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Design And Development of An Intelligent Water Discharger

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Abstract:

The present invention relates to an IoT based/integrated device for regulating water flow through taps. More specifically the invention relates to a device wherein water flow is regulated by fitting the device to any existing tap to optimize the flow of water to measure water consumption and conserve water.

Keywords: Water Conversation, 3d Design, Aerator, Esp8266, IoT device.

1. INTRODUCTION

‘‘When the well is dry, we know the worth of water” (Benjamin Franklin).

Water is the most valuable resource needed for the functioning of all life forms on earth. Earth is referred to as the ‘blue planet’ due to the abundant presence of water on its surface. Around 75% of the earth’s surface is covered by it. Water is not only essential for life, but also the elixir of the global economy through its various uses in agriculture, manufacturing, and energy production. The challenge is that the majority of available water on the earth’s surface is seawater which is unfit for human consumption and unfavorable for industrial uses. Less than 3% of the water on the earth is freshwater. Moreover, increase in population and the rise in the global economy has resulted in a boom in resource consumption implying increased utilization of global freshwater. Globally, freshwater consumption per year has increased by 600% since 1900. The rate of global freshwater use increased sharply from the 1950 onwards, but since 2000 appears to be plateauing, or at least slowing [1]. The chart for global freshwater utilization since 1900 is shown in figure 1.

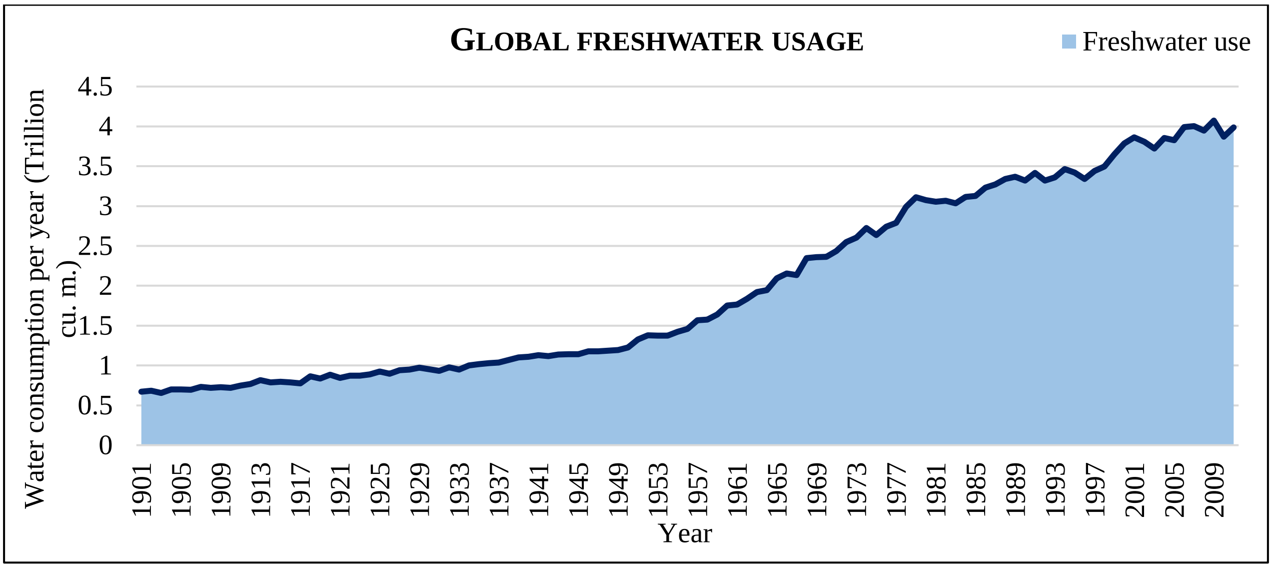


Figure 1: Global water consumption since 1901 till 2014

As explicated above, about 2.5% of the water is freshwater and can be used for human consumption. The remaining 97.5% is saline and deemed unfit for consumption. Out of the freshwater, around 68.7% is 'locked' in glaciers and ice caps, 30.1% as ground water and remaining 1.2% is available as surface water [2]. The stacked bar graph representation of the water sources is shown in figure 2.

