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ORIGINAL RESEARCH PAPER

Design and implementation of pesticide residues detection system

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Abstract

At present, pesticide residue testing is done by professionals in the laboratory, because test results are not fast enough for market demand. The process of taking data is cumbersome and error-prone; although some operators have developed wireless pesticide residue detectors. But its' Internet of Things (IoT) system can only upload detection results to the database, and does not carry out subsequent analysis or provide warning services. This study will redesign and implement an IoT pesticide residue detection system, which will allow users to view the detection results through the webpage and mobile app after uploading those results. At the same time, when there are some abnormal situations like missing spare parts or getting abnormal detection results, this system will automatically send a warning message to the relevant person's mobile phone, so the users can fix errors as soon as possible. Besides, this study also designed a sharing function; this function allows users to set conditions to list the filtered detection results, and automatically send the QR code and website address of the detection results list to the user mailbox. Finally, the user can send the QR code or website to other relevant personnel for confirmation of detection results.

1 | INTRODUCTION

In recent years, with the rising popularity of environmental protection and the concept of health care, consumers are paying more and more attention to the issue of food safety such as pesticide residues. Although the government has already implemented relevant certification marks for pesticide residues which helps consumers to refer to when they are shopping. The certification marks are not only complicated but also different to recognize. It is difficult for consumers to find products with the right certification marks they want. In response to the above problems, several pesticide residue detectors have been introduced the market to solve the above problems. These pesticide residue detectors allow users to immediately detect pesticide residues when purchasing or marketing agricultural products. In this study, the current domestic and international pesticide residue detectors are divided into two categories according to whether the IoT is used or not. The first category is "Non-IoT pesticide residue detector", which means pesticide residue detectors without IoT technology. The second category is "IoT pesticide residue detector", which means pesticide residue detectors with IoT technology.

After classification, the study found that most of the pesticide residue detectors currently on the market belong to the "Non-IoT pesticide residue detector" category. This kind of pesticide residue detectors can only display real-time detection results on the screen, and store the results in the detectors. Finally, users have to manually copy or use the USB storage device to take those results out of the detectors. Once users want to analyze the data results from the Non-IoT pesticide residue detector, it's not only inconvenient to take out the data, but also prone to data incorrectness; in contrast, the "IoT pesticide residue detector" does not have the above disadvantages. IoT pesticide residue detector can be combined with IoT to automatically upload detection data to the cloud database, and simultaneously integrate, analyse and apply those data, which greatly reduces the possibility of manual operation and error.

In the present international market, IoT pesticide residue detection systems only have simple data uploading and backend database control functions. They are not able to combine with webpage systems, mobile APPs etc., so when the system finds abnormalities of the pesticide residue, the current IoT pesticides residue detections cannot automatically notify the user or the relevant manufactures to deal with these conditions.

In terms of data control, when users operate the back-end database provided by pesticide residue detection, they can only see a large amount of unprocessed data, which is of little help.

The current pesticide residue detector uses acetylcholinesterase (AchE) to detect whether the pesticide residue in agricultural products exceeds the standard. However, different kinds of fruits and vegetables have different characteristics, which means it is necessary to use different parts, reagent dosages and reaction time according to their characteristics for detection. Also, the current detection environment of the user may affect the detection result. The pesticide residue detector in the market has not distinguished those differences. Therefore, user's detection data are prone to errors. Based on the above situations, the IoT pesticide residue detector system developed by this research will address these problems through two functions:

- Detection procedure for improved pesticide residue detection: This study will improve the current pesticide residue detector's detection process and provide a graphical operation guide interface for users to set according to different agricultural products and environments. Then, the official pesticide residue detection will be carried out to improve the detection accuracy of the pesticide residue detector.
- Improve the system of the "IoT pesticide residue detection": This study will develop a complete pesticide residue detector's system, which combines a pesticide residue detector, a cloud database, a mobile APP and a webpage system. First, the system will automatically upload the results to the cloud database after the pesticide residue detection. Then integrate and analyse those detection data, and finally present the analysis results on the mobile APP and webpage system through charts and lists, so that users can use the past detection data like references and comparisons when buying agricultural products or detecting new products. In addition, if abnormal situation arises, the relevant manufactures can be directly notified through the mobile APP and the webpage system to ensure that the detection process and results are correct.

Finally, this study has also been discussed with relevant industries to ensure that these two research directions can solve the problems of pesticide residue detector systems currently on the market. This research study also implements a pesticide residue detector that can be connected to a mobile phone.

2 | MATERIALS AND METHODS

2.1 | Pesticide residue detector

Pesticide residue detector is an instrument that combines elements such as digital displayer, buffer, test strip, and detector.

