

Automatic Toothpaste Dispenser

Team 38 - Renjie Fan, Yanbo Chen, Haoyu Tian

TA: Soumithri Bala

1. Introduction

1.1 Objective

Toothpaste is an indispensable household item in people's lives. Although the development of technology exceeded most people's expectation in the last 20 years, our method of using toothpaste didn't evolve a lot. Most people still manually squeeze toothpaste, which is effort consuming, wasteful and lack of methods of tracking the used amount of toothpaste.

In recent years, many toothpaste dispenser products entered the market, but almost all of them have significant flaws including messy dispensing mechanism, not automatic and bad compatibility.

We propose to design and implement a new automatic toothpaste dispenser supported with a smartphone app, based on the PSoC 4 BLE board, sensor programming, Radio Frequency Identification, and Android development, to provide a solution for the current situation. Our product would have the following distinct features from current products:

User Recognition: The RFID reader embedded in our automatic toothpaste dispenser is able to identify the toothbrush labeled with RFID and it can dispense a pre-set amount of toothpaste on the toothbrush.

Automatic Dispensing Mechanism: Our improved squeezing mechanism can accurately dispense toothpaste on toothbrush without leaking any. The diameter of toothpaste coming out from our device will be small enough that any toothbrush regardless of size can easily collect it.

Smartphone Interaction: Our outstanding Android application allows users to choose several different amounts of toothpaste matching with RFID and to store their choices. It can also record the amount of toothpaste used by certain RFID so that parents could use it to monitor the children daily brushing teeth behavior. In general,

our product records long-term data on users' daily toothpaste usage and provides visualization of data.

1.2 Background

Several kinds of manually operated toothpaste dispensers have been designed by different manufacturers such as iLife Tech and ECOCO. In general, the mechanism applied is based on the action that the user pushes the trigger inside the dispenser with the toothbrush. This mechanism seems simple and user-friendly at the first look. Unfortunately, the trigger will soon be covered with dry toothpaste, which was unintentionally dropped when the user was trying to hold toothpaste coming out of the tube. This major problem is widely reflected in customer reviews. For example, a user named "William J Leep" said that "the dispenser itself is fairly well made and easy to use. But, it dispenses too much and misses the brush 1/2 of the time"[1].

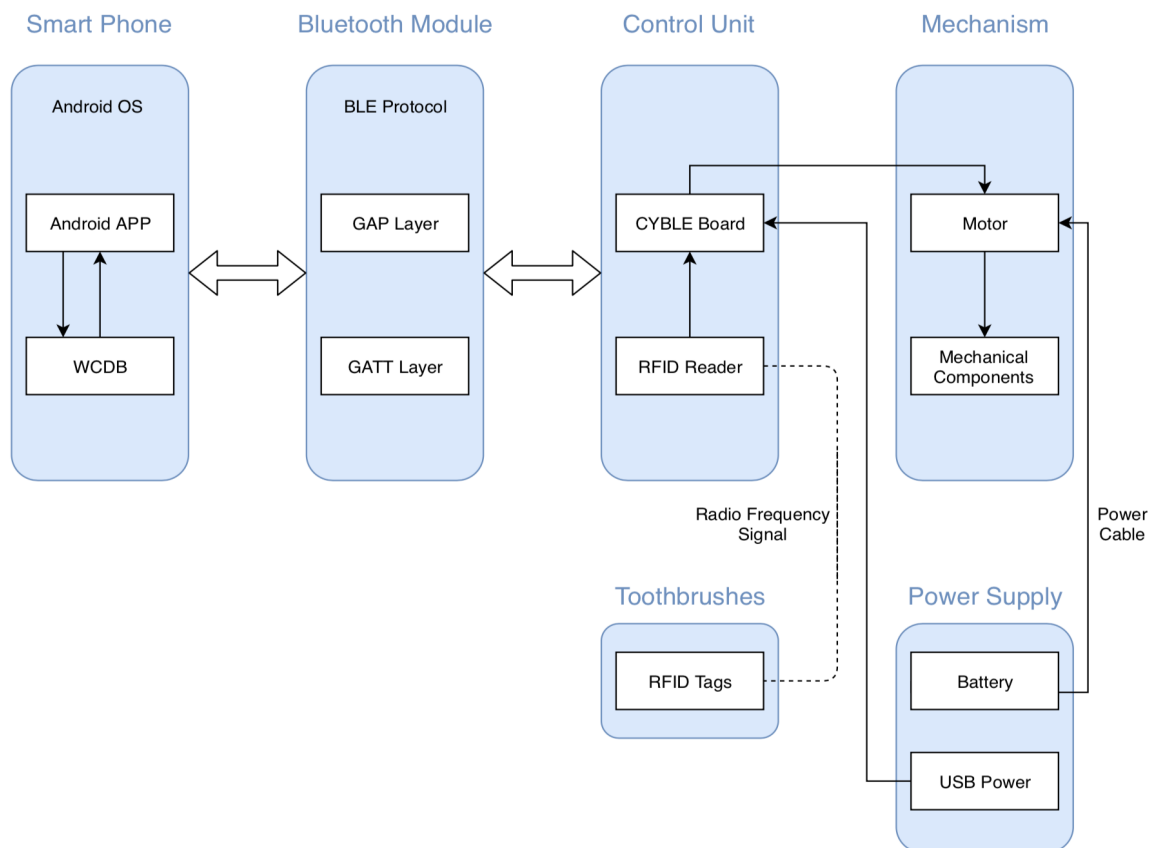
By making our dispenser automatic, the squeezing process can be standardized and thus the problem stated above can be mostly avoided. Since we are sponsored by Cypress Semiconductor Co., we plan to use PSoC 4 BLE board, which is supported by Cypress, to be the core of programming, controlling and communicating during the whole process.