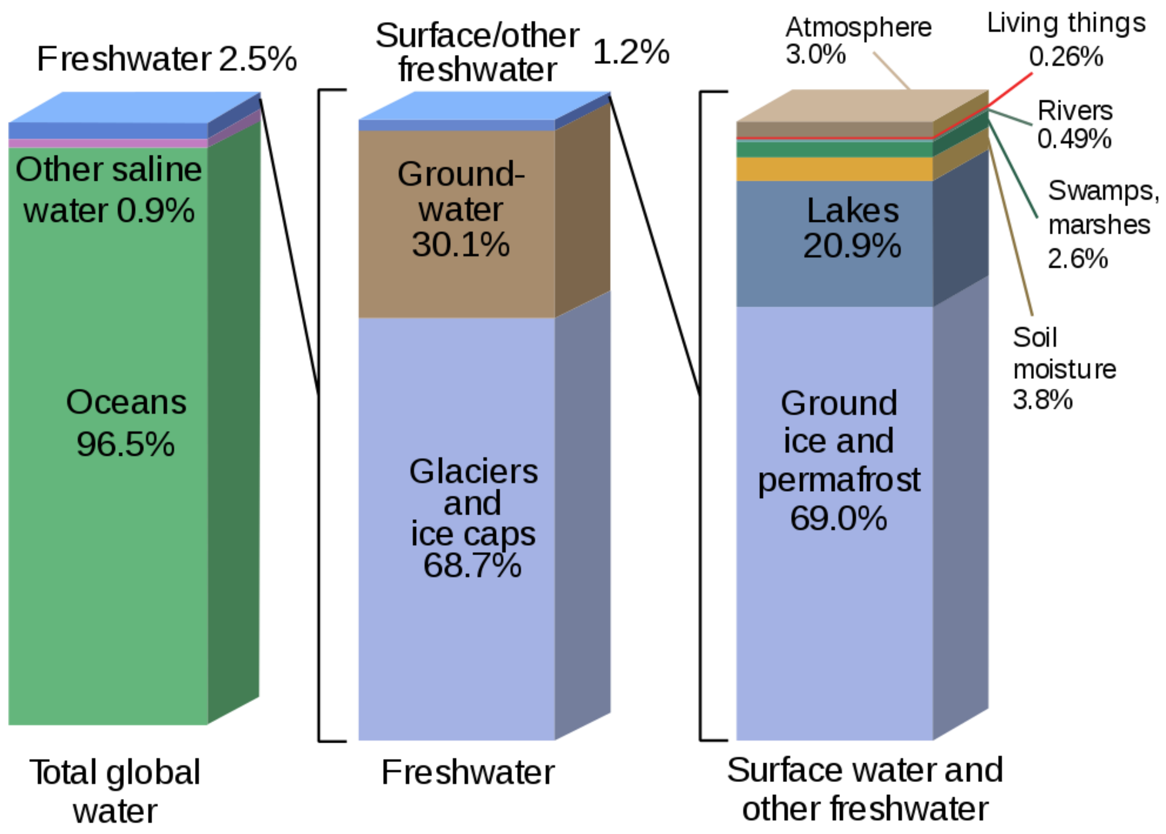


Figure 2: Stacked bar graph representation of the water on Earth

Water is used for direct as well as indirect purposes. Direct purposes include drinking, cooking, and bathing, while examples of indirect purposes are the use of water in agriculture, industry, producing electricity, etc.

India's water consumption is increasing by 6.104 billion m^3 of fresh water each year [3]. In 2010, the per capita freshwater consumption in India was about 602.3 m^3 per person per year [4].

India is one of the largest consumers of agricultural water, using up about 70% of the total freshwater withdrawal [3] and irrigating approximately 38.06% of the total agricultural land [5]. Likewise, India's industrial water withdrawal is pretty high, almost consistently withdrawing 17 billion m^3 of water per year since 1975. Furthermore, there is a steep increase in the usage of freshwater in households and public services in India. In 2010, about 7.36% of the total freshwater was used in this sector, which can be quantified as an increase of 56 billion m^3 of freshwater usage from 11.40 billion m^3 in 1975 [3]. Although wasting household water does not ultimately remove that water from the global water cycle, it does remove it from the portion of the water cycle that is readily accessible and usable by humans. Also, "wasting" water wastes the energy and resources used to process and deliver the water.

1.1. MOTIVATION AND NOVELTIES

Taps have been used in households for more than a hundred years, without any improvement in the amount of water they discharge. They are accompanied with problems of leakage, fixed flow rate, and unnecessarily high rates of water dispensation than required for most activities.

