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# A Review on Visual Water Quality Monitoring System in Precision Aquaculture

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**Keywords:** Sonification, visual analytics, water quality monitoring, real-time, precision aquaculture, fish farming.

**Abstract.** This paper presents the review of available visual water quality monitoring and proposes a conceptual sonification model of audiovisual analytics for precision aquaculture. This study reviews the current practice of the visual water quality monitoring system used to interpret the complex fish farming data. This study also explores the possibility of using an auditory display, by using sound as complementary elements to communicate information from the system to the user.

## Introduction

In the field of aquaculture, water quality monitoring and prediction plays an important role in modern fish farming management, which used sensory data to analyze the water conditions. As the increase of sensors technologies in aquaculture, more complex data can be analyzed and automated. These sensory data can be useful for the analyst to detect pattern and trend in monitoring and controlling water quality in the fisheries such as understanding the pattern of dissolved oxygen before and after fish feeding. It is also essential for a monitoring system to be able to present the overall pattern of the data in a single presentation to see the whole picture. The user can observe and modify the related values by adjusting the control by interacting with the graphical user interface.

In fish farming, multiple water parameters were observed for a single fishpond to prevent any factor that can cause catastrophic loses. In the year of 2014, about 160 tons of fish from the fish farm have been found dead in the east and west Johor due to possible factor of low dissolved oxygen level. The sudden changes in weather and temperature also can affect the water quality [1].

Water quality is determined by the variables such as temperature, dissolved oxygen (DO), pH value, conductivity, the concentration of ammonia and many others. Generally, multiple variables of water quality were observed from a sensor for analysis and these data were presented by using data visualization [2]. This is sufficient to monitor a single fish farm. However, it poses challenges to monitor multiple fish farms, as massive volume and variety of data generated from multiple sensors, causing a visual clutter. Moreover, to monitor multiple fishponds in a single control center even with multiple displays can prove too overwhelming. Generally, in the context of intensive aquaculture, several cages are typically grouped together. Thus, we propose that by integrating sonification in some of the data representation processes may alleviate the problem.

An alarm mechanism is crucial in a water quality monitoring as it can automatically notify alert to the user via text messaging, and then highlight the alert on the visual monitor. This mechanism however may take longer duration if there is a network or hardware malfunction. By implementing sonification system directly from the pond or cage, a user can get the information through sound in real-time. In addition, real-time sonification can also be used as an early warning mechanism for any potential failures.

Our project proposes a sonification ambient model that can be applied to complement the data visualization of the water quality monitoring system. Our objective is to improve the monitoring process and use sound representation to reduce overall mental workload. Sonification can be described as representing the data as non-speech sound and it has several characteristics that well suited for exploring temporal patterns as the human auditory system has an excellent temporal resolution.

**Current State Aquaculture Water Quality Monitoring**

This paper focuses more on scope of water quality monitoring system for cage farming. Water quality monitoring plays an important role in the survival and growth of fishes. A slight change in the water condition may stress out the fish that may even cause death. In modern intensive fish farming, more advanced technology system has been developed to ensure the quality of the water condition. In general, a water quality monitoring system for aquaculture may consists of, WSN, Ai-based program, automation process, alarm system, data storage, graphic user interface interaction, data analysis and real-time [3].

**WSN.** The sensor node is used to collect the data of the water parameter. Wireless Sensor Network (WSN) is commonly used in monitoring water quality in aquaculture [4, 5]. The WSN allows the data to be sent wirelessly to the command center and it capable to covers a longer range [6]. The common challenge is the sensors may malfunction as it will be exposed to the harsh environment [7].

**Alarm system.** The alarm system is essential in every modern aquaculture water quality monitoring system. The alarm can be used to notify of any conditions or problem such as system failure, extreme condition, or an abnormal setting. Generally, the system will be set to a certain quality standard, once abnormal data are detected, the system will notify the results via text messages and display the abnormalities on the visual monitor. Sounds and light type of feedback also have been used in the alarm system [8].

