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*Design of a specialist automatic control
system*

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1.0 Introduction

Many aquatic creatures became threatened by climate change and water pollution. It is critical to look after those animals and keep them healthy to prevent extinction. Aquarium upkeep takes time, and mistakes are common. A completely automated tank would be tremendously advantageous to the organisation since it would free up personnel to focus on other responsibilities such as species reproduction planning, data analysis etc.

I've created a few control mechanisms that will allow the company's tank to self-regulate. A complete temperature control system, as well as a pH warning system, will guarantee that the animals' fundamental demands get addressed. Following a review of various temperature and pH sensors, the most suitable option will get reviewed. I created a fully automated control system that requires little human involvement. For this reason, I utilised a Node MCU microcontroller. In addition, I reviewed several types of heating and cooling equipment alternatives in terms of cost, the convenience of use, and safety.

Hand-feeding fish may be a difficult and time-consuming task. I created an automated feeding system. Food gets dispersed into the tank based on fish movement detected by LDRs. Feeding equals a mess. The tank will naturally become unclean and will require filtering. I've discussed the essential equipment and usage instructions on how to keep the tank in good working order. Debris will inevitably accumulate, necessitating the installation of a filtration system in the tank. I chose an ordinary filter since it is both inexpensive and effective.

2. Device choices for the tank.

2.1 Sensors

2.1.1 Temperature Sensors

2.1.1.1 Stick-on thermometer

A stick-on thermometer is a simple, low-cost sensor that you can place anywhere in the tank at a minimal cost. It is durable and difficult to break (Sharp, 2021b). One issue of worry is that it will very likely record both the ambient and tank temperatures. That would be a big blunder that may have consequences on the species' well-being. The thermometer gets permanently mounted on the aquarium wall. Consequently, monitoring the temperature in the middle of the tank is impossible (Mari, 2016). They cost between £5-£10 (amazon.co.uk, 2021).



Figure 1. Stick on LCD Thermometer (Sharp, 2021)

2.1.1.2 Floating thermometer

A floating thermometer is another easy to use sensor that can either get mounted to the wall of the aquarium or get placed anywhere in the tank to float on top (Sharp, 2021b). A low-cost device that is unaffected by variations in ambient temperature because it only reads the temperature of the water (Sharp, 2021b). However, because the device is glass, it is susceptible to breakage, offering the possibility of mercury leaking into the tank (Woodford, 2018). Also, because the readings are non-digital, the chance of human error increases. What's more, providing a warning when the temperature is out of range would be difficult. It costs between £2.5-£5 (amazon.co.uk, 2021a).



Figure 2. Floating Thermometer (Sharp, 2021)

2.1.1.3 Digital thermometer

The most modern temperature sensor is a digital thermometer consisting of a probe (inserted into the tank) and a digital display monitor (Allen, 2013). It's pricey and requires batteries to operate (Mari, 2016), but the benefits far outweigh the drawbacks. It is possible to move the probe about the tank. Temperature readings can get taken from any location inside it. The possibility of bias is low because, like the glass thermometer, it is unaffected by ambient temperature. Because the records get shown on a digital screen that is exceedingly accurate, the human error gets reduced (Mari, 2016). When the temperature changes outside the specified range, this thermometer is programmable to provide a warning signal, such as an orange flashing light. Costs between £5-£15.

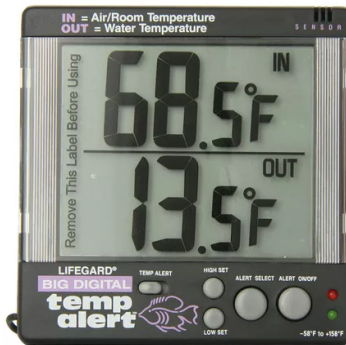


Figure 3. Digital thermometer (Sharp, 2021)

2.1.2 pH Sensor

To survive and maintain a healthy immune system, all species need a pH range that's appropriate for them (Holmes-Farley, 2004). According to (Britannica, 2019), pH measures an aqueous substance's acidity. pH testers determine whether a chemical is alkaline or acidic (Holmes-Farley, 2004).