As per the article [7], around 10% - that is about 25.5 gallons or 96.23 liters - of fresh water is wasted per day due to water leakage. In the same article, authors concluded that people could be able to complete their household chores with 30.2% less water with proper curtailment techniques. Moreover, the 'Renewable internal freshwater flows (RIFF)' refer to the internal renewable resources (internal river flows and groundwater from rainfall) in India as about 1080.17 m^3 per person per year which is very little as compared to countries like Canada, Russia, Bhutan. The rate of RIFF per capita has declined tremendously since 1975 at the rate of 65% per year [8].

Another consideration that motivated this project was the glaring disparity between the water consumption in urban areas and rural areas in India. In urban areas, 96% have access to an improved water source and 54% to improved sanitation. Whereas in rural areas, which accounts for 72% of India's population lives, only 84% have access to safe water and only 21% for sanitation.

The problem of water shortage has led to development of devices called 'aerators' in the market to reduce waterflow in households. Aerators in the present art have nozzles of fixed diameters which decrease the amount of water reaching the user by atomizing the water into droplets. However, this flow is fixed for a given nozzle diameter. Moreover, no device at present allows the flexibility to the user to regulate or alter the flow of water as per need, which is crucial as different amounts of water are required for different activities. Further, there is no mechanism to collect data on the quantum of water that has been wasted.

This motivated me to design and develop an intelligent water discharger that fits in the regular water tap of the kitchen sink and bathroom. The water discharger is a self-adjustable device operating on three different discharge capacities. Depending on the nature of the work the water discharger gets adjusted to the suitable discharge mode.

Improvements on the model include orifices of varying diameter to allow different rates of waterflow for different activities, devices with motion sensors that facilitate touchless operation of taps (an absolute requirement for current times), and an IoT interface to track water usage to generate user awareness.

2. RELATED WORKS

In the literature, there exist several state-of-the-art articles to design an intelligent water discharger. One of the most successful ways is the application of a microcontroller (MC). In [9], the authors applied MC to control the temperature of the water dispensed from the discharger. In the paper, the authors achieved the objective with several embedded filtering algorithms to deal with the temperature sampling errors resulting from the relatively poor sensitivity of the sensor. MC is also used in the patent [10] to fix the water supply control at a constant temperature by mixing hot and cold boiled water. In [11], MC is used to control the valve of the water discharger based on the height of water in a cup.

The second most successful way of designing a water discharger is the application of the Internet-of-things (IoT). In [12], the authors proposed a power-saving IoT-based water dispenser system. In [13], the authors proposed an IoT based water monitoring system to measure the water level in real-time. The same problem was tackled in the paper [14] by using Arduino and ultrasonic sensors. The design is also equipped with a user-notification module to notify the user in case of a low water level. In article [15], the authors proposed a water quality monitoring module and a self-healing algorithm to reduce human intervention and continuous data collected in remote areas. Many other papers were reviewed for the present study but limited the section to the most recent and significant state-of-the-art articles.

3. DESIGN AND DEVELOPMENT

The objective of the optimization and development process was to automate the current aerator available in the market. The aforementioned aerator is a device that is attached to a faucet. The aerator prevents the water from splashing by shaping the water stream coming out of the faucet spout. It also normalizes the stream water pressure, thereby conserving water. Below is the figure of the simple single action aerator.

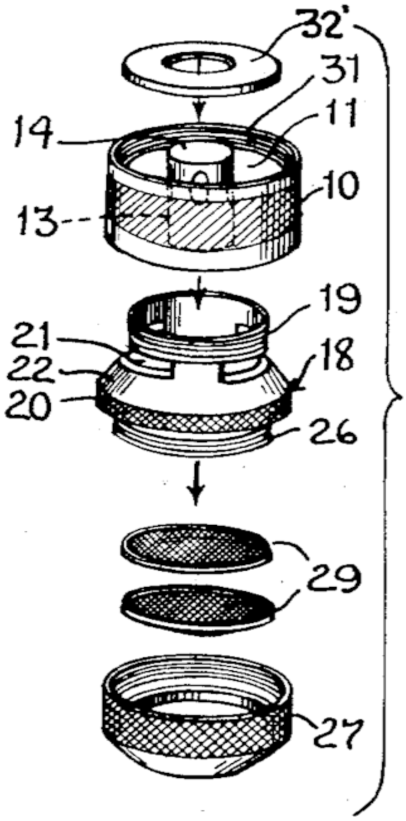


Figure 3: Aerator exploded view

The present project involved the usage of the ECO365 dual-flow aerator; the multi-action aerator allows not only streamlining the water pressure but also has two filters for flow.