**Automation process.** Automation process are the technology where a process or procedure is performed without human assistance [9]. It is often a combination of artificial intelligence-based (AI) and alarm system where the AI mimics some capabilities of a human brain in performing a certain task. A smart algorithm capable to detect abnormalities, for example, a system warning will be forwarded via text messages or email if the reading from the monitoring system is outside the preset range. Aquaculture farming system automation will provide the following benefits: (1) increase the production close to the market demand (2) improved environmental control (3) reduced damage caused by big disasters (4) reduced environmental management costs (5) reduced production costs (6) improved aquatic product quality [10].

**Artificial intelligence-based (AI) system.** Simbeye and Yang [11] created water quality monitoring and control for aquaculture based on WSN trough ZigBee that includes data analysis process, automation process, and AI-base system.

**Data storage.** Al-Hussaini et al. [12] have developed a monitoring and automation for Recirculating Aquaculture System (RAS) and using Fog computing. Their work focuses on a system that contains data collection, data analysis, data sharing on the server by using fog computing technology and decision making to control RAS.

**Data analysis.** Other researchers focused on water prediction to prevent the future problem by using a prediction model to predict the dissolved oxygen level ahead of time [13].

**Real-time**. A study [14] has proposed a set of low-cost sensors for monitoring the water quality and fish behavior in the aquaculture tank during the feeding process. The system includes a smart algorithm to reduce energy lost when sending data from node to the online database and smart alarm system to alert an abnormality in the value.

**Graphic user interfaces interaction.** Recent research already started to add and improve their Graphic User Interface (GUI). However, there were handful of studies that focuses on suitable data visualization process especially for water quality monitoring and to our knowledge, none of the previous work reviews on the effective ways to display multivariate sensor data, especially in aquaculture water quality monitoring.

This study [2] have developed a monitoring and control system for shrimp farms based on NI myRIO and Zigbee based on WSN. GUI is designed with LabVIEW programmer to collect, analyze and present data on a monitor for the end users. The system also allows the end users to get updated data online from sensor based spreadsheets. Also, the application is able to send alarm via text messages.

Al-Hussaini et al [12] have introduced Raspberry Pi, a single-board computer capable to store and display data, to display data in a form of graph plot table with time e.g. current, average, maximum, and minimum temperature sensor. Another study [15] have designed a web application user interface by using Google's design language. The design consists of data monitor, and all sensors data are displayed on the GUI as shown in Figure 1 below.


Fig. 1. The user interface of multiple sensors reading for a single fishpond [15]

For most cases, monitoring data are collected from sensor nodes; some system observes the behavior of the network in term of quality of the radio link of each sensor node, data aggregation, and battery status. Possibly, a host computer acting as the command center allows the owners to carry out a number of parameter settings to facilitate monitoring.

It is also possible to set a manual command so as to achieve reasonable adjustment and control of systems diversity. In the user interface, the data received can be compared to the predetermined threshold. Whether the data received are within or out of the safe range. Then the system should be able to give the appropriate warnings to the users when the phenomenon occurs.

## Discussion

The increase of available technology in aquaculture leads to the generation of higher volume and complex data. It also leads to the need to improve the automation and monetization process. It is important to improve this process in order to cope with the changes in technology.

A water quality monitoring system is the most important part in providing a healthy environment for the fishes. Normally, multiple sensors are used in water quality monitoring for a single pond. However, monitoring multiple ponds in control center may be challenging. By integrating sonification to the data representation may alleviate the problem.

Generally, the system preset its own water quality standards. Once abnormal data are detected, the system then will notify the result via text messages and display them on the visual monitor. This process may take longer if there is a problem with the network connection. By implementing a sonification system directly from the pond or cage, users can get the information through sound in real-time. Also, this can be used as an early warning mechanism to alert to user directly from the pond or cage for any practical equipment or management failures. In the context of aquaculture, it would be beneficial if there is a technology that could help in monitoring and provides real-time

feedback from each of fishponds. By listening only, the farmer able to identify and pinpoint the specific problem in the water quality parameter without looking at every component.