The device consists of 1 or 2 glass probes and a digital display instrument (Woodford, 2018a). It operates by sending a low voltage through the probe. The action results in finding the number of hydrogen atoms in the solution that's getting measured. Hence, determining the pH.

It's easy to use a digital pH meter. Before and after each use, the probe needs to gently get put in either distilled or deionized water, taking care not to hit it on the sides. Also, switch on the meter half an hour before measuring to allow it to heat (Cannon, 2020). The digital pH metre will immediately begin to display the value. The measurement is complete when the reading stabilizes.

One drawback is that calibrating it might take some time (wikiHow, 2008). The probes must get submerged in buffers (pH-controlled test solutions), and the meter must then get adjusted accordingly (Woodford, 2018a). The benefit of using a digital pH sensor is that the readings are quick and accurate (Lehman, 2017), and the digital aspect reduces the chance of human error. Following calibration, there are processes for recording and collecting data, which must be carefully handled by a person, not a device, increasing the possibility of mistakes.

There are also permanent pH sensors on the market, which can monitor the levels 24 hours a day, seven days a week. Prices on Amazon range between £20 and £50 (amazon.co.uk, 2021d). Because they are digital and constantly on, it would be possible to set alarms and maintain a safe pH level at all times (amazon.co.uk, 2021d).

As well, a pH test strip is also suitable. It works by dipping a stick into the tank water. The colours of the pH testing strip then change, allowing a human to determine the pH (Lehman, 2017). Alternatively, the water sample might get combined with chemicals before being visually compared to the colour index. The manual method takes a long time and is not always reliable, as anything operated by people and not digitally. However, it is a very cheap and easy option. Repeated measurements will offer an average minimizing bias, making the test more accurate. They cost around £15 for 150 strips (amazon.co.uk, 2021a).



Figure 4. pH sensor getting used on a chemical (Surat, 2020).

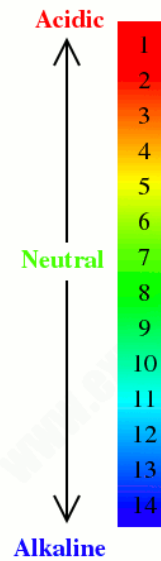


Figure 5. Index of colors to determine pH (Woodford, 2018a).

2.1.3 LDR

LDR is a resistor constructed of a semiconductor material that absorbs photons (light-emitting molecules) (Solliday and Jepsen, 2021).

LDRs (light-dependent resistors) get used in automatic security lighting, for example, to detect light levels. As the intensity of the light increases, their resistance lowers (BBC, 2019).



Figure 6. LDR (BBC, 2019)



Figure 7. Leaded light dependent resistor (Spurr, 2014)

2.2 Electrical Devices

2.2.1 Heating Device

2.2.1.1 Immersible Heater

Most hang-on tank heaters get encased in a plastic or metal covering that may be suction-cupped to the tank's back wall. Hang-on heaters are simple-use and come in several sizes to handle small and big tanks (Lorraine, 2020). These will have a maximum waterline, and if the water level rises over this, an electrical short may occur.

2.2.1.2 Submersible Heater

Submersible heaters get submerged in the tank's water (Edwards, 2019). They mount to the aquarium walls with suction cups or clips.

2.2.1.3 Substrate Heater

Substrate heaters, also known as cable heaters, feature a flexible cable with a heating element that gets buried beneath the aquarium sand or gravel (Edwards, 2019), which has the added benefit of entirely disguising the heater. The gravel gets heated and radiates the heat, and warms the water. This heater may not be efficient enough in big tanks because it can take a while for the heat to travel up the tank.

2.2.1.4 Filter Heater

Aquarium filtration devices may contain a heater (Lorraine, 2020); however, they are typically more expensive, and it is harder to manage the amount of heat introduced into the aquarium.

2.2.2 Air Pump

An air pump simply circulates air through the tank, ensuring that it has an adequate concentration of oxygen. Fish cannot breathe atmospheric air and must rely on dissolved oxygen in the water to breathe (Doll, 2020). The bubbles cause a disturbance at the water's surface, promoting gas exchange between the ambient air and the water in the aquarium.