- Digital displayer: The communication medium between the user and the detector. It provides operating instructions, assists the user to operate and show the detection results.
- Buffer: A solvent used to dissolve residual pesticides in the sample. After immersing the sample in the buffer for a few minutes, it extracts essential data that can be used to detect pesticide residues.
- Test strip: A test strip that reacts with the extract. This test strip uses the biochemical test method [1] developed by the Agricultural Research Institute of the Executive Yuan of Taiwan (R.O.C). There are two blocks on the test strip: one block is the reaction block acting on the extract, and the other block is the display block to show the detection results. At present, the test strips which use the biochemical test method are based on acetylcholinesterase (AchE) as a reaction component in the reaction block, and the display block contains red indophenol acetate. When the user drops the extract on the reaction block, the residual pesticide in the extract will break the colourless AchE in the reaction. Depending on the number of pesticide residues, the remaining amount of acetylcholine will be affected. After that, the next step is the reaction of the reaction block with the display block on the test strip for about 3 min. At this time the remaining AchE in the reaction block will be reacted with the indophenol acetate in the display block. Because AchE can hydrolyse indophenol acetate (red) to acetic acid and indophenol (blue)., the reaction block will change from colourless to a slight or obvious blue depending on the amount of remaining AchE.
- Detector: An instrument that detects and calculates detection results. The detector has a light source, sensor and computing devices. During the detection, the detector will first irradiate the test strip with the light source, and then the sensor device will test the absorbance of the test strip, and calculate the inhibition rate according to the difference between the rate of change of the absorbance and the control group. The calculation method is as follows: Inhibition rate (%) = (The absorbance of the control group − the absorbance of the sample) / the absorbance of the control group × 100 [2], and according to the relevant regulations in Taiwan [3], the pesticide residue at the inhibition rate of 0–35 is a safe range agricultural products that can be eaten directly; when the inhibition rate is 35–45, the pesticide residue has reached the range that needs attention, it means the agricultural product need to be washed before eating. When the inhibition rate is over 45, the amount of pesticide residue is too high and the agricultural products should not be eaten.

When the user uses the pesticide residue detector, the sample of the agricultural product should be first immersed in the buffer for a few minutes. Then, the buffer, which is called extract after the immersing step, should be dropped on the test strip for reaction and waits for 3 min. After that, the user can use a detector to detect the spectral change of the test strip, and then the detector will calculate the inhibition rate according to the value of the spectral change. Finally, the detector will show the detection result on the screen. In this study, the current domestic and international pesticide residue detectors are divided into "Non-IoT pesticide residue detector" and "IoT pesticide residue detector" according to whether the Internet of Things (IoT) is used or not.

- Non-IoT pesticide residue detector [4]: At present, the pesticide residue detector on the market mostly belongs to this kind of detector. Non-IoT pesticide residue detector does not use IoT technology but has a digital display, USB access slot or simple printer for the user to view and transfer data. The advantage of this kind of detector is that there is no need to worry about whether or not the internet is good in use. This kind of detector can operate normally even in a place with poor internet signals; the disadvantage is that the transmission method is limited. User has to get the data by manually copying or using a USB storage device. There may be a risk of transcription errors due to handwriting broken or lose USB.
- IoT pesticide residue detector [5]: This kind of detector has combined with the IoT technology, and can automatically upload real-time detection results to the cloud database. IoT pesticide residue detector can integrate, analyse and apply the detection result at the same time as well. In this way, the possibility of data errors is caused by manual operations will be greatly reduced. Also, in the case of the poor network environment, the IoT pesticide residue detector can temporarily store data and then transmit data when the internet is better, to avoid data transmission failure or loss.

2.2 | Pesticide residue detection services

After the research of this study, the common pesticide residue detection services currently on the market are divided into three categories according to their detection principles and processes. These three categories are pesticide residue rapid test strip, pesticide residue detector, and food-security laboratory.

- Pesticide residue rapid test strip [6]: Pesticide residue rapid test strip can detect agricultural products of fruits and vegetables, and the tested pesticides are organic phosphorus and carbamate. With this pesticide residue detection service, the user has to slice and left the sample of agricultural products in the buffer for a few minutes first. After that, drop the formed extract on the reaction block of the rapid test strip. Next, the user should react to the reaction block with the display block of the rapid test strip for 3 min. Finally, according to whether the reaction block has discoloration to determine if the agricultural product has pesticide residues or not. The cost of pesticide residue rapid test strip is about 100 NTD / time.
- Pesticide residue detector [4, 5]: Pesticide residue detector can detect agricultural products such as fruits and vegetables, rice, corn grains, tea, and spices. The tested pesticides are organic phosphorus and carbamate. In the detection, the sample is first sliced and left to stand in the buffer for a few minutes, after which the formed extract is dropped on the reaction block on the test strip, and then the user should react the display block of the test strip with the reaction block for 3 min. Finally, the user has to insert the test strip into the detector. The detector will irradiate the light source to the reaction block of the test strip, and the spectral change will be detected by the sensor, and then the residual amount of acetylcholinesterase will be calculated according to the spectral change. After all, based on the detection result, the detector will calculate the inhibition rate of pesticides on acetylcholinesterase according to the residue in the extract, and further determine whether the pesticide residue exceeds the standard. The cost of detection is about 100 NTD/time, and a pesticide residue detector is about several thousand to tens of thousands of NTD.
- Food-security laboratory [7]: Food-security laboratory can detect all kinds of agricultural products, and it can carry out detailed residue analysis and detect for more than 300 kinds of pesticides. Samples should be sent to the food-security laboratory. The detection process will take 5–7 days. The cost of detection is about 4000–7000 NTD/sample.

When the pesticide residue detector compared with the pesticide residue test strip, the advantage of the pesticide residue detector is that it can detect more kinds of agricultural products and can also analyse pesticide residues. According to the detection results, the user can adopt the corresponding method like eating directly, eating after careful washing or no eating, and the disadvantage is that additional cost of the detector is required; comparing the pesticide residue detector with food-security laboratory, the pesticide residue detector's advantage is that the detection time is short. The detection result can be known immediately, and the detection cost is relatively low. The disadvantage is that the agricultural products and pesticides that can be detected are less than the food-security laboratory.

