Aidan - Maryland

At-Home Dental Health Management System

Problem:
Dental health is an issue that affects people of all ages. Good dental hygiene is a crucial part in maintaining a healthy body. However, there is a problem. About 30 percent of Americans do not brush their teeth as often as recommended by health professionals (twice per day) and only 41 percent of Americans floss at least once per day.\(^1\) 43 percent of children aged 2-19 had dental cavities in 2015-2016.\(^2\)

However bad that might seem, young people are not the ones most affected by dental issues. The age group who suffers the most from oral ailments is older people. Here are some statistics on dental health in people over the age of 65:
- 1 in 5 people over the age of 65 have untreated tooth decay.\(^3\)
- 2 in 3 adults 65 or older have gum disease.\(^3\)
- About 1 in 5 people over 65 have lost all of their teeth, forcing them to wear dentures. This can change a person’s nutrition, as wearing dentures makes a person want to eat softer foods instead of the more healthy fruits and vegetables.\(^3\)
- Oral cancer is primarily diagnosed in older people. The median age of diagnosis is 62 years.\(^3\)

These problems are not necessarily caused by bad brushing or flossing habits. They can just be the result of aging teeth. The problem of bad oral health, especially in the United States, needs to be solved in order to prevent the issues listed above. Preventing oral health issues will have innumerable positive effects. Fixing and preventing issues such as cavities early on will lead to increased dental longevity, preventing the painful process of things like having teeth removed or needing dentures.

Current solutions to this problem include attempting to reinforce good dental habits: flossing and brushing daily and visiting a dentist more often. Unfortunately, these solutions have not significantly improved the dental health of people in the United States. A new solution is necessary.
**Robot Requirements Brainstorm:**

A robot that could help solve the problem of poor dental health would be a device that has a camera and a light (to improve visibility) that would be used to take pictures of a person’s mouth from several different angles.

This robot would not be a stand-alone device. It will allow the user to connect to a mobile application via Bluetooth or possibly wired connection. The application would receive the data collected by the camera and analyze it using a trained neural network. If there was a dental problem detected, the application would contact the person’s dentist with information regarding the issue.

The key advantage that such a device would provide would be in immediate response to dental issues. Most people see their dentist every 6-12 months. The large time span between visits allows cavities and other dental issues to accumulate unchecked. If however, this device were to be implemented, people could perform a self check as often as they wanted (ideally every day or every week), and if there was an issue, they could see their dentist immediately rather than waiting for the next appointment, possibly exacerbating the dental ailment.

There would be several financial requirements involved in creating such a device. One would be attaching the camera and light. Another would be the casing, small computer chip within the robot that allows for the storage and sending of the images, and the distribution and transportation of the robot to customers. However, the largest requirement would likely be obtaining the data with which to train the image analysis model. Possibly tens of thousands of images would be needed for this. Then, computer programmers would have to be paid to train an image analysis model based on the data, which would take a significant amount of time.
Prototype Design:

Isometric

Top
Notes:
These images were created using Autodesk Fusion. The large hole seen in the back view is a USB-C port, through which the device would be charged and transmit information to another device using a wired connection. The two white cylinders represent an on/off button and a capture button, which will take a picture. The camera is represented by the brass-colored ring on the top of the device. The LED that would provide increased image quality is in the rectangular hole close to the camera. Also attached to the submission is a STEP file that is the 3D model of the device. It contains all of the dimensions.
**Prototype Test:**

In order to successfully use this robot, a person would have to thoroughly clean their teeth so that a piece of food is not mistakenly identified as a cavity or other dental issue. However, from this use stems a potential problem/weakness of the robot. The robot (and the image analysis) may not be able to differentiate food stuck in a person’s teeth and a real dental issue.

Another possible weakness of such a robot would be failing components, in particular the LED. If the LED fails, the ability of the camera to take clear, well-lit images will be significantly decreased. This will, in turn, affect the way in which the images are analyzed.

