Water Monitoring and Analysis System: Validating an IoT-Enabled Prototype Towards Sustainable Aquaculture

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Abstract — The interconnection of things in the physical world with things in the virtual world opens up new possibilities for accessing things at anytime, anywhere. IoT technology has a viable economic application in the aquaculture farm industry of Dapitan City. The potential for increasing the production of cultured species can be attributed to the quality of water the farms maintain. For lack of science, water quality is not properly maintained on small-scale aquaculture farms. The researcher is compelled to bridge the gap between the scientific farming approach suitable for the small-scale aquaculture farm industry in Dapitan City and the integration of ICT as an economical tool. This study aims to develop an IoT-enabled prototype for a cost-efficient water monitoring and analysis system to be used as a tool for effective, efficient, and reliable scientific farming. The study employed descriptive research with the development of a prototype system that adheres to a scientific prototyping methodology. The developed system prototype is submitted as the empirical component of a technology acceptance validation among aquaculture farm operators, owners, and farm employees in Dapitan City. To materialize the steps in device prototyping—modeling of circuits, assembly of ideas, and getting direct output—the researcher employed the rapid prototyping technique in the execution of throw-away prototyping as the development methodology. A survey validating the technology acceptance of users has proven that the developed system prototype garnered a whopping high level of technology acceptance. The results simply imply that the prototype system is extremely useful and easy to use.

Keywords* — *IoT, Automation, Aquaculture, ICT, Water Quality, Technology Acceptance, Prototyping, Microcontrollers, Open source, Monitoring

I. Introduction

In 1999, Kevin Ashton gave the first presentation on the Internet of Things (IoT) to Procter & Gamble. In the language of the information and communications technology (ICT) industry, the concept was not new. In order to connect the concept of radio frequency identification (RFID) to an emerging new technology known as the Internet, he used the phrase (Ashton, 2009). Since then, the word has become more popular, and leading corporations have forecast a surge in IoT applications across a range of industries (Gartner,2013).

People have grown dependent on being online and hooked up to the Internet for particular purposes due to the growth of technology nowadays. ICT development has given rise to more exclusive services, like telemedicine, e-Health applications, smart homes, and others. Machine to machine (M2M) communication powers the heterogeneous IoT networks that connect users of these services. There are numerous Internet implementations in use today, offering a wide range of services and uses. The digitalization of the user and all the user-friendly and automated mechanisms are also the driving forces behind IoT applications that are hidden from the view of the general public.

Since IoT is a platform or network that connects devices and people along with applications, it can also serve as a pool of unrealized business solutions. Recently, IoT technology is noted as a $10-trillion market. Global financial and credit giant Morgan Stanley said, 75 billion devices will be connected to the Internet by 2020. Adding to this remarkable projected development, market consultant Frost & Sullivan said twelve percent (12%) of ASEAN IoT spending is from the Philippines.

As the Internet of Things (IoT) is gradually becoming the next wave in technology, especially in Electronics technology, the government has realized its potential in transforming the nation from a previously “outsourcing and call center” country into a more digitalized and industrialized one. As the result, more government bodies have been strong advocates for IoT.

The Department of Information and Communications Technology (DICT) is another strong supporter of IoT implementation. They have pushed for many projects, such as the Broadband plan, Free-Wifi Project, as well as the single government portal to provide fast and efficient delivery of services to citizens across the country. These projects will act as the stepping stones towards the masterplan to transform Philippines with IoT applications. Other government bodies such as Department of Trade and Industry, Housing and Urban Development Coordinating Council are involved in various IoT related projects in their respective fields of work as well.(Pham, 2017)

Locally, the aquaculture farm sector in Dapitan City provides a feasible economic use for IoT technology. In the previous three years, there have been an average of 21 aquaculture farms that have registered with the Bureau of Fisheries and Aquatic Resources (BFAR) and 18 that have not. The farms' ability to maintain high water quality has the potential to boost the output of cultivated species. One of the most important factors determining the water quality in which cultivated species may survive in excellent condition is temperature. Other important factors are pH level and water turbidity. Owners and operators of local aquaculture farms are still a long way from the scientific farming methods required to use all of Dapitan City's agricultural potential.

According to the interviews conducted among nineteen (19) aquaculture farm owners/operators, the common reason for not using scientific farming is the lack of capital to invest in scientific approach. These farm owners/operators have vouched that if only there exists an economical scientific approach, they will switch and use the available technology.

As a believer of the United Nation’s Sustainable Development Goals (SDG), goal number 2 – “Zero Hunger”, aims at eliminating hunger through food security, scale up nutrition and the promotion of sustainable agriculture, the researcher is prompted to help the aquaculture farm industry of Dapitan City by looking at the possibility of applying IoT technology in the aforementioned industry. The researcher is compelled to bridge the gap between the scientific farming approach suitable for small-scale aquaculture farm industry in Dapitan City and the integration of ICT as an economical tool.

Literature Review

Theoretical Framework

This study proposed to develop an IoT-enabled water monitoring and analysis system prototype. On the outset, it shall serve as basis of the aquaculture farm owners/operators of Dapitan City for decision making regarding the productivity of farm operations.

Figure 1 depicts a multi-dimensional theoretical framework serving as the backbone for the study. The development of the system prototype shall embark starting with the identification and definition of the water quality theories to cover the different common parameters needed for water quality monitoring. These parameters shall serve as input to the study.

The next dimension shall cover the various theories that can galvanize development of the system prototype. These include the prototype development methodology to be used; the concepts that make up an IoT system prototype covering sensors, microcontrollers, and application codes. The concept in Enterprise Reporting shall be used for the generation of report that will aid in decision-making. The Internet technology shall cover the concept definition as to the extent of how data from sensors up to the level of information generation shall be carried out.

Once the system is completed, as mandated in the tenets of Management Information Systems (MIS), a system is submitted for testing among its users prior to its distribution for actual implementation. This process serves as a benchmark that will define the acceptability of the prototype.

The last dimension, the IoT Theory, shall cover the concepts of IoT as the central theme of the study.