1.3 High-Level Requirements

1. The dispenser must be able to identify different users through different RFID tags on toothbrushes.
2. The dispenser must be able to dispense a certain amount of toothpaste automatically and the amount coming out of the tube should be controllable.
3. The dispenser must be able to communicate with the APP on user's smartphone, providing data necessary to show usage.

2. Design

2.1 Block Diagram



2.2 Smartphone

Smartphone with Android Operating System will serve as the platform to support the APP and will provide the base of Bluetooth connection.

2.2.1 APP

Mobile App is the interface between the user and the device. Users could control the amount of toothpaste dispensed and RFID tag matching through the APP. The APP also could display the visualization of users' data on using toothpaste. The APP connects with the CYBLE board by Bluetooth through the BLE protocol.

Requirement: Process and threads run fluently and few laggings.

2.2.2 WCDB

WCDB is a mobile database solution, which would allow the APP to perform Database CRUD operation according to the users' operation [2]. The users' data logged by the CYBLE board would be stored in WCDB by date partition.

Requirement: Performance (Batch Write Test) achieves above 200,000 ops/second.

2.3 Bluetooth Module

Bluetooth module provides fast connection and data transfer between the mobile APP and the CYBLE board. All user operations and logged data are transferred through Bluetooth module.

2.3.1 GAP

GAP is the abbreviation for Generic Access Profile. GAP controls and defines the connection between two devices. According to GAP, a device that advertises its presence and accepts connection from a GAP Central device is called GAP Peripheral device [3]. A device that scans for advertisements from GAP Peripherals and establishes a connection with them is called GAP Central device. Specifically for PSoC 4 BLE Board, there are two advertising mode: fast advertising mode and slow advertising mode.

Requirement: Fast advertising mode allows the advertisement interval to be speeded up to 20-30ms. Slow advertising mode can lower the advertisement interval down to about 30 seconds.

2.3.2 GATT

GATT is the abbreviation for Generic Attribute Profile. After the Central device establishes a connection with the Peripheral, both devices are said to be connected over a BLE link. On a connected BLE link, independent of the GAP role, GATT defines two profile roles based on the source and destination of data [3]. In our project, PSoC 4 BLE Board will be GATT server that will send data to GATT client, which is our smartphone.

Requirement 1: GATT Attribute Handle consists of 2 Bytes data placed at the very first of a GATT Attribute [3].

Requirement 2: GATT Attribute Type consists of 2 Bytes data placed after Attribute Handle [3].

Requirement 3: GATT Attribute Value consists of 0-512 Bytes data placed after Attribute Type [3].

Requirement 4: The size of GATT Attribute Permission is implementation specific and is placed after Attribute Value [3].

2.4 Control Unit

Control unit is consist of the processing board and the RFID reader. The unit mainly manipulates the toothpaste dispensing mechanism and data interchange between smartphone APP.

2.4.1 CYBLE control board

We will use the CYBLE-214015 processing board provided by Cypress as the central control unit of our project. For the user side, the CYBLE control board connects with the smartphone APP through Bluetooth to receive users' instruction and upload users' data. For the toothpaste dispensing part, the CYBLE control board receives hexadecimal identification from the RFID reader and controls the operation of the motor through an encoder.

Requirement: Operating voltage between 1.9V and 5.5V.

2.4.2 RFID Reader

We are going to use a product named Y13R RFID Reader Component. The reader could sense any RFID tag with wireless frequency about 13.56MHz within 50 mm range. It could read ID numbers inside RFID tags, transform them as a hexadecimal number and output them to the CYBLE board. Its output interface is UART(TTL) and IIC so we can directly connect it with our CYBLE control board.

Requirement 1: Operating voltage between 3.3V and 5V.

Requirement 2: Operating current between 19mA and 25 mA.

Requirement 3: Operating temperature between -13 °F and 176 °F.