In addition, if the pesticide residue detector can be combined with the Internet of Things, the detection results can be further applied: When the detection results are abnormal, the related personnel are immediately notified to deal with the abnormal situation; also the user may be required to enter the supplier name before the detection start. The system will classify the suppliers by calculating the pesticide residue detection pass rate of the supplier's fruit and vegetable, and the better supplier will be filtered out.

3 | INTERNET OF THINGS

The Internet of Things, which means, "connecting everything to the Internet," dates back to 1985. In 1999, Kevin Ashton, one of the founders of the Massachusetts Institute of Technology (MIT Auto-ID Center), coined the term "Internet of Things" [8]. However, the Internet of Things technology at that time was limited in development, due to high cost and low popularity rate of the hardware devices. Until the past 10 years, because there are more and more devices (e.g. smartphones, smartwatch), that can support IoT technology, the device have become more popular.

The Internet of Things is not the same as the past Internet applications. When the Internet of Things devices are connected to the Internet, they only share information without other complicated functions. Through the information shared by these different devices, we can summarize the behavioural characteristics of users and provide more customized interactive applications [9]. At present, the application of the Internet of Things technology is commonly used in smart cities [10], smart families [11, 12] and smart agriculture [13]. The Internet of Things is combined with three technologies. These three technologies are the perception layer, the network layer, and the application service layer.

- Perception layer: The perception layer is like the human sensory organ. Generally, when engineers are designing an IoT application device, corresponding sensors will be configured to the device according to the device's contents, so it can detect and analyse the state when the user operates the device.
- Network layer: The network layer is like the human's nervous system. It is mainly responsible for transmitting the data obtained by the sensing layer to the application service layer.
- Application service layer: The application service layer is like a human's brain. It will further analyse, summarize and organize the data transmitted from the network layer, and make corresponding response commands according to its different IoT application purposes.

For example, the pesticide residue detector will be configured with a detection light source and a sensor (perception layer) to detect the spectral change of the test strip, and then the sensor will convert the detection result into digital data. After that, the pesticide residue detector will transmit the digital data to the application (application service layer) via the network (network layer). Finally, the application can make corresponding follow-up actions based on the data. In cases, when the pesticide residue exceeds the standard, the application can send a warning notice to the user and related people.

3.1 | MQTT

MQTT is a communication protocol invented by IBM and Eurotech in 1999. The MQTT protocol is similar in structure to the traditional HTTP protocol. Both of these two protocols are use TCP/IP as the underlying layer. However, the MQTT protocol simplifies the content of the message during transmission, so it is more suitable for IoT devices with limited network bandwidth [14, 15]. In addition, MQTT is a transport protocol that uses the "publish/subscribe" mechanism which includes three important roles. These three roles are Publisher, Broker, and Subscriber. When the IoT device transmits a message by MQTT protocol, the Publisher will first send the message to the Broker, and the Broker will send the message to the Subscriber who' subscribes to the Publisher. The MQTT transmission protocol also provides three different levels (Level 0 ~ Level 2) of QoS (Quality of Service) message transmission mode.

- Level 0 (At most once): After Publisher sends a message to the Broker, it will not check if the Broker has received the message, but directly ends the transfer. In this mode, the message will only be transmitted one time. Therefore, when the network environment is not good, there will be problems such as the loss of information. This mode is suitable for general environment sensing applications because the general environmental sensing message is published at a short interval. So, it is not necessary to pay special attention to the loss of data.
- Level 1 (At least once): When Publisher sends a message to the Broker, the Broker will send a confirmation message to Publisher to confirm that it has received the message. If Publisher does not receive the Broker's confirmation message after a certain time, the Publisher will automatically confirm that the message is not delivered and re-transmitted again. This mode ensures that the message will be transmitted at least once, but sometimes it may be that the Broker skips the response due to a poor network environment when the browser sends back the confirmation message, and then there will be repeated transmissions because the Publisher will send the message again.
- Level 2 (Exactly once): When Publisher sends a message to the Broker, the Broker will return a confirmation message to the Publisher. Then, when the Publisher receives the confirmation message, it will send a message to the release message to the Broker. After that, the Broker will send the original message to the Subscriber when it receives the release message, and send a message to the Publisher to end the message transmission. This method ensures that the message will be sent successfully once, and there will be no problem with repeated transmissions. However, the transmission is large because it needs to be acknowledged multiple times. This mode is suitable for applications such as trading systems which may cause an error by repeated or missing messages.

FIGURE 1 Pesticide residue detector

As shown in Figure 1, this study designs a system that will combine pesticide residue detectors, user's pesticide residue detection mobile APP (Android), website system and cloud server with IoT technology to make real-time detection, upload, notification and analysis of data.

4 | SYSTEM'S INSTRUCTION

As shown in Figure 1, this study designs a system that will combine pesticide residue detectors, user's pesticide residue