In this project, we propose for an ambient sonification model that can be applied to the visual representation of the water quality monitoring system. Sonification can be described as representing data as non-speech sound and it has several characteristics that well suited to exploring temporal patterns as the human auditory system has an excellent temporal resolution.

### Overview of Visual Analytics and Visualization

According to Keim [16], visual analytics is the science of analytical reasoning supported by interactive visual interfaces. Visual analytics is a combination of three components namely visualization, human factors, and data analytics as shown in Figure 2

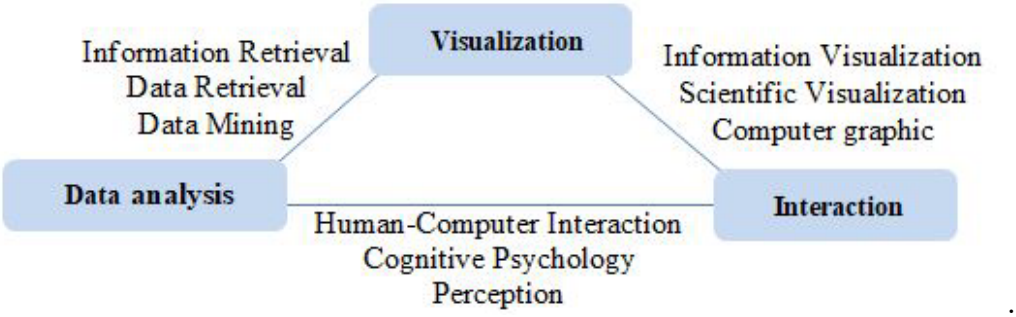


Fig. 2. Shows the related research areas in Visual analytics [16]

Information visualization is the study of (interactive) visual representations of abstract data to reinforce human cognition [17]. The field of information visualization has emerged from research in human-computer interaction, computer science, graphics, visual design, psychology, and business methods. [17]. Combining visualization and sonification is not new in the research field of data presentation and exploration. Usually, this happens when it involves of a larger stream of data or a real-time data stream that is rapidly changing. For example, sonification is used to monitor cyber-crime traffic in real-time combining with interactive visual display [18]. Sonification was also been used in others research field as a complimentary components. For instance, [19] have introduced a geo-audio visualization with an ambient sound framework to understand complex dengue data.

This study [20] shows that a continuous sonification improved the monitoring performance in a peripheral monitoring scenarios where the attention is focused on a primary task and other information is monitored indirectly at the same time [21].

### Auditory Display

Auditory display can be described as the use of sound to communicate information from a computer to the user. It consists of audification, sonification, earcons, and voice massaging. Can we hear patterns and trends if we listen to the data? Previous studies has supported that certain data is suitable for sonification for exploring patterns and trends in the data [22].

Auditory display has many advantages, especially for the visually impaired user. A blind person may able to use a computer with the help of screen reader as good as a well-sighted user. For example, a doctor performing a surgery while listening to the patient heart rate monitor. On the other hand, poor design in sound output may produce unpleasant or uncomfortable sound.

What is Sonification? Sonification is defined as 'the representation of information using non-speech sound to help in the understanding of data or processes by listening' [23]. Referring to these definitions, sonification applications should have the following three main elements; (1) The goal, tasks, and objectives to achieve (e.g. interpretation, communication, emotion etc.); (2) Input (data) and output (non-speech sound); (3) The technique(s) of transforming data into sound. There are

several existing sonification techniques that currently available; audification[24], parameter mapping sonification [25], model-based sonification [26] earcons and auditory icons [27].

Previous work has demonstrated the suitability of the auditory system for following multiple streams of information. For example, scientists apply sonification to understand the solar system by turning data collected by NASA satellite into sounds and music. Sonification may offer a means to display a potentially unlimited number of signal processing operations simultaneously [28]. The previous research also shows the effectiveness of sonification in sonifying multiple streams of information.

