HydroPro: An IoT-based Smart Water Bottle

1st Aadi Nirbhavane
Amity International School
Delhi, India
aadinirbhavane28@gmail.com

2nd Riti Kushwaha
School of Computer Science and Technology
Bennett University
Greater Noida, India
riti.kushwaha@bennett.edu.in

3rd Gaurav Singal
Computer Science and Engineering Department
Netaji Subhas University of Technology
Delhi India
gaurav.singal@nsut.ac.in

4th Abhinav Tomar
Computer Science and Engineering Department
Netaji Subhas University of Technology
Delhi India
abhinav.tomar@nsut.ac.in

5th Vipin Pal
Computer Science and Engineering Department
Netaji Subhas University of Technology
Delhi India
vipin.pal@nsut.ac.in

6th Ankur Gupta
Department of Computer Science
Rishihood University and Newton School of Technology, Sonipat, India
gupta1990.cs@gmail.com

***Abstract*— Water is a necessity for the correct functioning of the human body. In the modern era, most people have hectic schedules, making it difficult for them to remember to drink enough water and track their water consumption. This problem of not being able to track the daily water intake becomes even more pronounced for people of older age groups. In addition, people on medications also require strict water intake to dilute the toxins that the medicines introduce in their body. We present our product – HydroPro, a smart water bottle aimed at encouraging our target audiences to better their hydration habits. Our product gives a more personalized water tracking facility to the user wherein we take the user's environment parameters into account (namely temperature and humidity) to notify the user whether they have consumed enough water. The objective is to enable effective management of daily water requirements and to ensure users drink good quality water. The result shows the working effectiveness of smart water bottle system which is also tested and validated on mobile application.**

Keywords—Internet of Things, Smart water bottle, Clean Water, Drinking

I. INTRODUCTION

One of the most important factors for a healthier life is proper hydration. In recent times, schedules are hectic, and people tend to be constantly occupied, and may often find it difficult to remember to drink enough water or even track their consumption. A study was conducted with professionals and university students all under the age of 50, and the results showed that over 70% of the consensus noted forgetting to drink water. The problem of dehydration is much more fatal for older adults. Due to slight impairing of the central nervous system with age, older people tend to not sense the feeling of thirst as attentively as they may have when younger. And this could be a bigger problem as some medications they may be on cause fluid loss. The existing smart water tracking systems have various shortcomings that can be improvised to build a smarter product. Most prototypes of this genre have a typical characteristic of a water container connected with varying sensors and usually have a display to notify the user about the water level. However, these prototypes do not consider the environmental conditions of the user which plays an important role in determining whether the user has consumed enough water. So, we aim to build a more personalized smart product for a wide range of target audiences [1].

Exponential growth of the number of physical objects connected to the Internet, also known as Internet of Things or IoT, is expected to reach 75 billion devices by 2025. IoT is gaining momentum worldwide and has been used in various domains [8-13] to develop smart solutions by employing ICT technologies. These novel solutions connect many devices, such as watches, spectacles, shoes, camera systems, etc. to Internet and such devices are used to gather data to provide smart services to uplift the human life. A water bottle can be thought of a personal device that everybody uses irrespective of their profession or age. Integrating the water bottle with smart technologies provides an innovative solution to monitor the water consumption and water quality. Most smart bottles currently available in the market are not customized to the user's drinking habits. They arbitrarily remind the user to drink water every hour. Hydro Pro on the other hand tracks the user's drinking habits and notifies them only when it is necessary. Our product also takes the environment (temperature and humidity) into account while deciding the adequate amount of water to be consumed every day. It also helps the user track their heart rate which can be extremely useful for fitness-oriented people [13]. The concept is unique in that the product offers users a personalized experience while methodically taking charge of their daily water consumption.