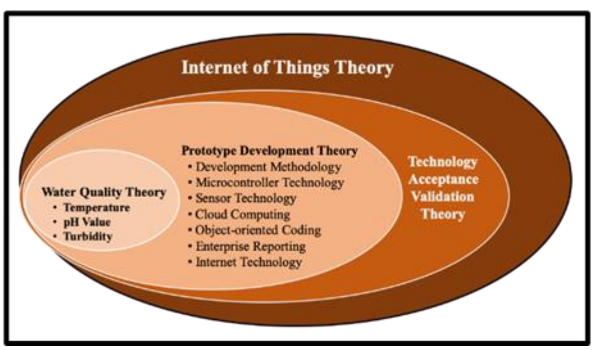


Figure 1: Theoretical Framework of the study

Water Quality Theory

The term water quality refers to the chemical, physical, biological, and radiological characteristics of water (Diersing, 2009). It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Johnson, 1997). It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to the health of ecosystems, safety of human contact, and drinking water.

The complexity of water quality as a subject is reflected in the many types of measurements of water quality indicators. The most accurate measurements of water quality are made on-site, because water exists in equilibrium with its surroundings. Measurements commonly made on-site and in direct contact with the water source in question include temperature, pH, dissolved oxygen, conductivity, oxygen reduction potential (ORP), turbidity, and depth.

Each water quality parameter alone can directly affect the animal's health. Exposure of shrimp and fish to improper levels of dissolved oxygen, ammonia, nitrite or hydrogen sulfide leads to stress and disease. However, in the complex and dynamic environment of aquaculture ponds, water quality parameters also influence each other. Unbalanced levels of temperature and pH can increase the toxicity of ammonia and hydrogen sulfide. Thus, maintaining balanced levels of water quality parameters is fundamental for both the health and growth of culture organisms. It is recommended to monitor and assess water quality parameters on a routine basis (Banrie, 2012).

Temperature is another important water quality parameter. It can affect fish and shrimp metabolism, feeding rates and the degree of ammonia toxicity. Temperature also has a direct impact on biota respiration rates and influences the solubility of O2 (warmer water holds less O2 than cooler water) (Banrie, 2012).

On the other hand, pH is a measure of acidity (hydrogen ions) or alkalinity of the water. It is important to maintain a stable pH at a safe range because it affects the metabolism and other physiological processes of culture organisms. It can create stress, enhance the susceptibility to disease, lower the production levels and cause poor growth and even death. Signs of sub-optimal pH are besides others increased mucus on the gill surfaces of fish, unusual swimming behaviour, fin fray, harm to the eye lens as well as poor phytoplankton and zooplankton growth. Optimal pH levels in the pond should be in the range of 7.5-8.5 (Banrie, 2012).

To manage and control the water composition, you need to sample and measure the composition particularly of the more important characteristics. The following are the four water characteristics that are of particular importance for fish pond management: chemical reaction of the water (pH); turbidity; water temperature; and dissolved oxygen content. (Food and Agriculture Organization of the United Nations, 2019)

Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. These properties can be physical, chemical or biological factors. Physical properties of water quality include temperature and turbidity. Chemical characteristics involve parameters such as pH and dissolved oxygen. Biological indicators of water quality include algae and phytoplankton. These parameters are relevant not only to surface water studies of the ocean, lakes and rivers, but to groundwater and industrial processes as well. (Fondriest Environmental Inc., 2019)

Prototype development theory

There are many different kinds of prototypes since there are many different kinds of designs and execution techniques. A prototype is an example of how the design will seem when it is manufactured, and it varies based on the design's specifics. A prototype for the electronics sector, for instance, will be very different from one for a mechanical engineering application. Prototyping is crucial in a variety of industries, including mechanical and electrical engineering, electronics, computer programming, software development, and computer engineering (Thomas Publishing Company, 2018).

On the other hand, prototyping method is a lightweight initial design of an interface or product, used to capture initial concepts and layouts to gather feedback from users, as well as project participants and stakeholders.

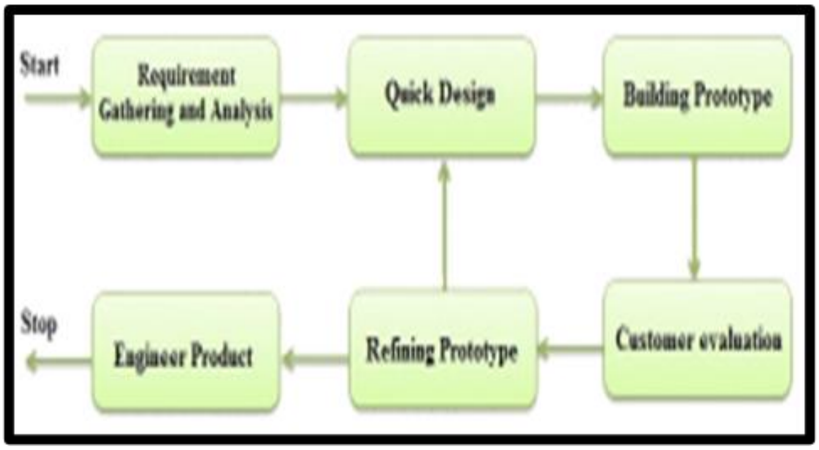
Prototyping can occur at a number of points in the design process, at varying levels of "fidelity" - from the simplest sketches to the most detailed renderings nearly at the level of what a final interface would look.

It is a methodology in its own right and a technique and supplemental methodology to other methodologies. In this study, the researcher will focus on the ways in which prototyping is used as a technique and a supplemental methodology to the systems development life cycle (SDLC). There are two common types of prototyping techniques/approaches, first is the Throw-Away Prototyping Model and the second one is the Evolutionary Prototyping Model. With 'throw-away' prototyping a small part of the system is developed and then given to the end user to try out and evaluate. The prototype is then discarded or thrown away. The evolutionary approach aims to develop a mature system through a series of prototype iterations. The prototype will undergo a series of refinements, and should eventually become the solution. In this study, the researcher focuses on the throw-away prototyping model. Throw-away prototyping model refers to the creation of a model that will eventually be discarded rather than reusing the same one for the final delivered product. After understanding the preliminary needed requirements, a simple working model of the system is constructed to visually show the customer or the end-users what the end-product may look like when they are implemented into a finished system.