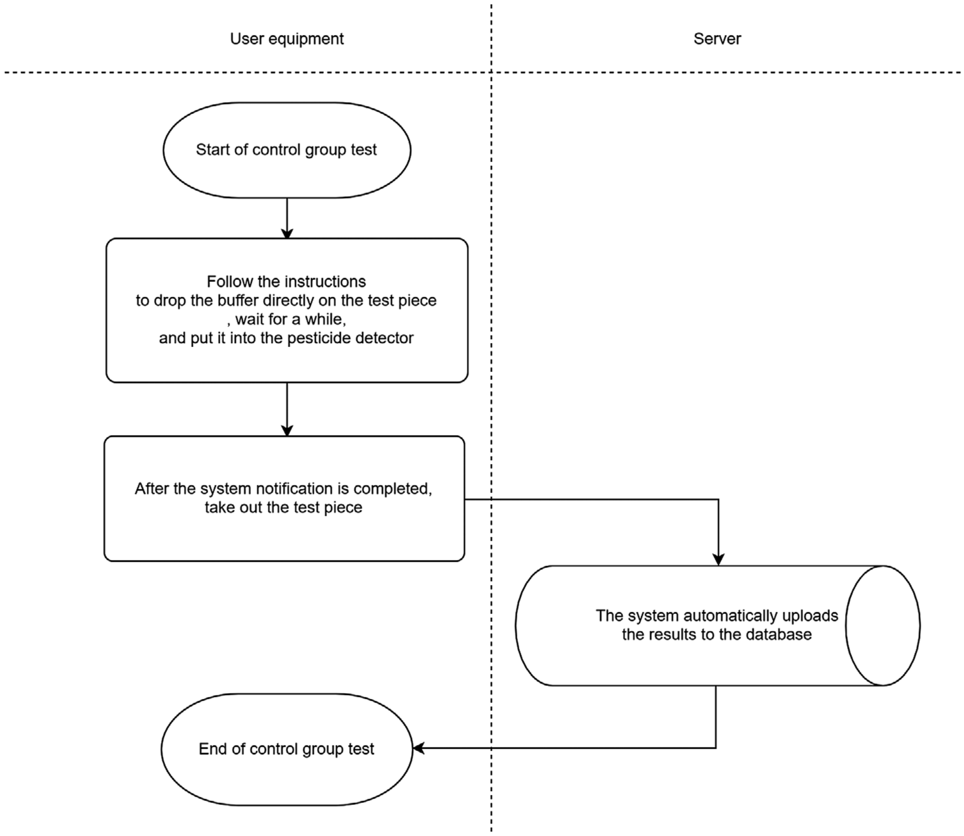

FIGURE 2 Control detection

detection mobile APP (Android), website system and cloud server with IoT technology to make real-time detection, upload, notification and analysis of data.

4.1 | Pesticide residue detection

According to the opinions of the food-security laboratory and related manufactures, this study designed a pesticide detection process that fits the needs of different users. First, because the pesticide residue detection results will be affected by the current environment and the detection equipment, the system will ask user to apply control detection before the sample detection.

As shown in Figure 2, the system will ask the user to directly drop the buffer on the test strip, then leave if for a specified number of seconds. After that, the user has to put the test strip into the pesticide residue detection for spectral analysis. This detection result will be uploaded to the cloud database as a reference value.

After doing the control detection, the user can start the sample detection. As shown in Figure 3, the sample detection is the pesticide residue detection for general agricultural products. After the user enters the name and supplier of the agricultural product, and inputs the remarks, the system will display corresponding instructions according to the agricultural product data which is inputted by the user. For example, when detecting cabbage, the system will instruct the user to take a slice of cabbage as a detection sample; when detecting orange, the system will instruct the user to peel the skin and take the pulp as a test sample.

After taking the sample, the user must soak the sample in the buffer. Because most of the users do not have the professional knowledge related to the detection of agricultural products and pesticides, the system will display the soaking time according to the characteristics of the sample. For example, after testing by the food-security laboratory, the general leafy vegetables need to be soaked for about 3 min, and grains such as rice need to be soaked for about 10 min to measure the accurate pesticide residues.

Finally, the system will ask the user to drop the soaked buffer on the test strip. After leaving the test strip for a specified number of seconds, the user has to insert the test strip into the pesticide residue detector for spectral analysis. At this time, the system will automatically compare this detection data with the data of control detection. Then, the pesticide residue inhibition rate of the sample will be calculated. If the inhibition rate is less than 0 or more than 85, the system will notify the user that there may be a problem with this detection data and ask if the user want to re-detect. If the user decides not to re-detect, the system will upload the detection result to the cloud database; if the user decide to re-detect, the system will first ask the user to redo the sample detection. If the measured inhibition rate