The motivation for building this smart water bottle was to cover a wide range of demographics. Hydro Pro is great for assisting people who are health conscious or fitness enthusiasts. The product will help to cut back on sweet drinks and sodas, help with weight loss, appetite control and, achieving fitness goals. It will also assist people in the older age bracket (60+) who require hydrating more often for compensating for changes that occur in the body's temperature regulation mechanism. Dehydration can adversely cause several ailments, such as fatigue, heat exhaustion and muscle pain. Older adults are urged to drink water even when they aren't thirsty and to limit beverages such as soda, coffee, and alcohol, which can cause dehydration. The smart water bottle is also aimed at people who are on medication. Certain medications need to be taken with plenty of water.

Keeping our target audience in mind, our objective is to achieve a wide range of functionalities and design a IoT-based smart water bottle. We name it as HydroPro. Following contributions have been made:

- Our paper entails the usage of temperature and humidity sensors which would sense the parameters of the surroundings of the user, and incorporate the data collected into calculating the appropriate amount of water to be consumed. The intuition behind this feature is that on hot and dry days more fluids need to be consumed by a person to regulate body temperature.
- We aim to have a lighting system on the water bottle which indicates the urgency with which the user needs to consume water.
- We also aim to have a level detection system built using an ultrasonic sensor to detect when the bottle needs to be filled up again and if the user has had adequate water.

2024 IEEE Region 10 Symposium (TENSYMP) | 979-8-3503-6486-6/24/$31.00 ©2024 IEEE | DOI: 10.1109/TENSYMP61132.2024.10752312

LED display showing heart rate/pulse rate etc. which can be a useful feature for workouts.

By increasing consciousness about the users' daily water consumption, this technology promotes greater individual awareness. As underlined above, water is essential for the smooth functioning of the body and a callous approach towards its consumption can have debilitating consequences, such as irritable bowel syndrome (IBS), kidney stones, lethargy, and a weakened immune system. Hence, the risk of dire medical conditions is greatly lowered. This allows not only for better wellbeing but is also financially beneficial for the user by reducing the need for expensive hospital visits and painful medical procedures.

This paper is organized as follows: Section II presents Literature Summary. Our approach is explained in Section III. Thereafter results are presented in Section IV followed by observations. Finally, work is concluded in Section V.

II. LITRETURE WORK

In the past years, there have been studied much research related to smart bottle models of hydration reminders. The overall goal was to remind humans so that they can intake adequate water in the body at the right time so as to make body stable.

Most of the studies have worked on designing a tool using sensors that have been connected to the microcontroller and GSM. After verification and validating the proposed study in [4], the sensor can be placed inside a water bottle to measure water levels as low and high, the measurement results obtained will be sent to the microcontroller and then processed and forwarded to the GSM modem using the SIM card and will arrive at the smartphone. Another research has been proposed in [7] on Smart Water Bottle. The objective of this research was to estimate and control the amount of liquid poured out of the bottle with the help of a random injection and accelerometer. In the study [14], touch and photoplethysmographic sensors were used by the rapid measurement of the amount of liquid inside the bottle, monitor activity using inertial sensors, and physiological parameters.

Apart from the existing research works which are based on regulation of smart water bottles, there have been devoted many studies on the importance of water intake for health because it helps build respiratory resilience, especially among parents, even research has been conducted that older people around the age of 50 - 60 years rarely feel thirsty [6]. There is another research proposed in [15] which is on the calculation of the decision maker for fluid deficiency using the fuzzy logic method. In this proposed study, there is a prediction of the level of water consumption by using a function of individual weight, activity and weather which is the primary reason of utilizing the fuzzy logic method in their research.

After scrutinizing the existing works, it is concluded that given the smart concepts are gaining momentum to provide a solution to sustainable problems. So, the existing limitations paves the need to do further research on smart water bottle system which lays the foundation of proposed work.

III. SYSTEM STRUCTURE AND PROPOSED METHODOLOGY

Similar to the proposed paper, there have been countless ventures that utilize sensors to bring about profitable advancements in the field. These sensors generate large volumes of data, which is often referred to as big data, and the analysis of this data becomes very crucial to the success of any venture. To comprehend this sensor data, we introduce the concept of context-aware computing [2].