The objective of throw-away prototyping is to ensure that the system requirements are validated and that they are clearly understood. The throw-away prototype is not considered part of the final system. It is simply there to aid understanding and reduce the risk of poorly defined requirements.

The Prototype Model

A prototype model summarizes the activities to be undertaken in the prototyping process. Depending on the level of fidelity of the prototype, these activities reflect the deliverables accomplished in each phase or step. As the deliverables of each phase serve as input to the succeeding phase, a checkpoint is established in every phase to determine if it is still on track to the desired prototype being developed. The prototype model shall observe the following phases.



1. Requirement gathering. As a plan is agreed upon with, this phase marks the beginning of the prototyping development where basic requirements are identified to come up with the understanding and the definition of a functional user requirement.

2. Quick Design. Using the defined functional user requirement, an immediate design is sketched with interrelated components using design tools to facilitate validity and reliability of each components *Figure 2: General Prototyping Model* on track with the defined requirements.

3. Building Prototypes. Using the sketched design, each components are built, connected, tested, and recalibrated according to the defined requirements. As a deliverable, this phase shall produce the prototype with the look and feel similar as to a final product required.

4. Customer Evaluation. This is the phase that will define the validity of the developed prototype based on the defined requirement as perceived by the end-user or the customer. The defined fidelity made known to the end-user, plays a big influencing factor on the evaluation. The evaluation technique varies depending on the kind of prototype developed and the metrics to be used in the evaluation. The prototype approach or technique shall set the direction of the evaluation whether to cycle back to quick design for further enhancements and improvements or to just to move on for the throw-away approach.

5. Refining Prototype. This phase shall take its natural course based on the direction of the evaluation defined in the previous phase.

6. Engineer Product. This phase is the "realization" of the developed prototype based on the evaluation results. In reality, some prototypes are developed to its actual product and some do not.

Sensors

In this study, the prototype to be developed shall involve different materials and tools, one of which are the sensors. A sensor is a device that detects or measures a physical property and records, indicates, or otherwise respond to it. In this study the sensor is used as an input device for the pH value, temperature and turbidity and send it to the microcontroller.

Microcontrollers and Application Codes

The prototype also has a microcontroller. It is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application. It contains memory, programmable input/output peripherals as well a processor. The type of microcontroller used in this prototype is a raspberry pi3. It uses C++ as the programming language used to input commands for it to function the needed task. It is a general-purpose object-oriented programming (OOP) language, developed by Bjarne Stroustrup, and is an extension of the C language. It is therefore possible to code C++ in a "C style" or object-oriented style. For the web application PHP programming language is used, PHP stands for Hypertext Preprocessor, it is a widely-used open source general-purpose scripting language that is especially suited for web development and can be embedded into HTML. While for the android application, the researcher used the MIT Appinventor2. It is an open-source web application originally provided by Google, and now maintained by the Massachusetts Institute of Technology (MIT). It allows newcomers to computer programming to create software applications for the Android operating system (OS).

Enterprise Reporting

Enterprise reporting is also considered in this study, it is a methodology that involves providing substantial information to the managers in an organization to help them make business decisions. The main goal of enterprise reporting or management reporting is to supply important timely information to managers in an effective way. Finally, the internet is one of the most important factor in this study for it is the pathway to all of the communications in this prototype from the microcontroller down to the generation of reports for the user.

Technology Acceptance Theory

While it is difficult to directly measure IT contribution because of its hidden and intangible benefits, researchers have developed other measures, such as information technology acceptance, which directly relates IT usage. A sound understanding of the determinants of IT technology will help IT managers effectively plan for IT implementation strategies and promote IT usage.

In the Information Systems (IS) community, TAM is the most popular model among those proposed to explain and predict the acceptance of a system. Fred Davis first proposed TAM in his doctoral thesis in 1985. He proposed that system use can be explained or predicted by user motivation, which, in turn, is directly influenced by an external stimulus consisting of the actual system's features and capabilities. His model is shown in Figure 3.

TAM and its extensions have been used in a wide range of applications in different disciplines, contexts and geographical locations, offering an important theoretical tool when it comes to predicting user behavior. Apart from the application in the information systems management domain, technology acceptance models have been utilized in other disciplines e.g. marketing and advertising.

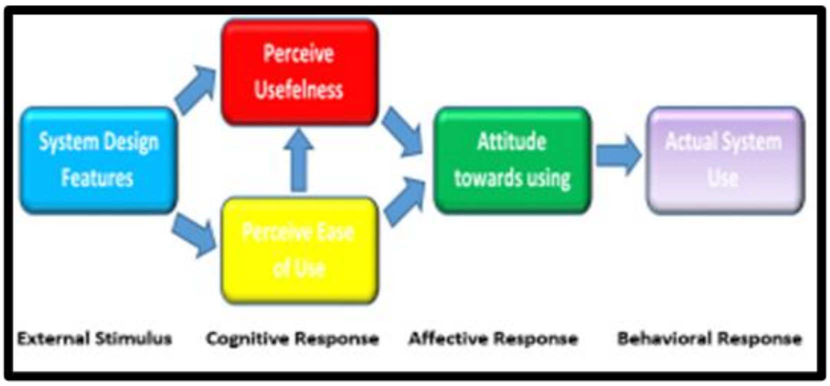


Figure 3: Research Model Based on Original TAM (Davis et al., 1989) (Gefen, Karahanna, & Straub, 2003); Dabholkar & Bagozzi, 2002; Gentry & Calantone, 2002). Given that information systems are extensively used in the marketing of products and services, TAM became a handy tool to examine the attitude of consumers towards technologies, such as chatbots, e-commerce platforms and online shopping tools, enabling online trading (Gefen, Karahanna & Straub, 2003; Araújo & Casais, 2020).

IoT Theory

Nowadays, the urge to connect everything to the Internet is growing, not just to send information to servers for processing and storage but also to provide full control of physical devices over the web.

The IoT envisages overall merging of several "things" while utilizing internet as the backbone of the communication system to establish a smart interaction between people and surrounding objects. Cloud, being the crucial component of IoT, provides valuable application specific services in many application domains. A number of IoT cloud providers are currently emerging into the market to leverage suitable and specific IoT-based services. In spite of huge possible involvement of these IoT clouds, no standard cum comparative analytical study has been found across the literature databases (Ray, 2016).