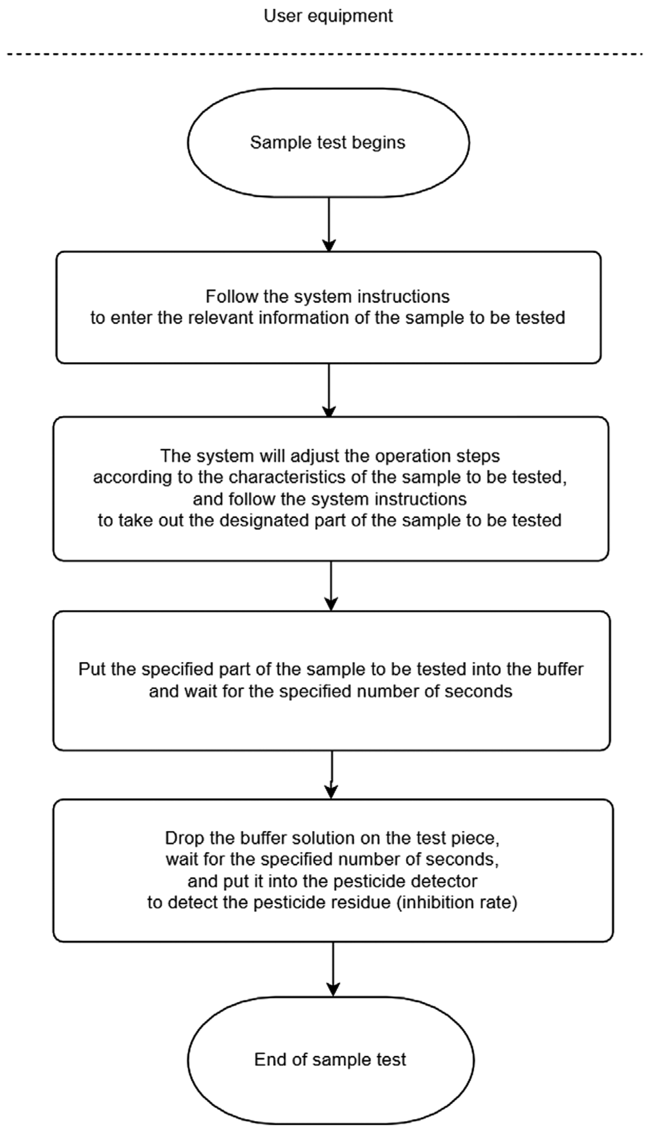

FIGURE 3 PLE detection

is in the normal range this time, the system will automatically upload the detection results to the cloud database. However, if the re-detect inhibition rate is still less than 0 or more than 85, the system will ask again whether the user wants to re-detect. If the user decides not to re-detect, the system will still upload the detection result to the cloud database; if the user still wants to re-detect, the system will ask the user to do another control detection and return to the steps of comparing the sample detection data with control detection data.

However, if the system simply shows the inhibition rate value in pesticide residue detection, most users may not understand the meaning of the value. Therefore, the system will first classify the value into three classes which are safety, warning, and danger. The classification method of these three classes is according to the relevant regulations of Taiwan. According to the regulations, it is safe when the pesticide residue inhibition rate is between 0 and 35; when the pesticide residue inhibition rate is between 35 and 45, it is better to wash the agricultural products carefully before eating; while the pesticide residue inhibition rate is over 45, the pesticide residual amount is too high to eat. This system will remind the user through a pop-up window, so the users can clearly understand the pesticide residue of the agricultural product. In addition, the system also notifies the users when there is an abnormal pesticide residual inhibition rate value which is less than 0 or more than 85.

The system considers adjusting usage in a poor network signal environment as well. Therefore, if the mobile phone cannot be connected to the network, the system will store the detection results on the mobile phone until the user can connect to the Internet successfully. Then the system will automatically upload the detection results to the database and clear those data on the mobile phone. This way, it can prevent missing or repeated uploading of the detection results caused by poor network environment.

4.2 | abnormal situation warning

In this system, it uses the MQTT protocol and the mail server to develop the warning function for abnormal situations. First, when the user logs in to the pesticide detection APP, the system will obtain the IMEI code of the mobile phone and check whether there is abnormal data in the cloud database. If there is abnormal data in the database, the system will send a warning message to the user's mobile phone and send an abnormal notification mail to the user's e-mail address as well. So that the user can solve the problem as soon as possible.

4.3 | Analysis of detection results and other services

This system does not only notify users about the pesticide residues of agricultural products easily but also integrates and analyses the detection results in the cloud database. When users use this system, they can view and edit through by the web system function. According to the different layout and functions, this system can be divided into five parts: Dashboard, log, purchase, supplier, and setting.

4.3.1 | Dashboard

When the user log into the webpage system, the dashboard page will appear immediately. This page is for users to quickly browse the recent detection data. In the dashboard, the webpage system will automatically analyse the detection results in the cloud database and list the last 15 results. Also, there are four kinds of time options which are today, last 7 days, last 30 days and last 90 days for users to select. The system will select the data in the time period selected by the user, and draw pie/line charts according to the data. The dashboard also provides the export function for users to print quickly.

4.3.2 | Log

In the log function page, the user can modify the supplier or note the specified detection results. Users can quickly view past detection results in this function. There will display the item name, detection time, measured inhibition rate, supplier and note of the detection results. This function page also provides the user three kinds of searching methods which are using date, keyword or classification of the agricultural products. Therefore, users can quickly find the detection results they want.

4.3.3 | Purchase

The purchase system provides a purchase page for the user to quickly order the required consumables. On this page, the user can quickly select the number of required consumables, and receive an order confirmation mail after the order is sent. After confirming the order, the supplier will deliver those products to the address written in the user's information page.

4.3.4 | Supplier

There are two functions in the supplier page, which are supplier and supply item.

Supplier
Users can add, modify and delete supplier data in this function. When a supplier is added, it will appear directly in the Existing supplier list, and the suppler which is deleted will be transferred from the Existing supplier list to the Deregistered supplier list. If there are some detection results connected to the deleted supplier, the detection results can no longer be edited. For those deleted suppliers, the user can use the recovery function to transmit the deleted supplier from the Deregistered supplier list to the Existing supplier list.

Supply items
In this function, the system integrates the detection results and lists a list of supply items of the supplier.

4.3.5 | Setting

In the setting page, there are two functions, which are Account Information and Share.

Account information
Because this system is for small or medium-sized enterprises, the user should edit basic information such as company name, unified number, person in charge, phone number and address in this function.

Share
Users can use this function to create a specific sharing page and corresponding QR code. When users are using this function, they can set the name of the sharing page, the condition of the detection results and the content of the bulletin board. After finishing those settings, the system will generate a URL and a corresponding QR code and send them to the users' mail at the same time. The users only need to make the URLs or QR code public to others, for other people to view past detection results on the users' sharing page.