A. HARDWARE AND SOFTWARE REQUIREMENTS FOR THE PROTOTYPE

The smart water bottle designed had the following hardware components:

- Two NodeMCU ESP8266 boards wherein one was utilised for the inputs and the other for taking output [14].
- A DHT11 temperature sensor (for measuring ambient temperature)
- A DS18B20 temperature sensor (for temperature measurement inside the bottle)
- A photoresistor (for light measurement)
- An HC-SR04 ultrasonic distance sensor (for measuring the water level)
- A piezo speaker (for drinking reminders)
- A 7-Segment display with TM1637 driver (for numerical water level display)
- NodeJS software
- Python 3.6 version or later versions
- The NodeMCU boards should contain the latest version of MicroPython flashed

B. HARDWARE AND SOFTWARE REQUIREMENTS OF THE IMPLEMENTATION

The smart bottle is integrated through an ultrasonic sensor, a push button, a NodeMCU and a LIPO battery. The controller communicates with the cloud using ESP8266 12-E wireless interface. Data is processed from the bottle and sent to the cloud – thingspeak [3].

C. IMPLEMENTATION STEPS

The implementation of the system has been done as follows:

1. The Ultrasonic Sensor and pushbutton are integrated with the NodeMCU digital I/O pins.

2. The ultrasonic sensor helps to send the distance of the water level from the cap of the bottle.

3. Based on the measurement of the distance of the water, the controller calculates the percentage of water consumed and transfers it to the thingspeak cloud using an http POST request. Similarly, the push button also detects the pressed event and reports the event to the thingspeak cloud.

D. SYSTEM ARCHITECTURE

Various types of sensors are installed on the smart bottle to sense the different parameters. The sensed data is processed using the logic written inside the controller and actions are performed according to varying conditions. The values of temperature and humidity are collected by the temperature and humidity sensor and are sent to the controller. Depending on these values, the controller then calculates the water that should be consumed and displays the same on the screen. The stress level of a person is detected by the stress level sensor when it is touched while drinking or holding the bottle which sends this level value to the controller. If it is detected that the stress level is above the predefined threshold, the user will be indicated to drink water with the help of LED lights. The function of controller is to compare the values of the different parameters with the predefined threshold values [5]. If value of any parameter is unacceptable, the user will be notified with

red color LEDs. All information will be logged so that the user can be aware of the values of the different parameters and the water intake throughout the day. If the level of water becomes lesser than 25%, the LED strip will glow blue in color thereby indicating that the bottle needs to be refilled with water. A daily basis report can also be viewed on the user's mobile phone with the help of a user-friendly UI.

Hardware: The weight sensor installed in the water bottle detects the amount of water in it. It also has the feature of storing pills. The bottle can interact with devices with the associated application installed. Thereby allowing the exchange of information [6].

Software Application: The app has functionality for managing, recording, and setting alarms for drinking water. Users are also provided with the recommended target intake amounts and a guide for them to consume appropriate amount of water based on their ages.

Interfacing Hardware and Software: The sensor in the bottle senses the amount of water that is consumed in real time and sends the information to the app. The app then analyzes this shared information, and then assists users to manage water intake by pushing alerts for their hydration status and a recommended time for their next drink.

A sensor (FDC1004) for detecting the level of liquid was embedded inside the bottle for measuring the water intake. This sensor calculates the water level by computing the capacitance level at the six copper plates placed between the walls of the smart bottle. Raspberry Pi can interpret these values of capacitance and corresponds them to the resistance wire [7]. This mechanism is exploited along with use of thermochromic paint for indicating the level of water on the external surface of the bottle. Context-aware computing is essentially a paradigm wherein context information linked to data generated by sensors is stored in a manner that allows easier and more meaningful interpretation of the same. Further, once context is understood, machine to machine communication in IoT becomes easier. From our reading, we learnt the very fundamentals of context-awareness, how it ties into IoT as a whole, and some challenges in future research in the field [8].

While implementing this prototype we must also make the network secure and connected for all the durations [8, 9, 10]. It can also lead to data breaches of personal user data to know the uses pattern [11]. So, data communication medium and protocol should be protected and encrypted, so there are no possibilities for any kind of malicious activity [12].