Nowadays, there is vast enhancement in technologies, as different tools and techniques are available in the agriculture sector. To improve efficiency, productivity, global market and to reduce human intervention, time and cost there is a need to divert towards new technology named Internet of Things. IoT is the network of devices to transfer the information without human involvement. Hence, to gain high productivity, IoT works in synergy with agriculture to obtain smart farming. (VN Malavade, 2016)

Conceptual Framework of the Study

Figure 4 shows the road map for the development of an IoT-enabled water quality monitoring and analysis prototype system for the aquaculture farm owners/operators in Dapitan City. Using as input, are the different theories and frameworks needed for the development of an IoT-enabled system prototype. The development of the aforesaid system prototype takes into action, uses technology acceptance theory to validate both the hardware and software components of the developed system prototype. As an output, a finished and validated prototype system shall be expected after the study. On the outset, the study impacts the Bangus aquatic farmers of Dapitan City through an economical smart aquatic farming as outcome.

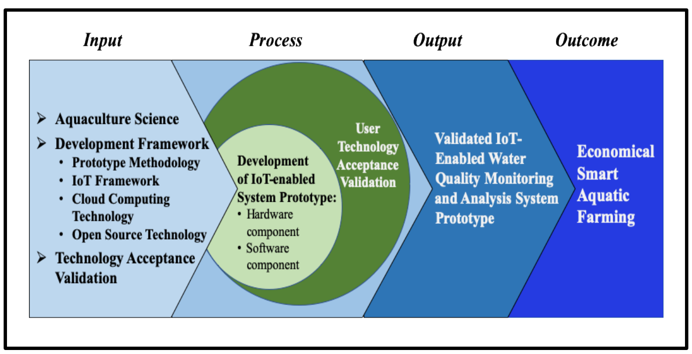


Figure 4: Conceptual Framework of the IoT-enabled Water Quality Monitoring and Analysis System Prototype

II. Methodology

The study employed a descriptive research with the development of a prototype system that adheres to a scientific prototyping methodology. The developed system prototype is submitted as the empirical component to a technology acceptance validation among aquaculture farm operators/owners and farm employees of Dapitan City. The research journey observed scientific procedures with the respective scope and characteristics.

Research Environment

From a small town replete with history, Dapitan took a giant step forward and became a chartered city by virtue of Republic Act No. 3811 which was signed by then President Diosdado Macapagal on 22 June 1963, thus becoming the first city in the Province of Zamboanga del Norte. It is officially known as the "Shrine City of the Philippines". It is one of the five cities of Region IX along with the cities of Isabela, Zamboanga, Pagadian, and Dipolog.

Famous for being the place where the national hero, Dr. Jose Rizal, was exiled, Dapitan City is located on the northeastern coast of Zamboanga Del Norte Province. Dapitan is bounded on the north by Sulu Sea, on the east by the towns of Sibutad and Rizal, on the south by La Libertad and Mutia, and on the west by Dipolog City and the towns of Polanco and Pinan. Terrain is characterized by hills and mountains in the interior and a narrow coastal plain where the city center is found. (dapitancity.gov.ph, 2019)

The city has a land area of 390.53 square kilometers or 150.78 square miles which constitutes 5.35% of Zamboanga del Norte's total land area. Its population, as determined by the 2015 Census, was 82,418. This represented 8.15% of the total population of Zamboanga del Norte province, or 2.27% of the overall population of the Zamboanga Peninsula region. The population of Dapitan grew from 27,517 in 1960 to 82,418 in 2015, an increase of 54,901 people. The latest census figures in 2015 denote a positive growth rate of 1.19%, or an increase of 4,977 people, from the previous population of 77,441 in 2010. It is politically subdivided into 50 barangays. (PhilAtlas, 2019)

This study was conducted in Dapitan City particularly on areas where aquaculture farms are located. Noteworthy, Dapitan City was identified as one of the improved cities in Mindanao as evidenced in the massive increase in businesses in the locality, where aquaculture posed promising source of income.

Research Respondent

This study took the aquaculture farm Operators (Leases), Owners (Farm Management) and farm employees of Dapitan City as respondents, who hailed from barangays of Antipolo, Banonong, Lawaan, Polo, and Sicayab Bucana. Representatives from BFAR Zamboanga del Norte also took participated in the technology acceptance validation survey as respondents.

A total of thirty three (33) respondents voluntarily participated and were tasked to evaluate the developed prototype system. These respondents were categorized into three types: Management/authorities represented Bangus farm owners who functions only in the management and also include representatives from the Bureau of Fisheries and Aquatic Resources (BFAR); Operators represented by aquatic farm leases or owners but functions in the operations of the Bangus farm; and farm employees represented by people who are hired by the Bangus farm management or operators as aid in the farm operation.

Research Instrument

IoT-enabled device system prototype. Composed of hardware and software component, the system prototyped was developed using a Theoretical Framework and adapting prototype methodology. Respondents were trained to use the developed system prototype as the first level of instrument in this study. The system prototype was composed of several sensors, a base station, a remote monitoring station, low power consumption with low cost and high detection accuracy sensors immersed under water. Data collected by the sensors are sent to the base station via internet protocol then forwarded to the remote monitoring station by packets of digital data. A personal computer and a mobile device installed with a Graphic User Interface (GUI) constituted as the remote monitoring station. The transmitted data were evaluated using various simulation tools for future correspondence and actions. Figure 5, the Architectural diagram of the proposed system prototype, depicts the interaction of the components and the data collected.