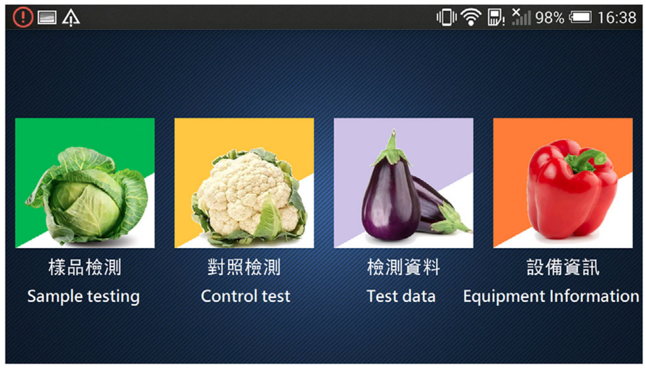

FIGURE 4 Mobile APP function menu

5 | EXPERIMENTAL RESULTS

This study uses the IoT technology to design and implement an IoT pesticide residue detector. In Section 4.1, it will introduce the functions of pesticide residue detector and mobile APP as shown in Figure 4 that users may use when they are detecting pesticide residue; in Section 4.2, it shows the web system such as dashboard, log, purchase, and setting.

5.1 | Pesticide residue detection

5.1.1 | Sample detection

The sample detection function detects pesticide residues in an agricultural product. After the detection is completed, the system will show the user of the pesticide residue of the sample. When the user enters the sample detection function, the system will first ask the user to input the name of the sample to be detected. As shown in Figure 5, the user can return to the main page through the Menu button which is on this page, or use Category, Search and Recently function to find the sample name at this Figure 5.

As shown in Figure 6, after the user selects or enters the sample name, the green button in the bottom right corner of the screen will change from "Not Entered" or "Not Select" to "Confirm". As shown in Figures 7 and 8, at this point, the user can just click this button to enter the purchase information page.

Finally, the detection result is shown in Figure 9. After the system detects the pesticide residue value, it will directly display the measured inhibition rate, result and detection time on the screen. At this time, if the users click "Log", they can enter the

FIGURE 5 Sample detection: Search

FIGURE 6 Sample detection: Purchase

FIGURE 7 Sample detection: Detection steps (A)

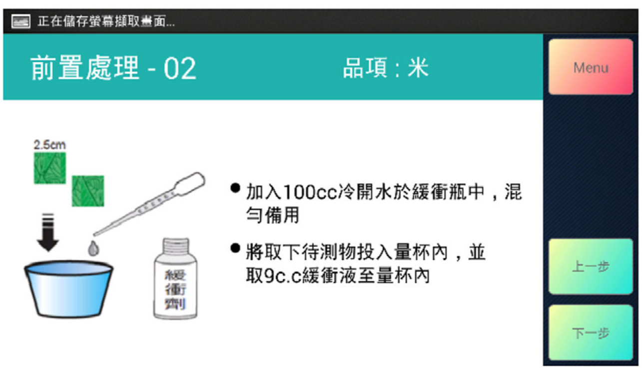

FIGURE 8 Sample detection: Detection step (B)

FIGURE 9 Sample detection: Finish

Log function to view the recent detection result, or they can click “Menu” to return to the beginning of the function menu.

5.1.2 | Control detection

In this system, because the current equipment and environment may affect the detection result, it is necessary to get the control reference value by the control detection. As shown in Figure 10, the system will instruct the user to do those operations after entering the control detection process.

5.1.3 | Log

As shown in Figure 11, the system log will store data in its data storage device.

5.1.4 | Device information

This “Device information” function will show the current account information. As shown in Figure 12, users can also log out of the account in this function page.

5.2 | Webpage system

As shown in Figure 13, this webpage system can be divided into five function according to its side menu. These five functions are “Dashboard”, “Log”, “Purchase”, “Supplier” and “Setting”.

5.3 | Performance comparison

After classification, this study found that most of the pesticide residue fast screening devices currently on the market belong to the “non-Internet of things” [3–5] pesticide residue fast screening devices. This type of fast screener [3–5] can only display the test results in real time and store the test results in the fast screener. Manual copying or the use of a USB storage device is required to retrieve the data from the fast screener [1, 2]. For