The optimizations made on the device include the addition of an electrical circuit and gear assembly to enable automatic, gesture-controlled mode change as well as recording data of water consumption in different activities to be stored on the cloud and be used for tracking the daily use of the water and water saved using the device.

3.1. System architecture

The design of the product was created on Fusion 360 which is a $3D\ CAD,\ CAM,\ and\ CAE$

tool of its kind. (It connects the entire product development process in a single cloud-based platform that works on both Mac and PC and has many features accessible from a web browser.)

The product uses two IR sensors for automatic operation. The servo motor is used as the main actuator that activates the mode of the aerator, and another actuator is the Bistable valve that turns 'on' or 'off' the water flow. All the sensors and the device are connected to the ESP8266 controller - the main controller on the device.

1 ESP8266 - The central controller on the device, ESP8266 is the low-cost Wi-Fi controller with a built-in TCP/IP stack and a 32-bit RISC microprocessor running at 80 MHz It has 32 KiB instruction RAM 32 KiB instruction cache RAM 80 KiB user-data RAM 16 KiB ETS system-data RAM. It supports IEEE 802.11 b/n/g Wi-Fi. The rationale for the selection of this component was its:

- Compact size
- Wi-Fi availability for IoT interfacing
- Low cost and compatibility

Figure 4: NodeMCU

2 Servo Motor - A servo motor is a rotary actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback.

Figure 5: Servo Motor

In the product the Tower Pro™ micro-servo motor is used. which uses the potentiometer internally for feedback. The rationale for the selection of this component is its:

- Compact size
- Precision
- Inclusion of a rotary encoder for absolute position determination.

3) IR Sensor: - The product uses the Two IR sensors: one to activate the valve and another placed parallel to it but in the opposite direction for mode selection. the IR detector is the photodiode-based detector and is calibrated to work on all skin tones in indoor ambient environments.

Figure 6: Digital Ir sensor

4) Bistable Valve: - It is a unidirectional bistable electromagnetic valve that can switch between the ‘on’ or ‘off’ resting position through the application of current. The product uses this valve because it requires electric power only for state change; power is not required keep the valve ON or OFF. This makes it more energy-efficient and thus environmentally friendly.

Figure 7: Bistable Solonide Valve

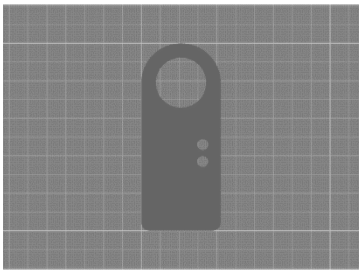
3.2. PLA Components

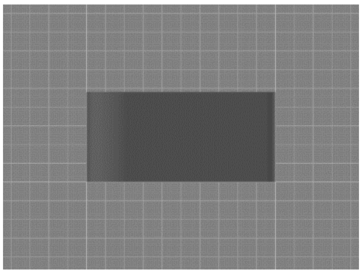
The list of components designed and assembled to get the final product are tabulated in table 1.

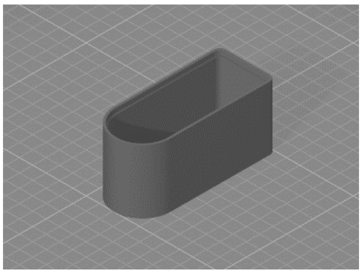
Table 1: List of tables:

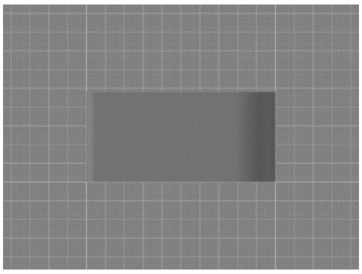
Sl. No	Name of the component	Usage
1	Aerator	To have different modes of water dispensation.
2	Servo Motor	To rotate the gear assembly that allows for automatic mode change.
3	Aerator attachment	Attaches to aerator to mesh with servo motor.
4	Top assemblies	Housing the valve and the aerator.
5	Bottom cover	Watertight housing that encloses all the devices.