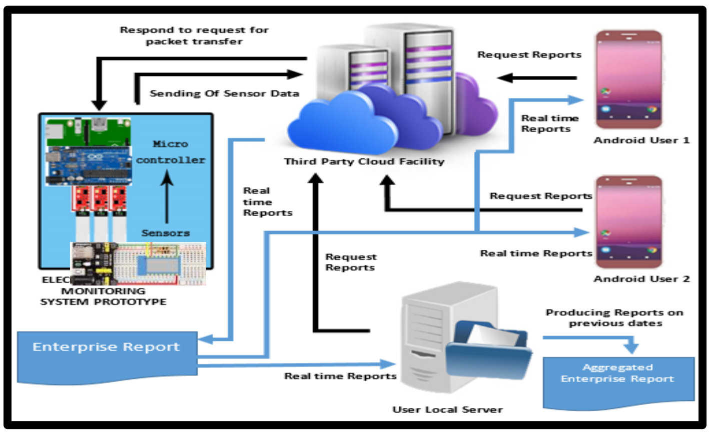


Figure 10: Block Diagram Presentation of the Architectural Framework of the IoT-enabled Water Monitoring and Analysis System Prototype

Empirical validation of technology acceptance of the developed system prototype. After the conduct of a user's training and a day of unsupervised use of the developed system prototype, survey questionnaires, as second level research instrument of the study, were floated to each Bangus farms with people who volunteered as respondents. The survey questionnaire was adapted from Davis' TAM.

Development Methods and Approaches

To materialized the steps in device prototyping – modeling of circuits, assembly of ideas, and get direct output; the researcher employed rapid prototyping technique in the execution of the throw-away prototyping as the development methodology.

Development Models and Tools

To achieve a faster, and more accurate prototypes, the researcher employed fabrication modelling to be able to perform the iteration technique in rapid prototyping. The model has allowed the researcher to test, and validate designs effectively. As output, the fabricated prototype provided a clearer picture of the design intent and structural requirements of the product.

In executing fabrication modelling, the researcher used a variety of power tools like electric drill, electric saw, soldering iron, screw drivers bread boards to fabricate and assemble the prototype. Materials range from easy-to-assemble modular systems like plastic to pvc pipes, and foam.

The Development Process

Employing the throw-away prototyping as a methodology, the researcher adhered to its defined development stages in developing the IoT-enabled water monitoring and analysis system prototype.

1. Requirement gathering. Conducted interviews to available farm operators, the aquaculture technicians from the BFAR and farm employees. Compliant to the defined Theoretical Framework in Chapter 2, research on the different theories and concepts were gathered for use. The deliverable of the phase was a clear functional and non-functional users requirements.

2. Quick Design. Using the deliverables in the Requirement Gathering phase, blue print design was drafted revealing interrelated components. Using design tools, each component's reliability where on track with the defined requirements.

Figure 6 shows the circuit diagram of the microcontroller and its sensors including the wifi module. Also the circuit of solar panel responsible for powering up the system.

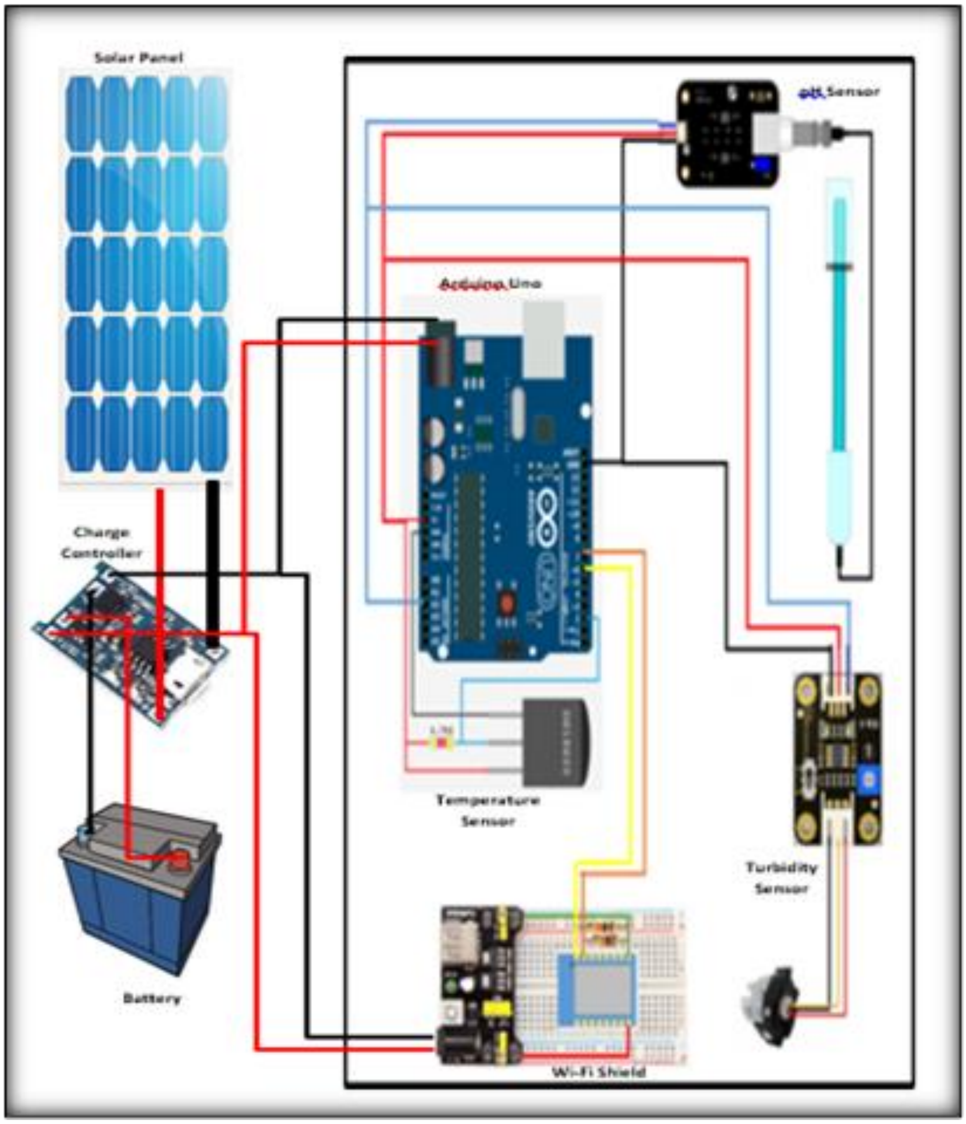


Figure 6. Circuit Diagram of the of the System

3. Building Prototypes. After constructing individual component following blueprint design, each components were connected according to design build, tested and recalibrated according to requirements and came up with the first prototype. Figure 7 depicts the look of the first generation prototype. It has an Arduino Uno microcontroller as its brain and a wifi shield for transmitting the data

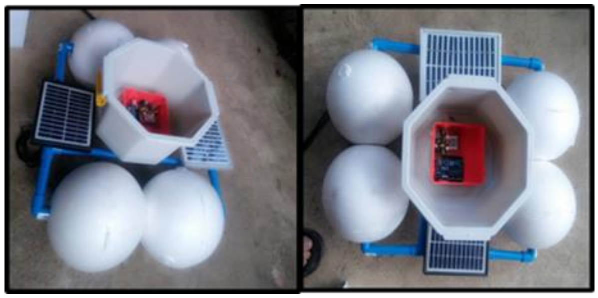


Figure 7. Smart WAMAS at first prototype coming from the sensors. This also has 3 sensor for pH, Turbidity and Temperature. It also has two solar panel that will be responsible for the power of the whole system and a motor cycle battery for energy storage.