E. METHODOLOGY

The approach for the development of the Hydro Pro water bottle system has been structured around the functionalities provided in the product. There were three primary phases for the same, as elaborated below. Each phase involved working on a particular subset of features of the product.

I. Functional Prototype on Hardware

In this phase, the blueprint of the product was laid out by analyzing the intended functionalities and determining the hardware components required for the same. These included: HC-SR04 Ultrasonic Sensor - The HCSR04 distance sensor computes the distance between itself and a target object by measuring the amount of time elapsed between the transmission of an ultrasonic pulse and its reception. This sensor has been applied in our product in order to track changes in the level of water within the smart bottle. The data so picked up by the sensor is sent to the cloud, from where the Android application takes note and updates the daily water intake progress accordingly.

DHT22 Temperature and Humidity Sensor - Humidity is measured using a capacitive humidity s sensor and the temperature is measured using a thermistor. Here, we aim on tracking the atmospheric temperature and humidity in order to determine the ideal water consumption rate and quantity for the user. This is based primarily on the fact that in warmer, more humid climates, increased perspiration elicits an increased requirement for water in the body. On the other hand, in colder climates it has been observed that although the human body perspirates at the normal rate, it often goes unnoticed due to the greater layers of clothing and thus, also elicits a need for more frequent hydration.

SEN-11574 PPG Sensor - The PPG or photoplethysmography sensor is mainly used for the purpose of monitoring one's heart rate. We have used this sensor here in order to provide the user with the ability to track their heart rate instantly. This is mainly targeted at more fitness-conscious users who would wish to monitor their heart rates during exercise.

A circuit diagram for the system was also designed during this phase so as to aid with its assembly. Upon acquiring the components, the working of all the sensors were first tested so as to ensure their proper functioning. The sensors were then connected to the microcontroller board and with the help of Arduino IDE, we were able to build the individual features and integrate them into the product. At the end of this phase, we had a working prototype of the proposed smart water bottle.

II. Software Integration

Following the hardware implementation, we set out to develop the assisting software for the product. This included interfacing the microcontroller with a Wi-Fi-accessible cloud service, through which we would be able to communicate the sensor data. This phase also included the development of an Android application, which would communicate with the cloud for retrieving sensor data. At the end of this phase, we had a user-friendly mobile application, through which the user could track the progress of their daily water intake goal, set, and receive regular reminders for hydrating, and note the time of their last drink.

III. Final Implementation

Lastly, the final product so developed was tested and modified as and when required. This involved testing the product with different levels of water as well as in different atmospheric conditions. The mobile application (shown in Fig.1) was also optimized to provide a more intuitive user interface.

IV. PERFORMACE EVALUATION

The working of our smart water bottle relied on the accurate functioning of the sensors we employed namely –