Figure 8. Air pump (ebay.com, 2021)

This device's airflow can be quickly regulated by using pneumatic control valves (Figure 8). They operate simply by twisting to open or close the tube. According to (fishlab.com, 2021) If the valve gets unscrewed all the way the air flow is 100% and if it is completely screwed in the air flow is almost 0%. However, screwing the valve all the way in can produce a lot of pressure on the pump (unless turned off).



Figure 9. Control Valve (fishlab.com, 2021b).

2.2.3 Cooling Device

An aquarium chiller operates in the same manner as a refrigerator does. A heat exchanger removes heat from the water that gets pushed through it. The chiller may get linked to the air pump, helping the process run more smoothly.



Figure 10. Aquarium Cooling Device (Gay, 2020).

2.2.4 Filtering Device

A filtration system is required to keep the tank functioning properly. The filter removes extra food, rotting materials, harmful chemicals, and fish waste products from water. Filtration implies fewer water changes and upkeep, since you have a cleaner tank for a longer time. If the debris doesn't get removed, not only will the tank seem unclean, but it may also accumulate poisons that are dangerous to fish and plants.

3. Systems within the aquarium.

3.1 Automatic feeding system

3.1.1. Fish detection system.

The species housed in the tank need to get fed regularly to ensure their health and well-being. The frequency and amount vary from species to species and should get tailored accordingly. However, rather than measuring the food and hand feeding each time, having this activity automatic would save a significant amount of time.

To begin, sensing fish movement will notify and activate the feeding system. LDRs, also known as photoresistors, are an excellent and inexpensive technique to detect motion. A bright light shining on the LDR causes the resistance to decrease, whereas a lack of it causes it to rise (Marian, 2011). It is straightforward to apply that process to an automated feeding system. The LDRs, uniformly spaced around the glass tube (Figure TBC), would detect the movement of the fish at various depths. When a fish approached the glass tube at a specific level in the tank, it covered the light behind it, activating the LDR reaction. At the bottom of the tank, the resistance value that triggers the response should get lowered, and at the top, it should be higher.

Fish like to feed at the surface of the water. The LDR will get triggered at the top of the glass tube more often than at the bottom. Different resistance values will ensure avoidance of overfeeding, reduce the risk of fish health, and also prevent waste of resources and money.

When fish aren't hungry, they usually spread over the aquarium and don't stay in one location, which reduces the possibility of the LDRs getting triggered when the fish are just floating around and aren't hungry. However, depending on the species, the level within the tank where the animals feed within the tank varies. Crabs, for example, generally stay near the bottom of the tank, implying that the LDR is constantly activated. In that instance, the feeding system gets activated a set number of times each day. This system is adaptable. The LDR's can get placed anywhere within the tank and can be programmed to get triggered for different values.

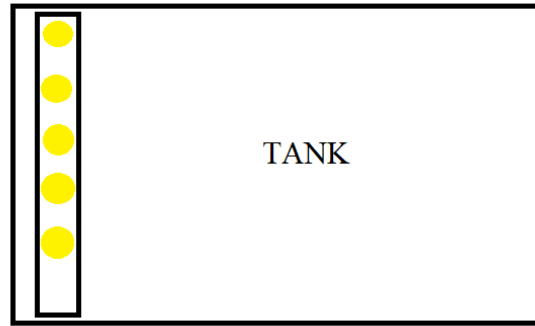


Figure . Representation of the LDR's placement in the tank.

The feeding tank will be installed on one of the aquarium's sides and connected to the tank through a tube. When the LDRs send a response signal to the automatic feeding tube, the hatch that connects the food storage to the feeding tube will open, as seen in the Figure. Once the system is up and running, the food will get distributed at full speed (the speed to be determined, but slow enough not to overload). The hatch is located at the end of the narrower tube and will close when the timer runs out. Gradually, the fish will begin to move away from the surface, causing the LDR to become less triggered. The speed of distribution of food will slow down. The velocity will decrease in percentages of 75%, 50%, 25%, and 0%. When the hatch reaches 0%, it gets closed again.