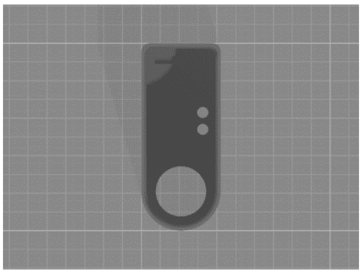
The orthographic views of the components from the first angle projection method are shown in figure 3.


(a) Bottom view

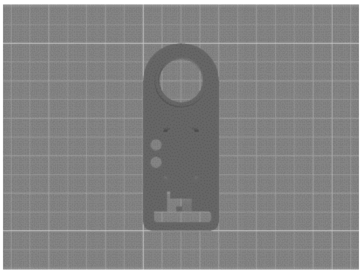

(b) Right-hand view

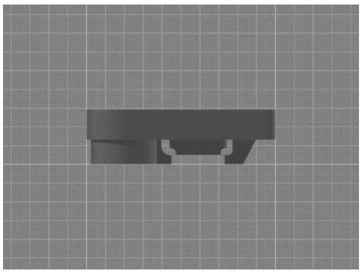

(c)

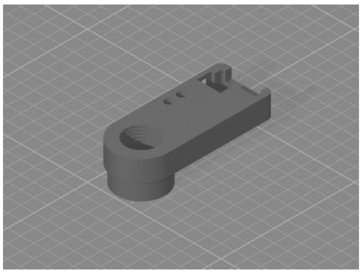

(d) Left-hand view


(e) Top view

(i) Component 1


(a) Bottom view


(b) Right hand view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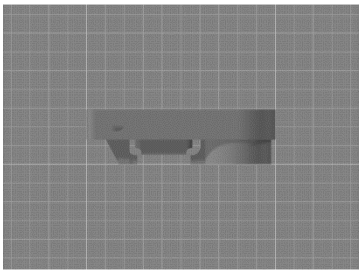
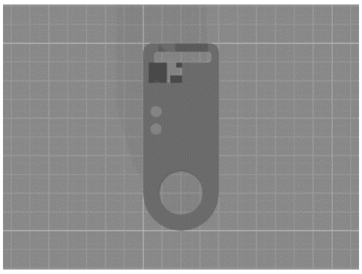
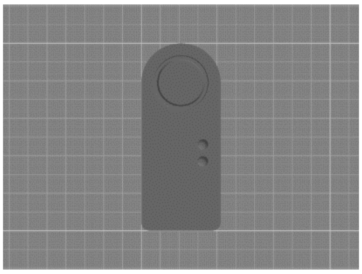