1. The SEN-11574 PPG sensor
2. The DHT11 sensor
3. The HC-SR04 Ultrasonic sensor

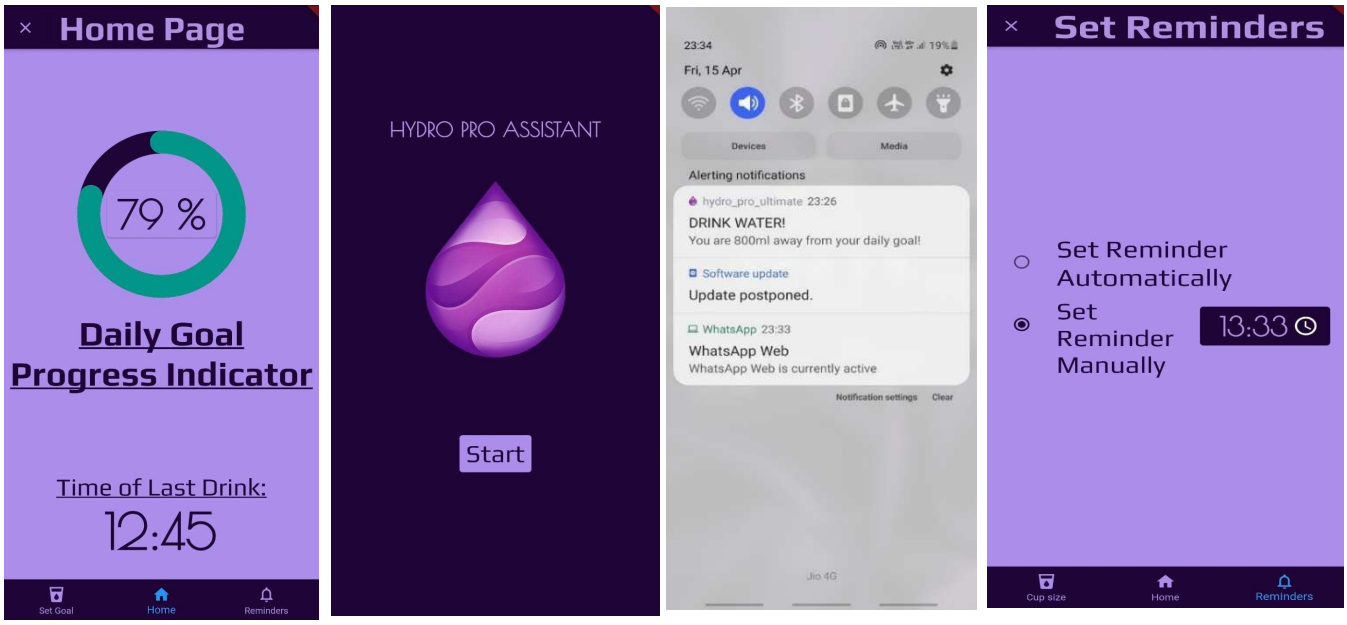

Figure 1: ANDROID APPLICATION

As our performance metric we choose accuracy percentages. On comparing the readings and measurements we received from our sensors with more accurate tools (like digital thermometers, pulse monitoring machines etc.) we got the following accuracy levels:

1. The PPG sensor gave readings within 5% of the actual value
2. The temperature and humidity sensor recorded reading within 2-5% of the actual value
3. The ultrasonic sensor recorded distance values within 1% of the actual value

EXPERIMENT SETUP

The primary functionality of the Smart Water Bottle system is to track the user's water consumption. This is achieved with the help of the ultrasonic sensor wherein it detects a change in the level of water inside the bottle. This change is monitored against the total capacity of the bottle to notify the user for a refill. Further, we also observe the ambient temperature and humidity for studying whether the user is consuming an appropriate amount of water for the same and alerting them to increase their intake accordingly. For this purpose, we take readings from a DHT sensor.

Finally, we have an added feature of taking the heart rate/ pulse rate using a PPG Sensor. This is especially useful for those users who are highly health-conscious and wish to closely monitor their vitals during exercise. By employing the ESP8266 Wifi module, we can establish a means of wireless communication between the sensors and the assisting mobile application, thus providing an easy-access interface for the user. When connected to the internet, the application can receive sensor data that is being picked up by the apparatus. It not only displays the same for the user's perusal, but also intelligently analyses the data to push forward appropriate reminders to the user.