## Conceptual Sonification Model for Precision Aquaculture

In general, big data is a term that describes a large amount of data that was beyond usage for the conventional database. Big data can be characterized by the following characteristics; the amount of volume, variety, velocity, variability, and veracity [29]. Internet of things (IoT) is the network of physical devices that embedded in objects with electronics, software, sensors, actuators, and network connectivity which enables these objects to connect and exchange data [30]. IoT is currently being the trend in aquaculture. With the advancement in sensors and chip technologies, it helps the aquaculture industries to collect a large volume and complex data to be analyzed. Also, these technologies help the user to monitor the water quality frequently.

## Data and Sensors Design

In our study, the sensors are required for data collection purposes. The design and recommendation of the sensor will be based on previous work guidelines such as wireless sensor network for water quality monitoring and control for aquaculture [11]. Figure 3 below shows the system block diagram of our planned model sensor using Arduino chip supported with wires connection.

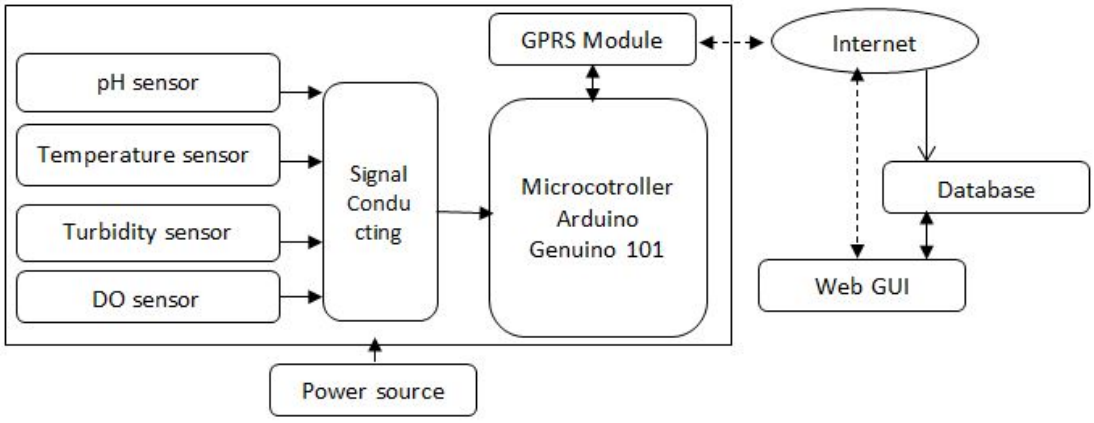


Fig. 3. Model sensor using Arduino support with internet wireless connection [31]

Referring to Figure 3, five types of water parameter will be observed in this research, by using five different types of sensors. These sensors will then connect to the Microcontroller Arduino supported module GPRS Module. The GPRS will be used to send data through the wireless network and transmit them to the base station host computer. The process management and visual real-time measurement of the whole system will be carried out by the station's host computer. An automation process will be included in the system to be able to detect any changes and to send an alert signal automatically. Still, there is no research on using sonification as real-time water quality monitoring for fish farming.

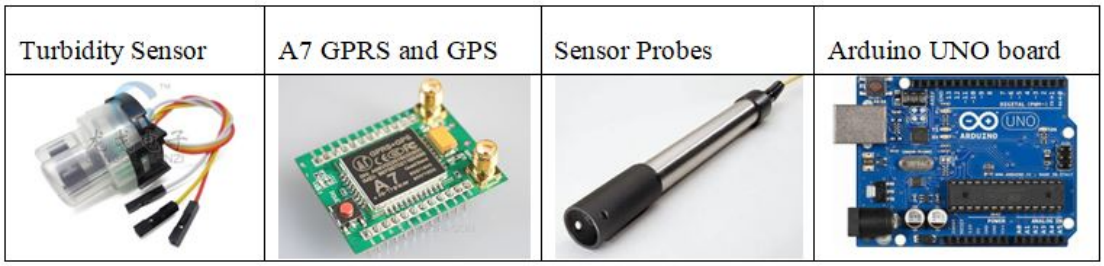


Fig. 4. The type of sensor and modules use to develop sensor device using Arduino UNO board

The general hardware parts required in sensors design for data collection of water quality parameters are shown in Figure 4. By adding GPRS module, we can monitor the data through online.