FIGURE 10 Control detection

FIGURE 11 Log data storage

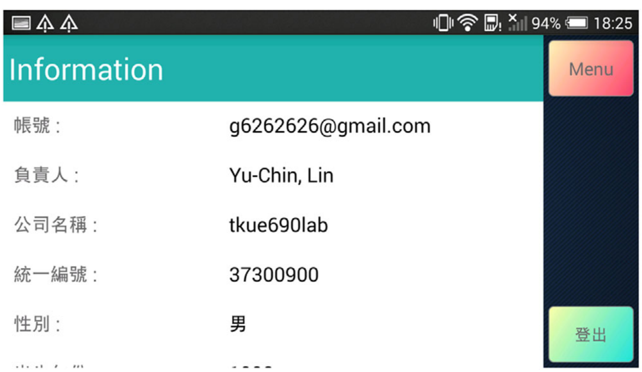

FIGURE 12 Device information

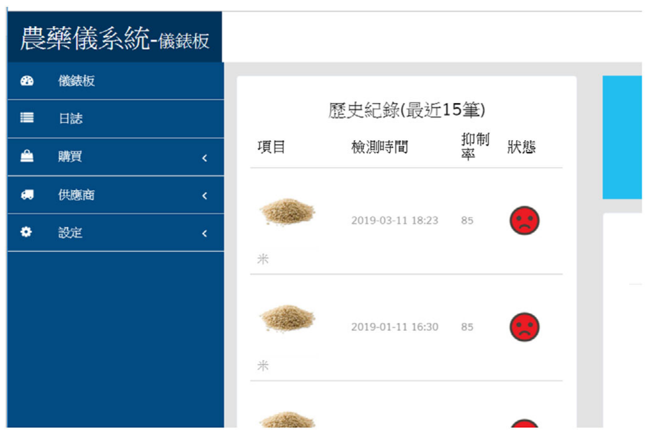

FIGURE 13 Web based dashboard

users, if they want to control and analyse the data of the previous test results, the steps required to retrieve the data are complicated, error-prone, and inconvenient in operation. In contrast, "Internet of Things" pesticides the residual fast screener does not have the above-mentioned shortcomings. The proposed Internet of Things Pesticide Residue Quick Screener can be combined with the Internet of Things to automatically upload the detection data to the cloud database in real time, and integrate, analyse and apply the data, which greatly reduces the possibility of errors caused by manual operations.

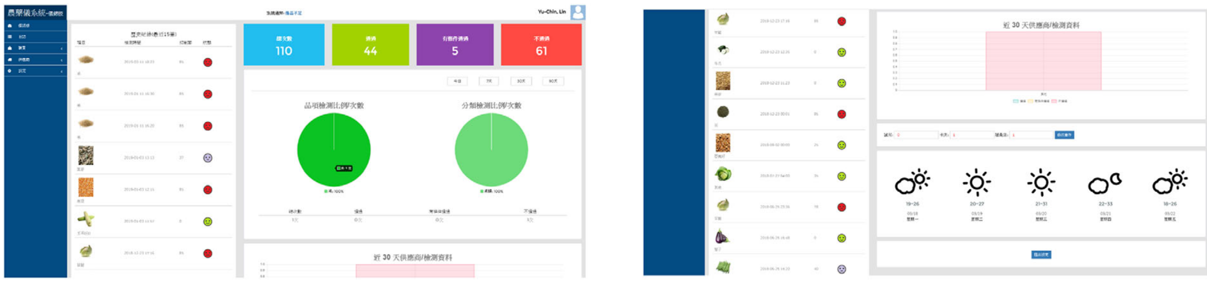

FIGURE 14 Dashboard: History record block

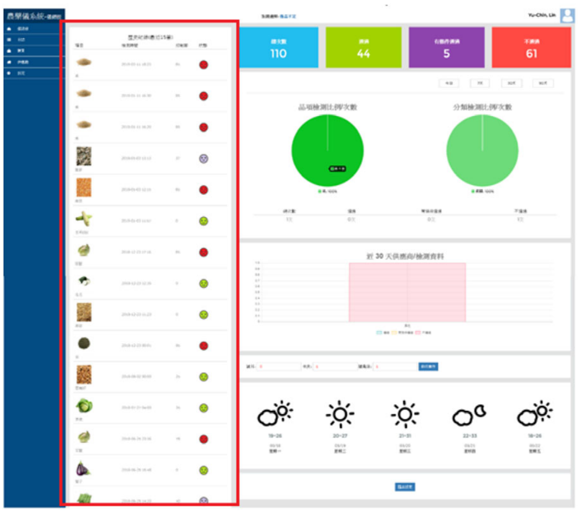

FIGURE 15 Dashboard: History record block

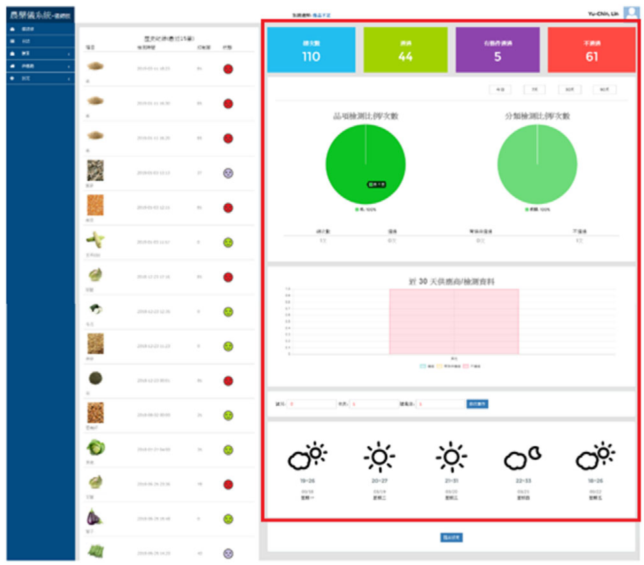

FIGURE 16 Dashboard: Chart block

5.3.1 | Dashboard

As shown in Figure 14, it will directly enter the dashboard page when the user logs into the webpage system. This page which shown in Figure 15 can be divided into three blocks which are historical record block, chart block and export block.

Chart block
As shown in Figure 16, the system will provide four kinds of period time which are "Today", "Last 7 Days", "Last 30 Days" and "Last 90 Days" for users to choose. Later, the system will analyse the detection results which are in the chosen period time and demonstrate them in pie/line charts.

Export block
As shown in Figure 17, the system provides an export function that automatically generates a simplified report of the detection results' form based on the filter criteria selected by the user. After the user can choose to print the form or export it to PDF file.