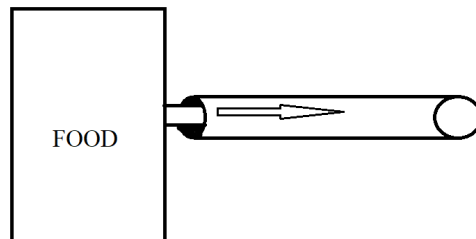


Figure . Representation of the food storage tank.

3.3 Water Condition alarm system

Regardless of the species cared for in the aquarium, they require consistent settings to support homeostasis (Oraby, 2020). Homeostasis is a process that living creatures use to maintain the reasonable circumstances necessary for life (Rodolfo, 2018).

3.3.1 Temperature Control System

Unlike humans and other mammals, aquatic animals do not produce their body heat. They must rely on the temperature of the water in the tank to maintain their body temperature (O-Keeffe, 2019). Out of range temperature can cause significant distress on the animals, even death.

I'd set up the temperature control system using a microcontroller Node MCU. A waterproof temperature sensor would get fully submerged in the water. This type of microcontroller migrates the data between devices using a wireless connection. I have chosen this type because it allows the simple transfer of data onto the database. The values collected by the sensor would then get processed through the Node MCU. The data would get sent to the cloud, available to view digitally. The data can then get used to producing graphs and tables.

Node MCU can be programmed to suit different purposes. In this case, water needs to get kept between $T1-T2$ °C (Assume $T1$ is lower and $T2$ is higher, for example, 20-25 °C).

`temp_sensor = GPIO1 (input for temperature sensor)`

Now, the temperature sensor gets set as General Purpose Input-Output 1.

Values of $T1$ and $T2$ then need to be set,

E.g. `high_temp = 25`

`low_temp = 20`

To maintain the water at a specific temperature, it will need to be heated or cooled. Depending on the output values of $T1$ and $T2$, the heater or cooler will turn on.

So, if the water temperature goes above the value of $T2$, it will be considered too hot and need to be cooled down.

`Cooler = GPIO2 (Output for cooling)`

Now, the cooler gets set as General Purpose Input-Output 2.

If the water temperature goes below T1, it will be considered too cold and will need to get heated.

Heater = GPIO3 (Output for heating)

Now, the heater gets set as General Purpose Input-Output 3.

The code for maintaining the right temperature in the aquarium would look like this, in simple terms:

```
if(temp_sensor >= high_temp) {  
    turn on cooler  
    turn off heater  
}  
if(temp_sensor <= low_temp) {  
    turn on heater  
    turn off cooler  
}
```

The code above basically means that if the temperature goes above 25 degrees (T2), the cooling device will turn on and the heating device will turn off. The heater and cooler cannot be running simultaneously, as the whole process would lose its purpose. It can only get heated or cooled at one time.

However, when the temperature recorded on the sensor gets below 20 degrees (T1), the cooler will turn off, and the heater will turn on.

3.3.2 pH Control System

The pH control system will also get controlled using the same Node MCU as for the temperature control system.

This time,

pH Sensor = GPIO4 (input from the pH sensor)

High_pH = pH1

low_pH = pH2

Keeping a constant pH level is very important for the well-being of the animals. However, it can be hard to automate the process. Instead, an alarm system can get created to notify the user when the pH

fluctuates out of range. A buzzer and possibly an orange LED on the side of the tank. Bright colours and the alarm should hopefully catch the attention needed to resolve the issue.

```
if(pH_sensor >= high_pH) {  
    send off warning to buzzer, led  
}  
if(pH_sensor <= low_pH) {  
    send off warning to buzzer, led  
}
```

Regardless of whether the pH is too low or too high, an alarm will turn on so that the issue can be manually fixed by adding needed chemicals.