2.5 Mechanism

2.5.1 Motor

We are planning to use four small motors with size 25mm long and 20 mm in diameter. According to our mechanical component design, each cylinder/plate is pushed by two motors to ensure the torque force is enough to push the toothpaste out from the tube. The CYBLE board controls the motors by sending ON/OFF signal.

Requirement 1: Operating voltage between 3V and 6V.

Requirement 2: Motors' torque force over the resistance of the toothpaste tube.

2.5.2 Mechanical Components

We will have a squeezer to intermittently squeeze toothpaste tube. As the squeezer is powered by a motor, we could use an encoder to monitor the rotation of the motor to achieve the goal. We will use a "buffer" between toothpaste tube and toothbrush

to control the amount of toothpaste dispensing. In our blueprint, the squeezer would be a cylindrical object rolling from the tail to the head of the toothpaste tube or two plates put on two sides of the toothpaste tube and they are going to move toward each other to squeeze the toothpaste. Basically, toothpaste coming out from toothpaste tube will be firstly stored in the buffer and then be dispensed out to the toothbrush. The exit of the buffer is smaller than that of the toothpaste tube. Our design for squeezing mechanism does not need to control the amount of toothpaste coming out of the tube, we just need to set the mechanism to a safe value and every time when our buffer(reservoir) is close to empty, the mechanism will push some toothpaste into the buffer. We only need to control how many toothpastes coming out from the buffer.

2.6 Toothbrushes

In order to identify different toothbrush users, a unique RFID tag will be attached to each toothbrush. The RFID tag is a sticker form and it will be pasted on the handle of toothbrushes. Ideally, the RFID reader's sensing range is within 50mm, which is short enough to avoid to sense more than one toothbrushes at the same time.

Requirement 1: Operating frequency about 13.56 MHz

Requirement 2: RFID reader's sensing range within 10 cm.

2.7 Power supply

A constant power supply is needed for the dispenser to be ready for dispensing at any time. The RFID reader and the motors will be powered by the PSoC 4 BLE Board through a USB wire. The PSoC 4 BLE Board will be powered by batteries. The batteries should be able to constantly recharge by the wall socket so we might use a lithium-ion battery with 5V voltage delivery capability.

Requirement: Power supply for each device maintains stable.

2.8 Risk Analysis

The mechanical components part is the most challenging task in our project, as we are lack of experience in Mechanical Engineering. Our mechanism requires high accuracy and high synchronization between the electrical part and the mechanical part, which would be time-consuming to test and moderate. If we cannot achieve the ideal level of automatically dispensing a pre-set amount of toothpaste, we wish to implement the automatically dispensing function at least. The bottom line of the mechanism is that the dispensing system should be activated by the approach of toothbrush attached by an RFID tag.

3. Ethics & Safety

3.1 Ethics

Our design of mechanical components might refer to the mechanical design of manual dispenser on the Internet. Therefore, this would potentially be a violation of #2 of the IEEE code of ethics - to avoid real or perceived conflicts of interest whenever possible. We currently come up with a mechanism that is significantly different from those manual dispensers. In the following modifications of our design, we will try to avoid using the ideas that appeared in the existing products.

Keeping the data safety and privacy should be our first concern, however, the data we collect about the daily usage of toothpaste is important for any toothpaste company (our potential cooperative partner) and they could pay us for analysing our data and advertising specific targets through our APP. This would be a violation of #4 IEEE code of ethics - to reject bribery in all its forms.

3.2 Safety

We are using a lithium-ion battery so it might explode when we overcharge the battery. We will make sure that our charging circuit design for this battery has the protection code, which will automatically disconnect when the charging voltage exceeds the designed level.

The RFID tags we can get are only made for appropriate environmental conditions. However, attaching it on the toothbrush might violate its original design purposes because we cannot avoid washing our toothbrushes with water. We plan on using waterproof material such as waterproof tapes to cover the tags but it might potentially influence the reading process.

We are using RFID in the toilet and this is the place that people could stay for about 1 hour each day. However, there potential radiation risk in high-frequency RFID. However, there is a small distance between the toothbrush and Human in the toilet so this is not a vital risk.

4. References

[1]William J Leep, Amazon Product Review, 'Messy!', 2018. [Online]. Available: https://www.amazon.com/iLifeTech-Toothpaste-Dispenser-Automatic-Squeezer/product-reviews/B00NRW4LAS/ref=cm_cr_dp_d_hist_1?ie=UTF8&filterByStar=one_star&reviewerType=all_reviews#reviews-filter-bar [Accessed: 06-Feb-2019].

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[3]Krishnaprasad MV, 'Getting Started with PSoC® 4 BLE', 2018. [Online]. Available: <https://www.cypress.com/file/141171/download> [Accessed: 06-Feb-2019].

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