By way of the iterative prototyping, after several tests, with the recommendations of different experts on the field of electronics and computer engineering the researcher decided to go back to the design phase to redesign the whole system.

Figure 8 reveals the second generation of the prototype.it has already a smaller battery, li-ion batteries are used around 7.5 volts just enough to power the micro controller and the wifi shield. And also only 1 solar panel with 12 volts 2 watts used.

Figure 8. First Revision of the System

The Prototype's Information System Component

A. Functional User Requirements

Using the scope of the study in chapter I as guide, the researcher had come up with the user requirements through an interview with the respondents before everything has been designed.

The following are the user requirements:

1. The system shall retrieved the data using mobile application.
2. The mobile application can get the data anywhere any time.
3. The system shall have a designated computer for the storage of data that will be used as basis for decision making of the users.

B. Non-Functional User Requirements

The non-functional requirements of the system shows the overall performance of the system. Relatively these requirements also determines the technical architecture of the system.

The following are the non-functional requirements of the system:

1. The local server should not be dependent on any operating system platform.
2. The local server allows any printer to be connected at the user's discretion for printing the reports.

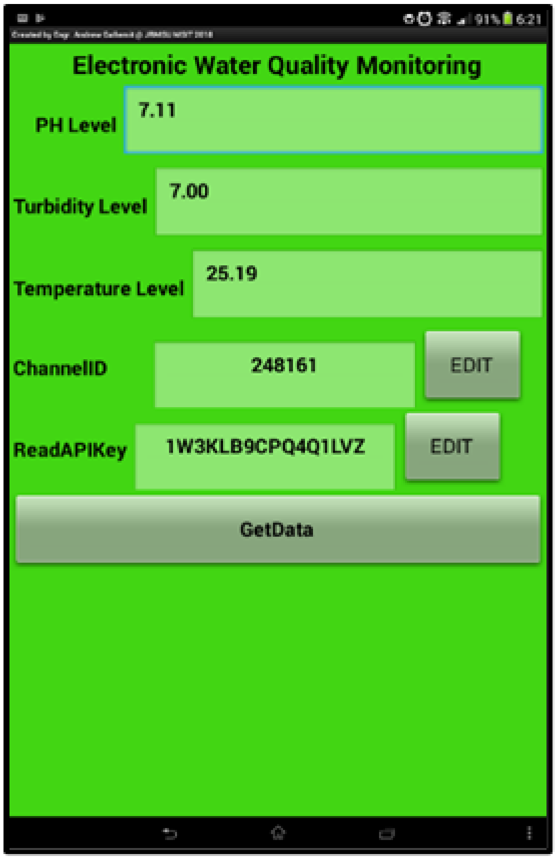


Figure 9 is a sample screenshot of the mobile application (Android App). The mobile application handles the monitoring of the pond water anytime anywhere.

Figure 10 is a sample screenshot of the third party Web Server as part of the IS component of the developed system prototype. It is responsible for storing the data coming from the microcontroller and stores it in its database.

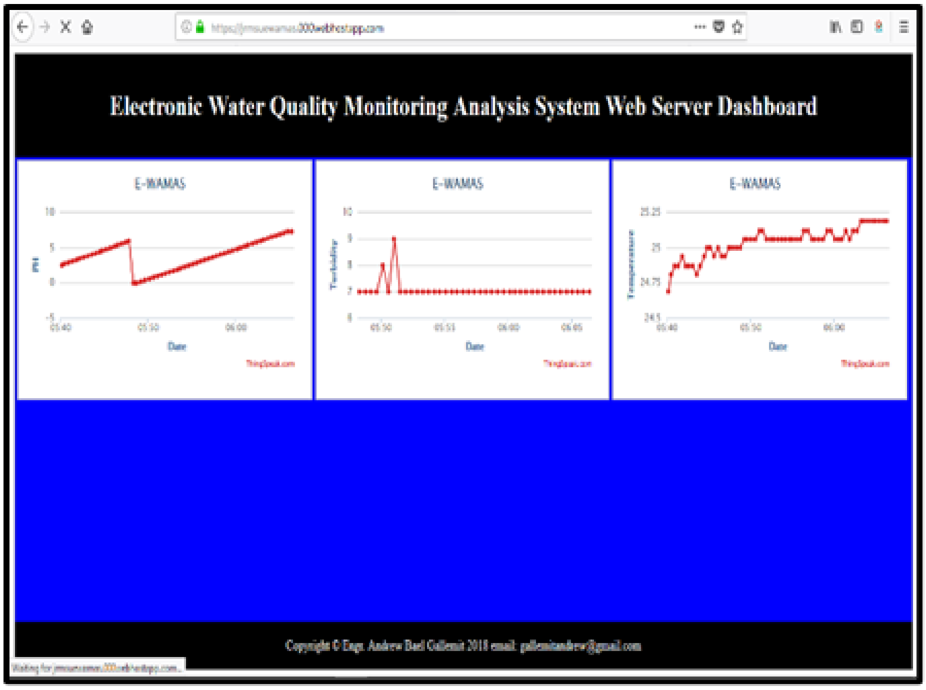


Figure 9. Android App GUI Figure 10. Web Server App screenshot

Customer Evaluation. The completion of the system prototype – the device and the IS components, necessitated the submission of the developed system prototype for alpha testing. Alpha testing involved researcher's known personalities in the academe and the industry deemed to be experts in IoT prototyping for comments and suggestions on the technical aspects. Suggestions that were within the scope of the study were incorporated to the system prototype otherwise, they were noted and were incorporated in the recommendation for future studies. The beta test was accomplished by introducing the updated (after the alpha test) system prototype to the researcher's selected non-technical circle of friends including those who were in the aquaculture industry for comments and suggestions on the interface IS component of the system prototype. Doable comments and suggested features within the scope of the study were incorporated to the system prototype otherwise noted and were incorporated in the recommendation for further development.