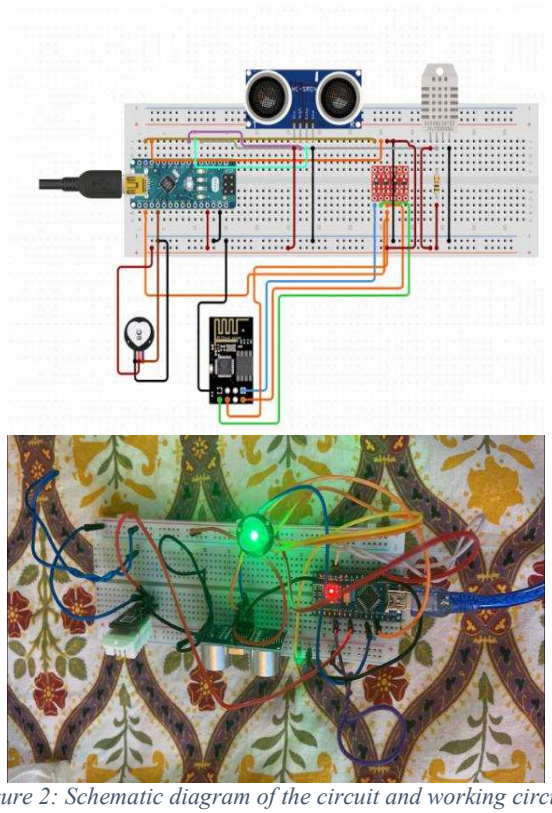

Figure 2: Schematic diagram of the circuit and working circuit implementation of the circuit

Above is the schematic diagram for our circuit which has the following components:

1. Arduino NANO
2. PPG sensor SEN -11574
3. HC-SR04 Ultrasonic sensor
4. DHT 11 Humidity and Temperature sensor
5. ESP 8266 WiFi module

Alongside is the working circuit for our smart water bottle product. To achieve the working circuit the following connections were made:

- Connecting the ultrasonic sensor to Arduino NANO
  1. The ECHO pin connected to D7
  2. The TRIGGER pin connected to D9
  3. The GND pin connected to the GND of the Arduino
  4. The Vcc pin connected to the 5V pin of the Arduino
- Connecting the DHT 11 temperature and humidity sensor to the Arduino NANO
  1. The GND pin connected to GND of the Arduino
  2. The Vcc pin connected to 5V pin of the Arduino
  3. The S (Serial data pin) to D4
- Connecting the PPG sensor to the Arduino NANO.

1. The GND pin of the sensor to the GND pin of the Arduino
2. The Vcc pin of the sensor to the 3.3V pin of the Arduino
3. The Signal pin of the sensor to the analog pin 0 of the Arduino.

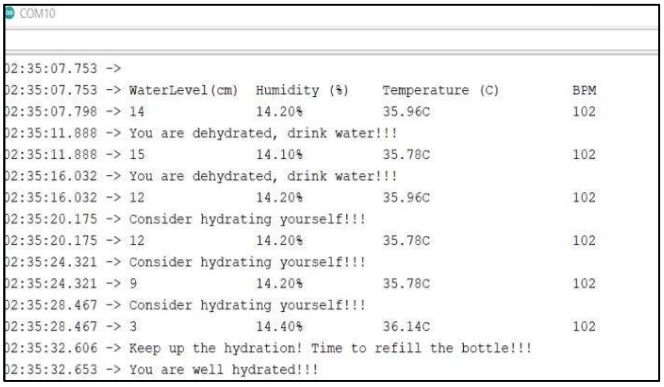

Figure 3: Output received on the serial monitor

EXPERIMENT RESULT

The evidence of the working of our product could be viewed on the serial monitor and serial plotter. The output we received on the serial monitor consisted of:

1. The timestamp of when the monitoring was taking place

2. The water level in the bottle as measured by the ultrasonic sensor in centimetres

3. The temperature and humidity readings of the user's environment as measured by the DHT11 sensor.

4. The pulse in beats per minute (bpm) as measured by the SEN-11574 PPG sensor.

5. Personalized messages for the user depending on their water intake. The message displayed can be one of the following:

i) "Keep up the hydration! Time to refill the bottle" - Displayed when the user has consumed about 75% of the water in the bottle.

ii) "You are well hydrated !!!" - Displayed when the user has consumed an appropriate amount of water considering the temperature and humidity level sensed.

iii) "Consider hydrating yourself!!!" - when the user is at the brink of getting dehydrated

iv) "You are dehydrated, drink water!!!" - when the user needs to drink water at the earliest to prevent dehydration.

Figure 3 is the output has received on the serial monitor.