## Conceptual Model

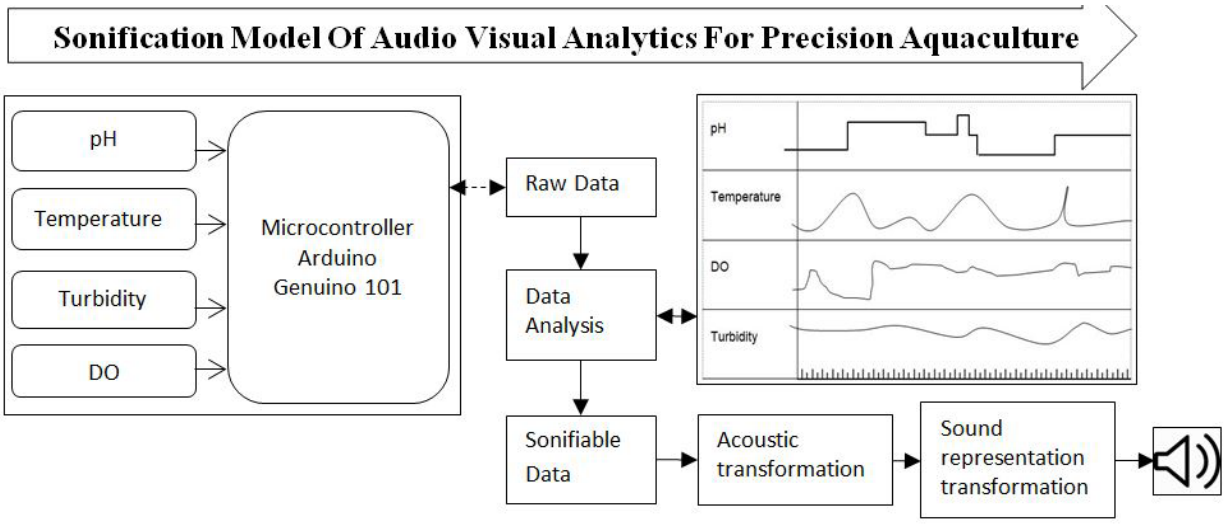


Fig. 1. The general structure for real-time sonification of data analysis for precision aquaculture

In general, this conceptual model consists of four components, sensor, data transformation, interactive visualization and sound representation as shown in Figure 5. In this research, several sensors are used to detect water quality parameters in the fishpond. Four types of sensor will be tested to capture the stream of data namely pH balance level, temperature, dissolved oxygen level (DO) and turbidity. Raw data will be stored and analyzed based on the farmer's needs, and the large data will be prepared and transformed using visualization technique. For the sonification process, the selected data from the visualization process will be transformed into auditory display. An ambient sound will be used to represent the data. Among others, the line graph usually being used to track the changes over a long period of times. Also, bar graphs are used to compare things between different fish cages.

## Conclusion and Future Work

This paper presented the review on the existing technology for water quality monitoring system, the possibility of using the auditory display in aquaculture and finally proposed a conceptual model of ambient sonification to compliment the data visualization in the water quality monitoring system. The resulting findings from this research will possibly help and improves the water quality monitoring process in fish farming by using existing sensors and potentially improve on the analysis process in aquaculture. Also, our proposed model can potentially improve the monitoring performance in peripheral process monitoring, where the attention is focused on a primary task and other information is monitored indirectly at the same time.

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