and Intelligent system. Crab Condo farming was embedded the necessary devices for monitoring and automatic performing. These systems track the progress of crab status and notify when crab molting to soft-shell crab through the developed web application and LINE application. An experiment on cultivation of on a crab condo farming takes place at Prince of Songkla University to study a system of automation and analysis of effect on molting of soft-shell crab. The IoT devices were designed and installed inside the crab condo farming. They were used to monitor the effect on molting to soft-shell crab using sensor data. All sensed data from IoT system are stored on cloud server.

We have success to raise the mud crab and having a soft-shell crab in the controlled environment farm using our IoT and intelligent system. The surviving ratio of mud crab is increased. Also, it has resulted in select fertilizer formula suitable for the age of the crab. Moreover, we have fertilizer formula for high ratio of mud crab survival. By using intelligent system, AI also reduces the working hour for farmer. The system will notify to farmer via Line or web-based applications when the mud crab is molted. With this success story, the food suppliers can reduce the cost of logistic and also raw material waste due to the bad condition of logistic. Crab condo can be extended to be fully automation Crab condo factory. Apart from using technology to control the quality of raising molting mud crab, the technology will help farm to save time and labor cost. Technology helps in the different stages of crop growth and the guidance should be given at the right time responses for measuring environmental water such as oxygen in water, Electrical Conductivity in water, power of hydrogen or potential for hydrogen and temperature. Aquaculture are suffering a lot of problems such as micro-plastic, economy (cost of labor), social and international politics. In future work, smart farmer can do as commercial for precision farming increasing the 100 boxes or more. We will predict the production with big data and higher deep leaning for contributing the infrastructure supported to whom it may concern in the beyond technology.

5.2 Recommendations

In terms sensor technology using in the sea signal cable will had sweat stain cling to copper problems with conductivity and rust iron because salinity of sea water and in terms of Octolasmis cor in crab, and maggots environmental, the crab to die but it was observed the highest severe in the open environmental. Researchers suggest to wash with potassium permanganate which can reduce the damage and increase survival rates of mud crab.

Today's technology had developed and improved continuously. In the future, sensors and more advanced cheap devices can be used for further development. This work is a prototype for study and collect the environmental data to raise the mud crab and able to control the other factors in the future.

The intelligent system has been developed for measurement and detection, it has supported the reduction of human works in the selection of crabs and soft-shell crabs. The application is used to notify and report crab status to farmer in real-time. Therefore, this developing work is successful to proposed IoT and intelligent prototype system for crab condo in order to solve problems relate to aquaculture, especially the raising of crabs with water and feeding factors as the main component allowing aquaculture people to know the problems of the area and increase the potential for the efficiency of the animals that come out using the development of intelligent agriculture[28]

5.3 Future work

Technology are intended for automation control devices. This technology will save time to aquaculture soft-shell crab. aquaculture need some technology helps in the different stages of crop growth and the guidance should be given at the right time response for measuring environmental water such as oxygen in water, Electrical Conductivity in Water, power of hydrogen or potential for hydrogen, temperature. Aquaculture are suffering a lot of problem, economy, social, and politics so future work will increase the raising from 20 boxes to 100 boxes for easier industry.

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Appendix

Appendix

Appendix A: The disease found in mud crab

Diseases found in controlled cultivated indoor crab farm were detected in physical characteristics that are different from normal. However, that the growth to halt or die, which was diseased that as follows, as shown in Appendix 1– Appendix 3.

Appendix 1 Mud crab perennial dies for unknown reasons

Appendix 2 Mud crab perennial dies for calcium deficiency

Calcium deficiency of mud crab shell made of crab cause unhealthy died before molting crab.

Appendix 3 Mud crab perennial dies for Octolasmis sp

The symbiont on the Octolasmis sp crab, although the crab gum is used as the adhesion. They only use the food that comes with water through the crab's gills before it is swallowed up by the crab, but it created a problem for the homeowners' paving is that the barnacles need space for growth. increase the size in the crab shell cavity and sticky substance that Octolasmis sp built to adhere to that crab gum. This made the crab unable to extract minerals from the old shell to be used to create a new shell before molting. Important sticky substance at Octolasmis sp created adheres to the junction between the crust of the old and the new stain. Making difficult to shake off the old crabs Especially the separation of both layers of the stains around the gum teeth. Flimsy and easy to tear Causing the fluke crabs to die before molting will find Octolasmis sp on female crab gills than males.

Appendix B: Food for mud crab

Appendix 4 Pellet food for crabs.

Pellet food not less than 40% protein per tablet for crab but crab after 1 week of feeding crab will anorexic alternate feeding by using fresh squid shown on Appendix 5.

Appendix 4 fresh squid.

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