INFERENCE OF THE RESULT

In the designed product, we were successfully able to implement the following functionalities:

1. Level detection system built with ultrasonic sensor to detect when the bottle needs to be filled up again and if the user has had adequate water.
2. With the help of temperature and humidity sensors which would sense these parameters for the surroundings of the user, we aim to notify the user whether or not he/she has consumed enough water.
3. Ability to observe heart rate/pulse rate as a useful feature for users to monitor their exercise closely while working out.

OBSERVATIONS

Through designed smart water bottle, we were able to make the following developments:

- The product can be used by the consumer to track the amount of water they drink on a daily basis.
- The consumer is able to check when they last drank water using the application.
- The smart water bottle adjusts the amount of water to be consumed by the user each day according to the environmental factors.
- The product should allow the user to track their vitals.
- An efficient and user-friendly application that can be used to analyze the user's water drinking habits.

Smart bottles come in a variety of shapes and sizes now, but the underlying technology is the same. Our smart water bottle uses software that allows the user to link the bottle to an application on their smartphone. The application can be used to keep track of one's water intake on a daily basis. The idea is simple: people become more aware of their water consumption and may compare on different days taking into account various variables (e.g.: temperature and humidity). This in turn gives them greater cause and motivation to drink the recommended amount of water.

Smart water bottles come with a variety of enhanced benefits and functions. Our smart water bottle has advanced sensors that can identify the required amount of water to be consumed based on the temperature and humidity values collected. Our smart water bottle has the potential to become one of the most crucial necessities for their respective consumers as anyone who would be interested in purchasing such a product must have a profound interest in going digital with their daily needs and thus be willing to pay a fair price for it. If one is a part of the water market or looking to get into it – there are several advantages that are generally considered when making the choice between smart water bottles or regular ones. Without much thought we can make the conclusion that smart water bottles can have a very important role to play in contributing to the healthy lifestyle of a consumer. Staying hydrated is necessary for a wide variety of reasons, the most important of those being:

- Body temperature regulation
- Joint health
- Ensuring that organ function that is optimal

- Infection prevention
- Improving mood and sleep patterns.

People need to drink about 2 litres of water each day on average, and we've found that our smart water bottle is one of the most effective ways to assist them to do so. This is because our product leads to a route of digitizing a person's water consumption. Smart water bottles are a terrific way to take care of your customers, whether they're having trouble sticking to their diet plan, taking medication, or simply wanting to stay hydrated and healthy. A current research of smart water bottles in patients at risk of kidney stones has yielded promising results. This is a randomized control experiment that found that persons in the intervention arm consumed more fluid.

Reusability is another key advantage of smart water bottles. Today, being environmentally friendly is a must for everybody working in the water industry. As a result, while providing the crème de la crème to your users, you'll also be helping a greater cause. This should encourage customers to stay loyal to your company, which can lead to increased income. The digital water bottle market is expected to boom in the next few years as people's living standards rise. The future has arrived, and adopting digital is the best way to stay ahead of the competition. Remember that people's demands drive digital transformation. As a result, supplying consumers with what they require should be a top concern for all manufacturers.

V. Conclusion and Future Work

The purpose of this research was to create an effective system and product (HydroPro) to digitize the daily water consumption needs of people. We have effectively created a product that does so using appropriate advancements in the field of Internet of Things. The proposed product - Smart Water Bottle can and will be used to help a wide variety of demographics (E.g.: - medical patients and the elderly). It can also be treated as a luxury product by those who wish to digitize this aspect of their life. The visually engaging application created is user-friendly and informative. We can only hope to grow the positive impact the product is already having in terms of regulated water consumption, reduced instances of dehydration and reduced usage of plastic bottles. Most positive effects of the product can be observed immediately. The environmental impact is an outlier as the reduced usage of plastic will have to be monitored over a significant period. The sensors were tested in various situations and yielded good results in each test. Though a level of surety can be provided with the product there are some areas which we would like to work upon as a team. We would like to create a more robust application with additional customizable functionalities.