Refining Prototype. This phase took its natural course based on the direction of the evaluation defined in the previous phase. It also involved the validation and verification of incorporated features as update by the people involved in the beta testing.

Engineer Product. This phase, with functionally developed system prototype, is the "realization" phase in the entire throw-away prototyping methodology. In real industry standards, some prototypes are developed into its actual product for production and commercialization while others maybe shelf and put on-hold for production.

Prototype Quality Procedures

A. Test Cases

The Validity of hardware and software of the system (Smart Water Quality Monitoring and Analysis System Prototype) was tested and validated last November 2017 by Engr. Ardcel Enriquez, Engr. Randy L. Pasmal, Engr. June Carlo Reyes and Engr. Michael Glenn Tan, all computer engineers and experts of their field of study. Table 1 shows the summary of results of the test cases done during the hardware and software validity testing.

Table 1. Summary of Test Cases done on Hardware and Software of the Smart Water Quality Monitoring and Analysis system Prototype.

Test Case No.	Module	Test Case Name	General Rating	Conducted By
1.1	Sensors	pH Sensor Data Reading	Passed	Engr. Ardcel Enriquez
1.2		Turbidity Sensor Data Reading	Passed	Engr. Ardcel Enriquez
1.3		Temperature Sensor Data Reading	Passed	Engr. Ardcel Enriquez
2.1	Microcontroller To Wi-Fi Shield	Sending of pH Sensor Data to Thingspeak	Passed	Engr. Randy Pasmala
2.2		Sending of Turbidity Sensor Data to Thingspeak	Passed	Engr. Randy Pasmala
2.3		Sending of Temperature Sensor Data to Thingspeak	Passed	Engr. Randy Pasmala
3.1	Mobile Application	Connecting to Thingspeak Channel	Passed	Engr. June Carlo Reyes
3.2		Getting Sensor Data from Thingspeak	Passed	Engr. June Carlo Reyes
4.1	Local Server	Getting Sensor Data from Thingspeak and Save to Database	Passed	Engr. Michael Glenn Tan
5.1	Reports	Viewing and Printing of monthly report	Passed	Engr. Michael Glenn Tan & Engr. June Carlo Reyes
5.2		Viewing and Printing of weekly report	Passed	Engr. Michael Glenn Tan & Engr. June Carlo Reyes

A. User's Training and Beta Testing

After the systems hardware and software validity test, beta testing was done using the aquatic farm owners, operator and farm employees as users of the system. On January 2018 a User's Training was conducted at Dapitan City Agricultures office attended by 33 participants, 3-Farm employees, 11-Managemeent Authorities and 19-.Farm Operators.

B. System Acceptability Survey

A five-point Likert-scale response referenced was used in the questionnaire to calibrate their level of agreement on the technology acceptance of the system specifically on the (1) perceived usefulness; and (2) perceived ease of use. To facilitate the interpretation of results obtain from the survey, an interpretation table was established. And to achieve precision of interpretation from the five-point Likert-scale response, recalibration was made with range intervals derived from the formula:

$$\text{Interval} \quad \frac{N-1}{N}$$

$$= \frac{5-1}{5}$$

$$= 0.8$$

Where N is the maximum number of levels in the Likert scale. Using the resultant 0.80 as the interval for the range, an interpretation table was drawn. This interpretation table was used in the discussion of the statistical results. The outcome of the survey formed the basis for the release of the Electronic Water Quality Monitor and Analysis System Prototype.

III. Results and Discussion

After the development of the water quality monitoring and analysis IoT-enabled system prototype employing the rapid prototyping technique as development methodology, alpha testing and beta testing were done.

Alpha and beta testing have contributed to the achievement of an IoT-enabled system prototype that can monitor and analyze the quality of water in aquaculture. The system prototype was equipped with features that can be expressed in terms of the robustness and reliability of networked sensors, timeliness with accuracy in the transmission of data from the device to the cloud and to server, and the timeliness with precision of reports to aid informed decisions.

The IoT-enabled system prototype was moved around to nineteen (19) Bangus aquaculture farms in the city of Dapitan from November 2017 to March 2018. The routine involved a user's training with demonstration in each farm. A return demo concluded each farm training to make sure that the personnel can use the prototype independently. The IoT-enabled system prototype was left in every scheduled farm for a one-day use.

Validating Technology Acceptance

Before the IoT-enabled system prototype was retrieved a day after the farm use, survey questionnaires were distributed to farm personnel including the owner/operator who volunteered to be respondents of the technology acceptance survey. On the same day, the survey questionnaires were retrieved along with IoT-enabled system prototype and move to the next scheduled Bangus aquaculture farm. Table 2 summarizes the demography of respondents as Part 1 of the technology acceptance survey questionnaire.

The survey was conducted in Dapitan City over a total of 33 respondents accounted by categorized as Management/Authorities with 11 or 33 percent, Operators with 19 or 58 percent, and Farm employees with 3 or 9 percent. In terms of sex, Male respondents have dominated accounted with a total of 24 or 73 percent while a total of 9 or 27 for the female respondents. In terms of the marital status of the respondents, majority were married with 24 as total or 73 percent while six or 18 percent were single and 3 or 9 percent were widowed.