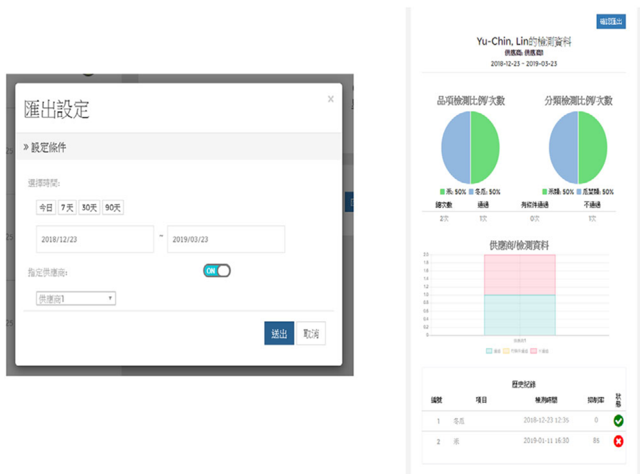

FIGURE 17 Dashboard: Export block

5.3.2 | Purchase

As shown in Figure 18, our backend system also provide several pesticide residue detection's consumables. Users can enter the amount of consumables once they required and copy the account information into the form through the "Apply Account Basic Information". When the users complete the relevant information, they can submit the form after click "Confirm" and "Submit".

FIGURE 18 Purchase information

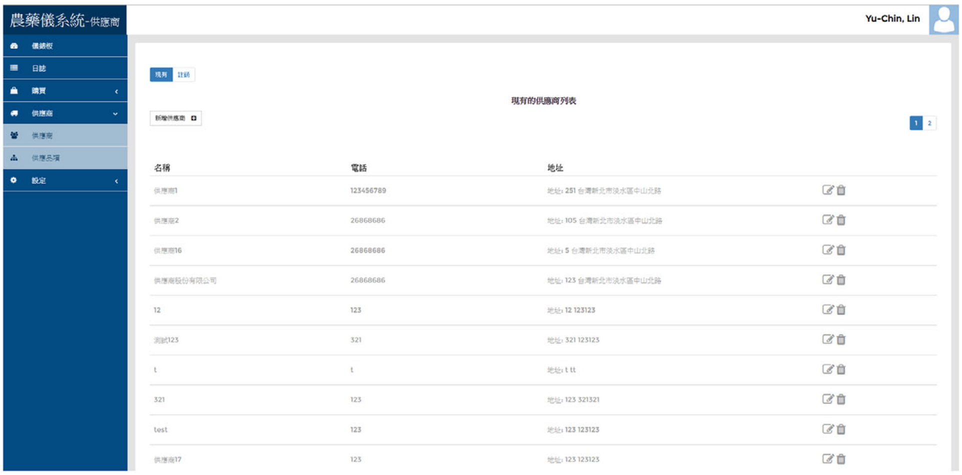

FIGURE 19 Supplier information

Supplier
As shown in Figure 19, the system will first list the simplified list of the data, and user can edit those supplier data in this function page.

Share
This function is to set the conditions for the user to filter out a specific list of detection results for others to view. As shown in Figure 20, the system will first list the existing sharing page and show related information such as QR code, URL, type, and time in this function page. The QR code and URL are connected to a separate webpage which only shows a list of specific detection results.

6 | CONCLUSIONS

This study uses the IoT technology to implement pesticide residue detectors which solves the problems of data extraction and data analysis of the non-IoT pesticide residue detector on the market. It improves based on the foundation of current IoT pesticide residue detections, which is still usable with lack of a support system. For example, when users want to view past detection results with current IoT pesticide residue detectors, they can only find raw number data or through the back-end system. Also, when the detection results are abnormal, the current IoT pesticide residue detector cannot notify the user in time. Therefore, this study designed a data analysis webpage system that combines the webpage, IoT pesticide residue detector and mobile APP with the MQTT module to make an immediate warning function. Therefore, it can solve the problems of the current pesticide residue detector. Additionally, there is a sharing function for users to set a sharing page of detection results for others to view.

This study also hopes to further improve the function of this system in the future. For example, the current system in this study is designed for small or medium-sized enterprises and too complex to use for general public. In addition, when the enterprises use this system, their customers can only receive the detection results' sharing page, and cannot communicate

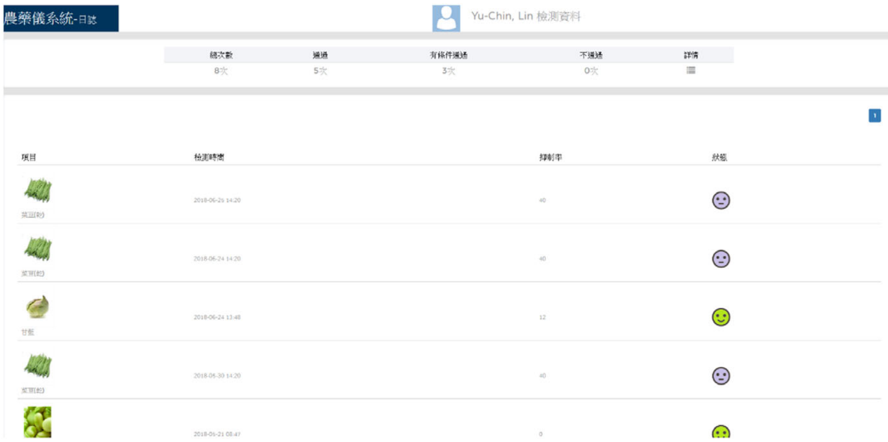

FIGURE 20 Share function

with the enterprises through this system. This study hopes these functional deficiencies can be improved in the future.

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CONFLICT OF INTEREST

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*The authors confirm that each of the co-authors acknowledges their participation in conducting the research leading to this manuscript and has agreed to its submission to be considered for publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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