(d) Left-hand view



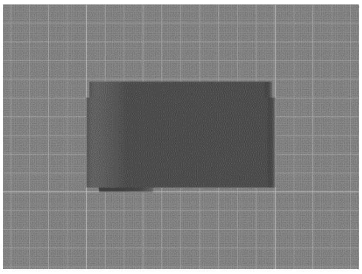
(e) Top view

(ii) Component 2

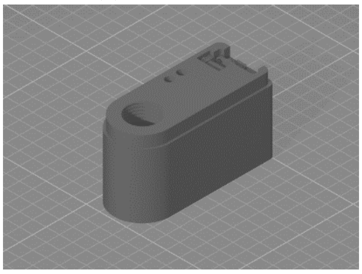
(iii) Component 3



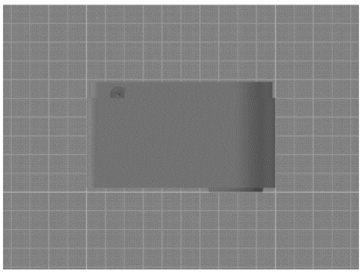
(a) Bottom view



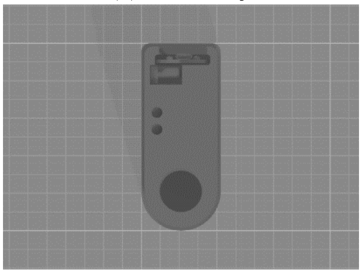
(b) Right-hand view



(c) Assembly



(d) Left hand view



(e) Top view

(iv) Assembled product

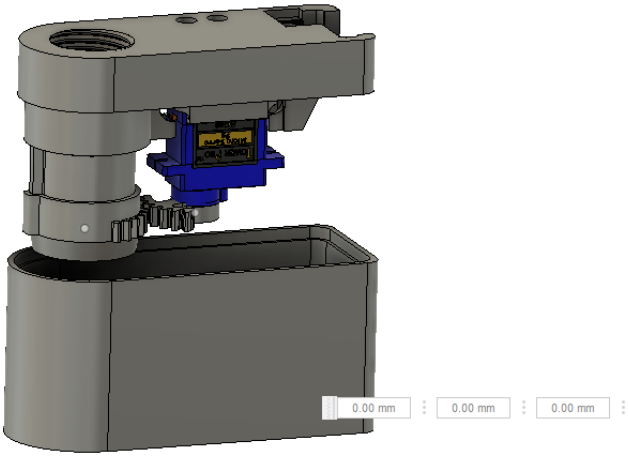


Figure 8: Full Assembly

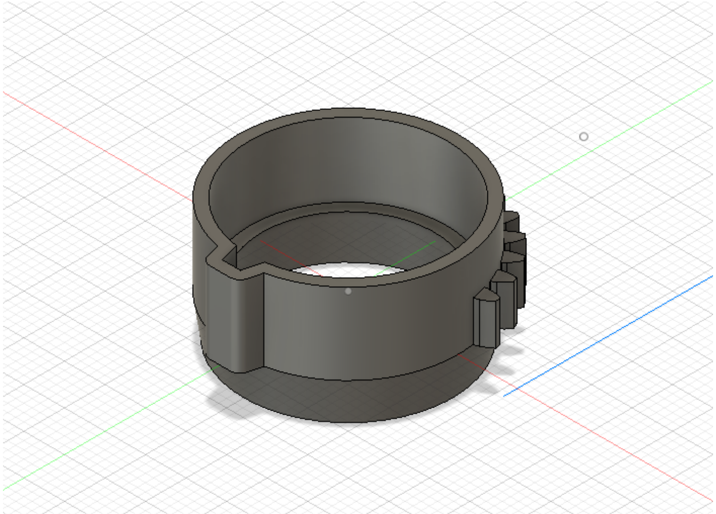


Figure 9: Aerator attachments

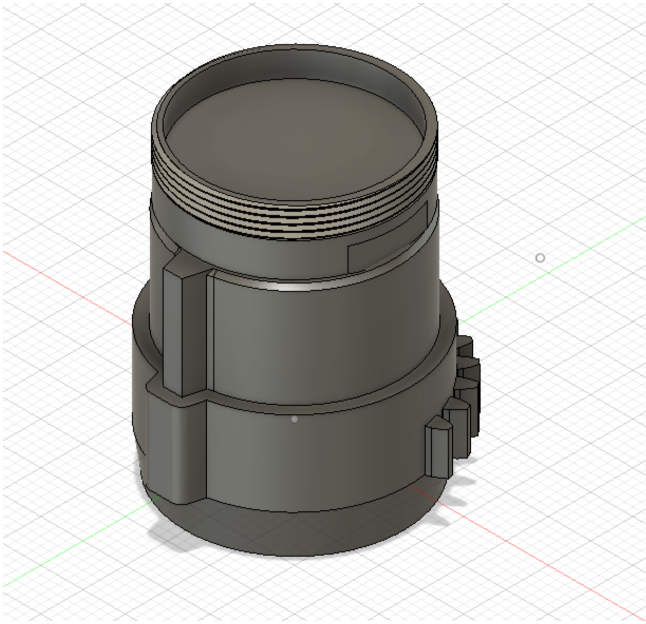


Figure 10: Aerator attachment

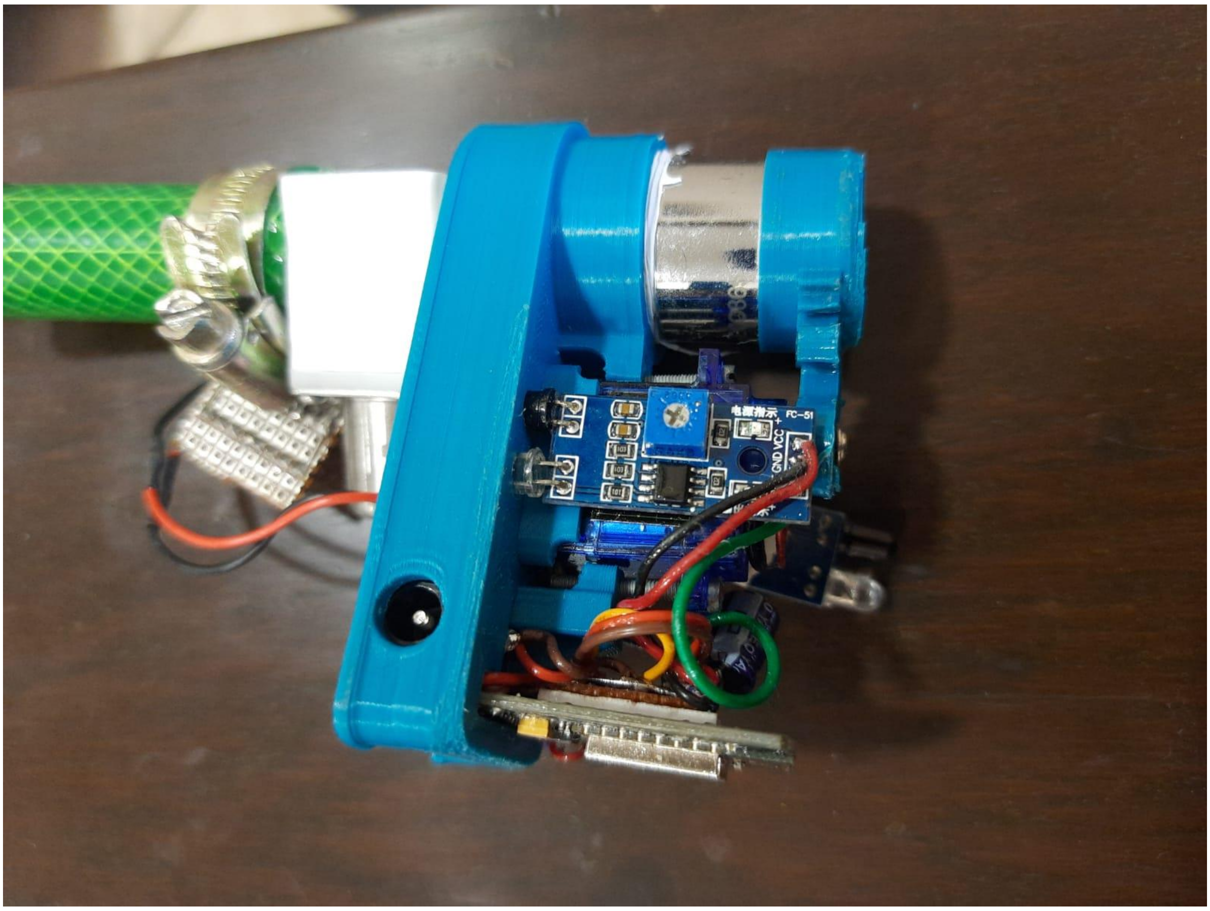


Figure 11: Original Image of device

Figure 12: All Prototypes

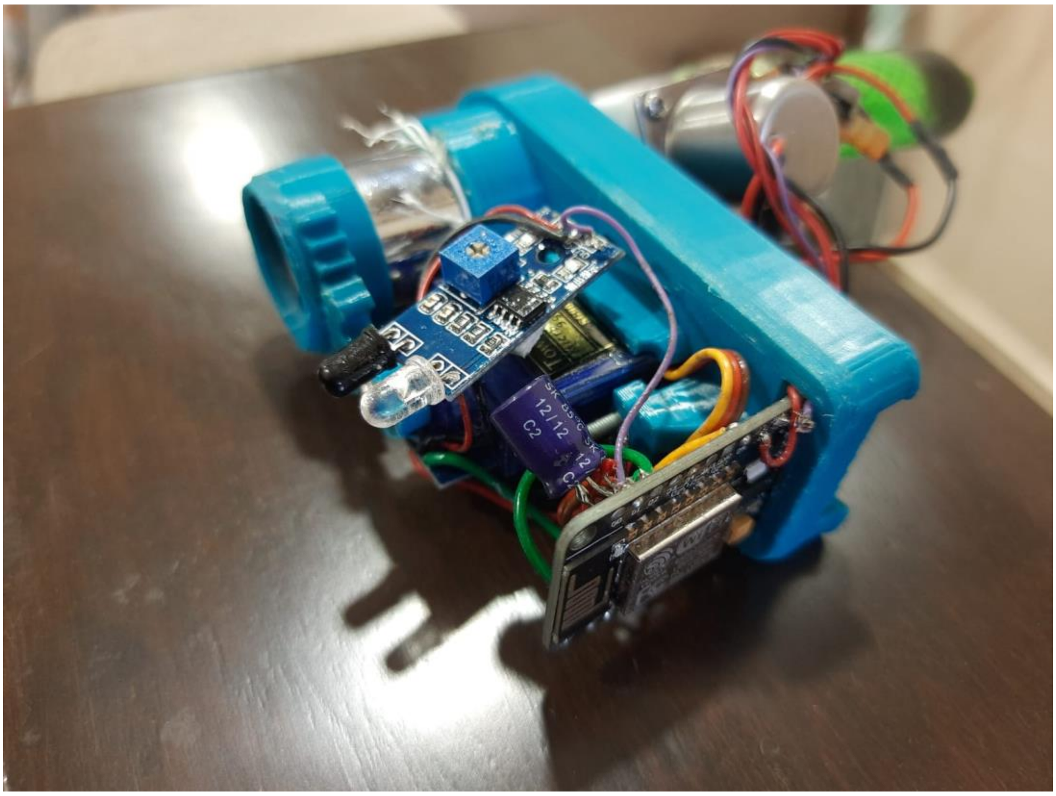


Figure 13: Interview of original device

3.3. 3d printing:

3d printing is additive manufacturing, it is the construction of a three-dimensional (3D) object from a CAD model or using the computer-generated 3D file, the CAD model is then saved in stereolithography file format (STL), SLT is the default file format for additive manufacturing it stores the data based on triangulation of the surface of the CAD model

Once the STL file is created the file is passed to the new software called slicer, which converts the model into a series of thin layers and produces a G-code, the G-code file is what is understood by the 3d printer.