A third possible weakness of the robot would be its inability to compensate for not being cleaned. If the user of this robot does not clean the camera lens, the image quality will be greatly impacted, preventing meaningful image interpretations.

Despite these weaknesses, there are many strengths of this robot. As mentioned above, this robot could allow dental issues to be immediately diagnosed and treated rather than waiting several months for a dentist appointment. Another strength of this robot is that its use is not very time consuming. All a person has to do is follow the instructions for taking pictures of their teeth from several angles and connecting the robot to their mobile device. One use could take a minute or less. A third strength of this robot would be in its consistency. One could argue that a robot would not be needed for this application at all; the camera of a person’s phone could be used to take pictures instead. However, not every phone camera is the same. Phone cameras have significantly different resolutions and qualities. An image analysis program having to account for the differences in various phone cameras could result in problems. The use of a single non-varying camera between all users would eliminate the variable of camera resolutions in various mobile devices.

This robot would be tested on dental patients. In order to test it, a dentist would first examine a patient to determine whether or not there are any dental issues present. Then, the dentist would use the robot to take and analyze images of the patient’s mouth. If the dentist and robot are in agreement, that trial will be counted as a success. If the robot is incorrect in its judgement, the trial will be counted as a failure. This test will be done many times by dentists across the world in order to test the accuracy of the device.

The testing process described above would allow for improvement to occur. Cases where the robot failed would be analyzed. Then, a course of action for improvement would be determined. For example, maybe the error was caused by something like inconsistent lighting conditions. If this was the case, the neural network would have to be trained to deal with various lighting conditions. If an error was instead caused by inconsistent tooth size between patients of different ages, then the image analysis program would have to be modified to incorporate the age and tooth size of the person being examined. Once the identified issues have been fixed the device will be tested again so that further improvements can be made. Repeatedly testing and making modifications are a crucial part of the Engineering Design process and result in an optimal product.
**Engineering Design Process:**

1. Step 1: Define the problem. This was done at the beginning of this paper in the section titled “Problem.”

2. Step 2: Background Research. This was also done in the section titled “Problem.” The sources from which the information was derived are at the end of this paper in the section titled “Sources.”

3. Step 3: Specify requirements. The requirements of this project were to create a robotic device that solves a real-world problem. Dental health, or lack thereof, is most definitely a real-world issue that needs to be fixed and could use the help of a robot.

4. Step 4: Brainstorm solutions. Some solutions to this issue include 1) a toothbrush that keeps track of brushing habits and alerts the user if they need to brush more, 2) a camera that can be used to take pictures of the mouth and detect dental issues, and 3) a device that cleans a person’s teeth for them, using cleaning guidelines recommended by dentists.

5. Step 5: choose the best solution. I ended up choosing the second idea because it would be the most effective in solving the issue of dental health problems. Ideas 1 and 3 require daily commitment on the part of the user, which could be a problem. Also, Idea 2 would allow for immediate response to a detected dental problem, whereas ideas 1 and 3 don’t.

6. Steps 6 and 8: Develop the Solution and Test and Redesign. Both of these steps are described above in the sections titled “Robot Requirements Brainstorm” and “Prototype Test.”

7. Step 7: Build a Prototype. Although this project didn’t require a prototype, it did require a design element, including drawings. Drawings of this robotic device can be found in the section titled “Prototype Design.” If I were to actually build a prototype, however, I would design a CAD model of the device and then create an application in a language that supports machine learning and image recognition. The programming language would likely be Python, as it has a really great set of machine learning libraries that would be useful for a project like this.

8. Step 9: Communicate Results. Since there was not an actual prototype or physical model in this project, there is no way to communicate the results of a working model. However, if this device were to be actually produced, the results could be published in a medical journal or in the form of a product available for public purchase.

**Sources:**


3. [https://www.cdc.gov/oralhealth/basics/adult-oral-health/adult_older.htm](https://www.cdc.gov/oralhealth/basics/adult-oral-health/adult_older.htm)