We would like to make provisions for a more creative display of the analysis methods we perform upon the users' collect data. We would also like to add a way for users to set manual reminders to achieve greater personalization than what we already provide with the product. Our product currently offers users an avenue to analyse their water intake needs on a weekly basis. We would like this analysis to take place during shorter intervals of time (about a week) and display the same. Our users can currently track their daily water intake and vitals using the application. An on-bottle display of ppg sensor's reading for immediate observation as per the user's wish would also be an improvement that we can consider. All in all, one can make the conclusion that the product- smart water bottle has the potential to have a significant impact on society.

References

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," IEEE Commun. Surv. Tutor., vol. 17, no. 4, pp. 2347–2376, Fourthquarter 2015.

[2] C. Perera, A. Zaslavsky, P. Christen, and D. Georgakopoulos, "Context Aware Computing for The Internet of Things: A Survey," IEEE Commun. Surv. Tutor., vol. 16, no. 1, pp. 414–454, First 2014.

[3] L. Hood, J. C. Lovejoy, and N. D. Price, "Integrating big data and actionable health coaching to optimize wellness," BMC Med., vol. 13, p. 4, 2015.

[4] Pankajavalli, P. B., Saikumar, R., & Maheswaran, R. (2017, April). Hydration reminding smart bottle: IoT experimentation. In 2017 Innovations in Power and Advanced Computing Technologies (i-PACT) (pp. 1-5). IEEE.

[5] Sonali Vishwakarma, Anushree Goud, "A Literature Review on: Smart Bottle using IOT," International Journal of Computer Sciences and Engineering, Vol.7, Issue.6, pp.300-302, 2019.

[6] Lee, Nam Eui, Tae Hwa Lee, Dong Heui Seo, and Sung Yeon Kim. "A smart water bottle for new seniors: Internet of Things (IoT) and health care services." International Journal of Bio-Science and Bio-Technology 7, no. 4 (2015): 305-314.

[7] Niijima, A., Kusabuka, T., Uchida, S., & Watanabe, T. (2015). Smart bottle cap: Controlling liquid flow from a bottle with a smartphone. Proc. IoT, 203-204.

[8] Gaurav Singal, H Garg, V Laxmi, M S Gaur. 2014. "Impact Analysis of attacks in Multicast Routing Algorithms in MANETs." 9th IEEE International Conference on Industrial and Information Systems (ICIIS2014), Gwalior, IEEE 1-6pp.

[9] S Brahmbhatt, A Kulshrestha and Gaurav Singal. 2015. "SSLSM: Signal Strength Based Link Stability Estimation in MANETs." International Conference on Computational Intelligence and Communication Networks (CICN), IEEE 173–177pp.

[10] A Thomas, V K Sharma and Gaurav Singal. 2014. "Secure Link Establishment Method to Prevent Jelly Fish Attack in MANET." International Conference on CICN, IEEE 1153–1158pp.

[11] R. Kumar, M. Swarnkar, Gaurav Singal, N. Kumar. "IoT Network Traffic Classification using Machine Learning Algorithms: An Experimental Analysis.", Internet of Things, IEEE, Volume 9, Issue 2, 989-1008, 2021.

[12] A Sharma, R S Tanwar, Y Singh, A Sharma, S Daudra, Gaurav Singal, T R Gadekallu. "Heart Rate and Blood Pressure Measurement based on PPG Signal with Sliding Window and FFT Implementation", Computers and Electrical Engineering, Elsevier, 2022.

[13] Tomar, A., Jana, P.K. (2019). Mobile Charging of Wireless Sensor Networks for Internet of Things: A Multi-Attribute Decision Making Approach. In: Fahrnberger, G., Gopinathan, S., Parida, L. (eds) Distributed Computing and Internet Technology. ICDCIT 2019. Lecture Notes in Computer Science, vol 11319.

[14] Jovanov, E., Nallathimmareddygari, V. R., & Pryor, J. E. (2016, August). SmartStuff: A case study of a smart water bottle. In 2016 38th annual international conference of the IEEE engineering in medicine and biology society (EMBC) (pp. 6307-6310). IEEE.

[15] Şen, Z., & Altunkaynak, A. (2009). Fuzzy system modelling of drinking water consumption prediction. Expert Systems with Applications, 36(9), 11745-11752.