3D printers mostly use the polymer-based material to print in the prototype bloom we are using the PLA polymer.

3.4. Data Collection

The product was once assembled and tested in the actual condition for two days without aerating the normal water pressure. We recorded the flow of the water from the faucet and recorded the values while doing various activities such as washing hands, utensils etc. The data can be summarized in the following tables.

Figure 14: Water flow Without Aerator

Figure 15: Flow With Aerator in Shower Mode

Figure 16: Flow With Aerator in Foam Mode

Time taken to dispense 100 mL at Maximum Flow Rate/ s								
Without Aerator			**With Aerator, Shower Mode**			**With Aerator, Foam Mode**		
Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
3.68	3.60	3.67	6.54	5.96	6.79	86.71	89.65	87.32
3.65			6.43			87.89		

Time taken to dispense 100 mL at Lesser Flow Rate / s								
Without Aerator			**With Aerator, Shower Mode**			**With Aerator, Foam Mode**		
Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
5.23	5.54	5.12	8.92	9.34	9.21	93.44	92.29	93.98
5.30			9.16			93.24		

Mode	**Flow Rate (L/min)**
Maximum Flow	
Without Aerator	1.64
With Aerator, Shower Mode	0.93
With Aerator, Foam Mode	0.068
Lower Flow	
Without Aerator	1.15
With Aerator, Shower Mode	0.66
With Aerator, Foam Mode	0.064

Percentage Saving of Water with Shower Mode at Max Dispensation = 43%

Percentage Saving of Water with Foam Mode at Max Dispensation = 96%

Percentage Saving of Water with Shower Mode at Lower Dispensation = 43%

Percentage Saving of Water with Foam Mode at Lower Dispensation = 94%

The above results indicate that the flow rate with aerator was quite less so the device helps in saving the water and logs the data in an online server.

4. Advantages of the Invention:

1. Atomizing the stream of water, thereby reducing water flow rate
2. Provision of multiple modes, including economic, regular and heavy, for waterflow depending on requirement by user
3. Contact free operation through hand gestures
4. Mechanism for data collection and analytics on water usage thereby creating user awareness.

5. Conclusion:

We can conclude that we have designed an optimized product that can be retrofitted on the market available aerator, it can log and automate the flow of the water according to the use. as tabulated in the result in a day we can save up to 96% water by using the device.

Acknowledgement

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