Smart Bottle Cap

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SUMMARY We present a new simple Internet of Things (IoT) device that we call “Smart Bottle Cap”, which enables a standard bottle to become a user-controllable liquid pouring system. It consists of a mini vacuum pump to start the liquid flowing, a microcontroller to control the liquid flow, a BLE module to connect it to a smartphone, an accelerometer to detect the tilt angle of the bottle, an LED for drawing the attention of users, and a 3.7 V LiPo battery. The device’s novel point is that a flow control mechanism built into a standard bottle cap makes the system suitable for general use and enables it to be easily extended.

key words: Internet of Things, bottle cap, liquid flow

1. Introduction

Controlling the amount of water that people drink is an important factor for ensuring that they will lead healthy lives. It is also important to control the volume of liquid flavoring one puts into dishes being cooked to facilitate skillful and healthy cooking. Some ICT devices have been developed for pouring liquids [1]–[3], but few people made use of them to date. To address this issue, we propose a device we call “Smart Bottle Cap”, which allows the liquid flow from a bottle to be controlled through the use of a smartphone. The device is attached to a bottle cap so that it can be attached to an existing bottle easily. It can be connected with a smartphone over Bluetooth Low Energy (BLE) so that it can work with smartphone applications. Users can use it easily for a wide variety of applications, which is an important factor for enabling people to use it in their daily lives.

2. System Description

Smart Bottle Cap consists of a mini vacuum pump (3 V Mini Vacuum Pump, manufactured by Seeed Studio), a microcontroller module (LightBlue Bean, manufactured by Punch Through Design), and a 3.7 V LiPo battery (Fig. 1). The pump provides almost constant pouring speed of about 1.1 ml/s. LightBlue Bean has a microcontroller to control the

liquid flow, a BLE module for connection to a smartphone, an accelerometer to detect the tilt angle of the bottle, and an LED for drawing the user’s attention. We made Smart Bottle Cap prototypes as shown in Fig. 2.

Smart Bottle Cap can be used as follows (Fig. 3): first, a user sets an pouring volume (e.g., 50 ml) with a smartphone. The data is sent from the smartphone to Smart Bottle Cap over BLE. The user then tilts the bottle, and the pump starts to pour the liquid. The pouring process stops automatically when the pouring volume reaches the preset volume.

The pouring volume can be estimated by the equation $L = v * t$, where L is pouring volume, v is pouring speed, and t is pouring duration. Using the vacuum pump enables the pouring speed to be kept almost constant and pouring duration is calculated from duration of tilt detection with the

Fig. 1 Smart Bottle Cap system architecture.

Fig. 2 Smart Bottle Cap prototypes.

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Fig. 3 Usage of Smart Bottle Cap.

Fig. 4 Experimental results for pouring volume accuracy.

accelerometer. We conducted an experiment to verify the accuracy of the pouring volume with Smart Bottle Cap. The experimental procedure as follows: 1) A bottle is filled with water. 2) The preset pouring volume is sent via a smartphone as 50, 100, or 150 ml. 3) When the bottle is tilt, water is poured to a measuring cup. 4) Smart Bottle Cap will stop to pour water according to the preset volume. 5) The weight of the cup is measured to calculate the poured volume. Three trials were conducted for under each of the three volumes. The results obtained are shown in Fig. 4; the average error rate was found to be 3.5%.

3. Applications

The preset pouring volume can be set automatically by utilizing sensor data of a smartphone or data on the Web. Some previous studies claimed that digital data should be converted directly into physical entities to be used in physical tasks [4], [5]. We agree with them and propose some exercise and cooking applications in which sensor data and Web data are convert into pouring volume (Fig. 5).

3.1 Calorie Control Application

When people use a smartphone while walking, they can count the number of steps they take and also estimate their

Fig. 5 Smart Bottle Cap applications.

Fig. 6 Mixology application.

calorie consumption. Using Smart Bottle Cap, they can set a target calorie intake that will be converted to the amount of liquid they can drink without exceeding the target. The target data will be sent to Smart Bottle Cap as a preset volume, and the user will be able to drink liquid as long as the target is not exceeded. It enables users to control their calorie intake without having worry about how many calories they are consuming.