Using range to categorize the age groups of the respondents, the majority 49 percent or a total of 16 aged 20 to 40 years old. 11 or 33 percent belonged to the 41 to 65 age group while the remaining

VARIABLE	Number of Respondents n = (33)	
	Frequency	Percent
1.) Respondent Type:		
Management/Authorities	11	33.33
Operators	19	57.58
Farm Employees	3	9.09
2.) Sex:		
Male	24	72.73
Female	9	27.27
3.) Marital Status:		
Single	6	18.18
Married	24	72.73
Widowed	3	9.09
4.) Age:		
20 to 40 years old	16	48.48
41 to 65 years old	11	33.33
Above 65 years old	6	18.18
5.) Highest Educational Attainment:		
Elementary education	6	18.18
Secondary eduction	11	33.33
Bachelor degree	16	48.48
6.) Years of working in the Bangus farm:		
Below 10	5	15.15
10 to 14	18	54.55
15 to 19	9	27.27
20 to 24	1	3.03
7.) Have tried using similar system:		
No	33	100.00

Table 2: Respondents' Demography

18 per cent, accounted as six, aged 65 years old and above. Most of the respondents, 49 percent or a total of 16, were college degree holders while 11 or 33 percent have finished secondary education. Only 6 or 18 percent finished elementary education.

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In terms of work experience, either directly or indirectly, in an aquatic farm, majority of the respondents, accounted as 18 or 55 percent, have experienced 10 to 14 years. Nine of the respondents, or 27 percent, were accounted for the range 15 to 19 years while five of them, or 15 percent, have accumulated less than 10 years of work experience. Only one respondent, or three percent, has the least work experience of 20 to 24 years.

In terms of the experience in using a similar IoT-enabled system, all 33 respondents have not tried using it which implied a hundred percent tally.

Part 2 of the survey questionnaire is the technology acceptance portion that was adapted from the Davis' TAM. It was aimed at measuring the perceived level of the respondents' technology acceptance of the IoT-enabled water quality monitoring and analysis prototype system. Table 3 depicts the result of the statistical treatment of the survey.

The survey questionnaire was to answer two variable constructs – perceived usefulness (PU) and perceived ease of use (PEU). Both the PU and the PEU have equally ten questions that allowed the respondents to rate as their perceived technology acceptance based on the items defined in by Davis in his TAM. All of the criteria under PU obtained weighted means ranging from 4.58 to 4.70 interpreted with a verbal description under "Extremely Agree" category. With an aggregate mean of 4.71 under a standard deviation of 0.470, PU garnered an interpretation of "Extremely Agree" verbal description.

CRITERIA		ASSESSMENT LEVEL			
		Mean Rating		SD	Overall Rating
Perceived Usefulness (PU)	1. I find using the Smart WAMAS Prototype improves the quality of the work I do.	4.76	*(Extremely Agree)*	0.435	4.71 *(Extremely Agree)* SD = 0.470
	2. I find using the Smart WAMAS Prototype gives me greater control over my work.	4.76	*(Extremely Agree)*	0.435	
	3. I find the Smart WAMAS Prototype enables me to accomplish tasks more quickly.	4.76	*(Extremely Agree)*	0.435	
	4. I find the Smart WAMAS Prototype supports critical aspects of my job.	4.67	*(Extremely Agree)*	0.479	
	5. I find using the Smart WAMAS Prototype increases my productivity.	4.70	*(Extremely Agree)*	0.467	
	6. I find using the Smart WAMAS Prototype improves my job performance.	4.58	*(Extremely Agree)*	0.561	
	7. Using Smart WAMAS Prototype allows me to accomplish more work than would otherwise be possible.	4.76	*(Extremely Agree)*	0.435	
	8. I find using Smart WAMAS Prototype enhances my effectiveness on the job.	4.70	*(Extremely Agree)*	0.529	
	9. I find using the Smart WAMAS Prototype makes it easier to do my job.	4.64	*(Extremely Agree)*	0.489	
	10. Overall, I find using the Smart WAMAS Prototype usefil in my job.	4.76	*(Extremely Agree)*	0.435	
Perceived Ease of Use (PEU)	11. I find the Smart WAMAS Prototype cumbersome to use.	4.64	*(Extremely Agree)*	0.549	4.42 *(Extremely Agree)* SD = 0.594
	12. Learning to operate the Smart WAMAS Prototype is easy for me.	4.79	*(Extremely Agree)*	0.415	
	13. I find interacting with the Smart WAMAS Prototype often frustrating.	3.52	*(Moderately Agree)*	0.755	
	14. I find it easy to get the Smart WAMAS Prototype to do what I want it to do.	4.55	*(Extremely Agree)*	0.564	
	15. I find using the Smart WAMAS Prototype rigid and inflexible to interact with.	4.45	*(Extremely Agree)*	0.617	
	16. I find it easy for me to remember how to perform tasks using the Smart WAMAS Prototype.	4.39	*(Extremely Agree)*	0.659	
	17. I find interacting with the Smart WAMAS Prototype requiring a lot of mental effort.	4.21	*(Extremely Agree)*	0.740	
	18. My interaction with the Smart WAMAS Prototype is clear and understandable.	4.67	*(Extremely Agree)*	0.645	
	19. I find it takes a lot of effort to become skillful at using the Smart WAMAS Prototype.	4.18	*(Moderately Agree)*	0.528	
	20. Overall, I find the Smart WAMAS Prototype easy to use.	4.82	*(Extremely Agree)*	0.465	
Aggregate Mean				0.532	4.57 *(Extremely Agree)*

Table 3: Technology Acceptance Level of the IoT-enabled Water Quality Monitoring and Analysis Prototype System

Likewise, PEU's criteria collected weighted means ranging from 3.52 to 4.82 with two (2) criteria, 13 and 19, accumulated "Moderately Agree" verbal description. The rest of eight criteria have "Extremely Agree" verbal description. The computed aggregate mean for the PEU variable construct resulted to 4.42 interpreted as "Extremely Agree" verbal description under a standard deviation of 0.594.

The overall aggregate mean of PU and PEU when combined accumulated 4.57 with a standard deviation of 0.532 that falls under the "Extremely Agree" verbal description.

IV. Conclusion

Based on the findings derived from this study, the following conclusions were drawn.

1. A robust and reliable network of sensors that can produce timely readings of temperature, pH, and turbidity for a body of water has already been build.
2. A fast, timely and accurate analysis interface of the data transmitted from an IoT device installed in a body of water has been developed.
3. A report generation for decision-support undertakings were already developed to help the aquaculture farm owners and operators in their decision making.
4. Already had measured the technology acceptance among users of the prototype in terms of perceived usefulness; and perceived ease of use.

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