5. Hazards

4.1 Personal Safety

In some instances, fish may transmit disease to humans, which is rare. If an infected fish is in the tank, the bacteria can enter your body through even the tiniest cut or scrape on your skin. Simply placing your hand in the tank to move a decoration, brush algae off the glass, clean a filter, and so on might expose you to the illness. Even though this is a low-risk scenario, it is essential to have your skin covered when working in the tank. Full-length reusable or disposable gloves are readily available and inexpensive. A long-handled set of tongs is another suitable piece of equipment for moving or picking up anything in the tank. Even if you're using gloves, wash your hands and arms after using the aquarium.

4.2 Animal Safety

Wires and electronic devices in the proximity of the aquarium can pose an electrical hazard. Before running the tank, a risk assessment must get performed. All potential hazards must get documented and examined regularly. Regular inspections are essential to guarantee that the animals and people's health get safeguarded.

It is critical to ensure that there aren't any fractures in the tank glass and that there are not any water leaks. Every plug should feature a 'drip-loop' (Merriam-Webster.com, 2021) so that when the water drips on the cable, it does not run directly into the socket but rather drips down the wire. There should be no unsecured cables above the tank, since they might electrocute the organisms in the water if they fall.

A drip-loop is a descending loop (such as a wire entering a structure to enable rainfall to drop or a pipe to collect water condensed in the pipe system) (Merriam-webster.com, 2021).

Powders and liquids used to keep the water in the tank in pristine condition constitute a chemical hazard. Only authorised individuals should have access to these and get instructed on how to utilise them. To avoid unauthorised use of the chemicals, it would be a good idea to store them in a cabinet with a lock.

Furthermore, all bottles and containers with chemicals or food should have unique labels, usage instructions, and expiration dates.

6. Conclusion

An automated control system for an aquarium will save time and decrease human error. A healthy aquarium needs specific parameters, such as a correct temperature. Endangered aquatic species are very susceptible, and extra precautions must get taken to protect their well-being. The tank must be clean, contain enough oxygen, and be safe for the animals. I proposed a handful of control methods to meet those criteria with as little human interaction as possible, freeing up time for other vital duties like data analysis. Data collecting is difficult and time-consuming; it's possible to make a human error, which may get avoided by employing electronic devices.

The report's recommended automated feeding system will save time measuring food and manually feeding the fish. Data on how frequently the fish are getting fed may get collected. The variety of velocity speeds at which food gets dispensed reduces resource waste.

I created a control system for temperature and pH control using a microcontroller – Node MCU. A fully automated temperature control system needs minimal or no human interaction. Without needing to do anything, the water gets either heated or cooled. I researched many types of heaters and would recommend the submersible heater. I considered simplicity of use and hazard constraints when evaluating available options. The heater gets fully submerged in water and poses no electrical dangers.

I also looked at several sorts of standard thermometers. I would indeed recommend using a digital thermometer in the tank. Regular checks against the Node MCU's acquired data will reduce any chance of error. However, automating a pH control system is a little trickier. The pH level gets recorded automatically. However, instead of taking corrective action, an alert system gets activated. Typically, chemicals must be carefully measured and mixed into the tank to correct the pH, limiting the alternatives for further automating the procedure.

Aquatic creatures do not breathe atmospheric air and require an air pump to allow oxygen to dissolve in the water (Doll, 2020). I proposed utilising a pneumatic control valve. The valve allows adjusting the amount of air discharged into the tank.

Finally, the aquarium tank must get kept clean to protect the animal's health. An aquarium filter is an efficient tool for doing this. It suctions water through the tube, through a replaceable filter and back into the tank.

Automating the tank using these methods will save a significant amount of time and resources. However, I believe that employing a hydraulic power unit would be helpful to the entire plant. A hydraulic tank performs several vital tasks. It usually contains many filters, each with its pump and motor. They are more efficient than store-bought filtration equipment, especially in big tanks. Big tanks may require more than one ordinary filter. The hydraulic power unit also has coolers and heaters which are a lot more powerful compared to store-bought.

According to (AHE News, 2018), a hydraulic power supply system may also regulate the pressure. It can either raise or lower it depending on the case. Because pressure buildup can often go undetected by humans, automatically-regulated pressure is an advantage.

Overall, using a hydraulic power unit would be beneficial. The system would boost the overall efficiency of the plant by utilising more contemporary technologies.

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