3.2 Cooking Support Application

Recent studies show that technology can support cooking [6], [7]. Today people sometimes cook meals by using a smartphone to refer to recipes on the Web. The recipes include information about when and how much liquid flavoring should be added. In such cases, Smart Bottle Cap receives the data via a smartphone, which enables the user to pour the appropriate amount of flavoring. Its LED will also blink to let users know when they should pour the flavoring. All the users have to do is to tilt the bottle when the LED starts blinking, so they are freed from having to measure the amount of liquid to be added. This means that Smart Bottle Cap can be used not only for cooking, but also for mixing drinks at home. An example “mixology” application is shown in Fig. 6. This application enables users to make cocktails without the need for a recipe; all have to do is tilt the bottles.

3.3 Other Applications

Smart Bottle Cap has the potential to be used in many kinds of applications. Since it can be attached to many kinds of standard bottles, the ways in which it can provide itself useful are not limited to those that have been described so far. When used in the field of medicine, for example, it may prove to be beneficial in preventing the accidental ingestion of liquid drugs. It may also be useful for people watering their household plants.

3.4 Limitations

Smart Bottle Cap has two important limitations, which can be addressed in future work. First, the average error rate to pour liquid, which was 3.5%, is not enough low for some applications (e.g., those in the field of medicine). Second, the pouring speed is slow, for example, it takes 91 seconds to pour 100 ml. These limitations depend on the spec of the vacuum pump. Therefore, a higher spec pump will lower the average error rate and increase the pouring speed.

4. Demonstration

We demonstrated the calorie control and cooking support applications Smart Bottle Cap provides at the 2015 IEEE Internet of Things conference [8] and at the 2016 Maker Faire Tokyo exhibition [9], [10] to get feedback from users. In both demonstrations, we got many useful feedback comments. The positive comments included:

- “This device is so cool. I’d buy it even if it costs 20 dollars.”
- “It seems to be useful for cooking because measuring how much flavoring is needed is a rather pain for me.”
- “I’d like to use it for drinking medicines.”

The questions and negative comments included:

- “How can I wash it? It seems it might be difficult to keep it clean.”
- “Can it estimate the contents of bottles automatically?” (Answer: “No.”)
- “Can it pour liquids mixed with solids?” (Answer: “No.”)

5. Discussion

Our contribution is to propose a new simple IoT device “Smart Bottle Cap”, which enables a standard bottle to become a user-controllable liquid pouring system. Though there are still some limitations as to its usage, Smart Bottle Cap seems to be attractive for many users. The applications we proposed will help daily activity that needs to measure the amount of liquid.

The concept of Smart Bottle Cap is an IoT device that can be attached to existing items. In the era of IoT, it is difficult to replace all analog items with IoT devices. Therefore,

we believe that IoT devices should be attached to analog items to change them so that they can be more easily controlled as stated in [11]. The many recent efforts that have been made in the field of ubiquitous computing have led to the development of small and cheap modules such as microcontrollers, sensors, and BLE modules that enable new attachable IoT devices to be made easily.

In future work, we plan to use the feedback comments we got to further improve Smart Bottle Cap. We also plan to develop another IoT device based on the concept we have described in this paper, one that will bring added convenience to the lives of many users.

6. Conclusion

In this paper we presented a new IoT device we have developed and call Smart Bottle Cap, which can be used with a smartphone to control the amount of liquid flowing from a bottle. People who use Smart Bottle Cap to replace a standard bottle cap will find that the connection with the Internet via a smartphone it provides enables them to control the bottle. We also described some possible applications for the device, including one that uses sensor data of a smartphone and data on the Web to set preset pouring volumes automatically. This frees users from having to measure the amount of liquid needed for a given purpose. In future work, we plan to use feedback comments (both positive and negative) we obtained for Smart Bottle Cap to further improve the device. Smart Bottle Cap can be used easily for a wide variety purposes, and we believe that it will be one of the representative products in the era of the Internet of Things.

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