Toothcare: A Toothbrush Quality Identifying App Using Machine Learning and Image Processing

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Abstract - Toothbrushes of varied qualities, designs and standards are globally available, yet majority of them do not conform to international standards. There is no proper guidance or awareness given for the people with this regard. So, generally people do not know to choose the suitable toothbrushes they need, when they require to replace the used toothbrush, and whether the existing toothbrush is suitable for use. Therefore, the Toothbrush Standard Monitoring App provides a solution for all the above mentioned issues. This app is capable to scan the user's toothbrush and identify its condition. Machine learning and one of image processing techniques, image classification are mainly used for development of the app. Android Studio, Java programming language and firebase are used as development platform, backend development language and database platform respectively. The main purpose of implementing this app is to improve the dental health of human beings with the help of modern technology, and this will be the very first such solution implemented, addressing the above-mentioned health and social issues. This app functions in order to make people aware about the quality of toothbrushes and the conditions, hence reducing dental health issues and acknowledging people regarding the time period when they need to replace the existing brush with a new one. Accordingly, the app suggests certified toothbrushes following the user's data, monitoring the quality and damaged capacity of the toothbrush using image processing and informs the user whether the toothbrush can further be used or needs to be replaced. For this process, a TensorFlow Lite model with 83.48% of accuracy has been developed.

Keywords: image classification, machine learning, image processing, Tensor Flow Lite

I INTRODUCTION

There are many types of toothbrushes in the market with different qualities, designs & standards but all those toothbrush models are not suitable for everyone according to their dental structure and age. So, the populace does not know what kind of toothbrush they need. Toothbrush Standard Monitoring App gives a solution for that issue by suggesting suitable toothbrushes according to user's dental structure and user input data when registering to the app.Many do not have an idea when they should replace their toothbrush. For the record, an average person should replace their toothbrush every three-four months, but in most cases, it does not valid and it depends on user's habits and toothbrush condition.(Ganss et al., 2009) So, Toothbrush Standard Monitoring App has a solution for that issue too. App is capable of scanning user's toothbrush several times between three to four months and predict the average time period that user need to replace toothbrush or user can directly check whether existing toothbrush is suitable for use or should replace by scanning it. (Leeuwen et al., 2019)

Figure 1 – Different bristle conditions
Source - Wiley Online Library

Another issue is the population does not know whether the current toothbrush is suitable for their dental structure and age group. Toothbrush Standard Monitoring App is the solution for that. App gives the users an option to scan their toothbrush for check that it is suitable for the user. (Solanki, 2011)

Above mention issues are mainly affecting human's dental health and Toothbrush Standard Monitoring App is a better solution for those issues.

The mobile app uses mobile phone's inbuilt camera as an input media to the system for scanning toothbrushes. Machine learning and Image processing technologies are used to identify the scanned toothbrush and predict the time period for replace toothbrush. TensorFlow Lite is a machine learning platform that uses on android devices. This platform is used for developing machine learning and image processing features on the application. Android studio, java programming language and firebase are used to develop the application UI, backend and database.

Toothbrush Standard Monitoring System's main aim is to improve dental health of our society.

II. RELATED WORKS

introduced many new products and technologies. Hence machine learning and image processing concepts are emerging concepts now a days. "An Approach for Object Detection in Android Device" by Savitha G, Venugopal P S, Dr. Sarojadevi and Dr. Niranjan Chiplunkar paper presents about object detection on android devices. For object detection, morphological opening and closing filters are used in sequence. For the drawing contours of the detected objects, contour-based learning techniques are implemented. Objects are extracted in the process and stored for further analysis in an array. All these algorithms are implemented using OpenCV functions. (Savitha et al., 2014)

Rattapoom Waranusast, Pongsakorn Intayod, Donlaya Makhod researches about using image processing and machine learning on android devices for Egg Size Classification. Chicken eggs, used as an ingredient in almost every food culture worldwide, are a popular ingredient in human food. In many food recipes, judging the size, and therefore weight, of an egg is often important. Authors develop a mobile application for classify egg's size using an image displayed on an android device. They used a known size coin as reference object. Radius of the coin and eggs dimension are automatically detected and calculated by image processing algorithms. Egg sizes are categorized using a support vector machine (SVM) classifier based on their characteristics computed from the calculated measurements. The experimental results show that the measurement errors were low at 3.1% in egg measurements and the overall size classification accuracy was 80.4%. (Waranusast, Intayod and Makhod, 2016)

"Lightweight Mobile Object Recognition" paper presents Client-server framework where many methods of image restoration and approaches to image segmentation can be checked with the help of a network connected Android device as the most stable lightweight descriptor found in tests, a modified version of the CEDD (Color and Edge Directive Descriptor) and manual or salience-based object selection is also included. With the updated descriptor and distinct object segmentation, the main purpose of the research is to illustrate the possibilities of lightweight object recognition. (Czuni et al., 2014)

Andres Campoverde and Gabriel Barros presented "Detection and Classification of Urban Actors Through TensorFlow with an Android Device". They had developed a mobile app for identify urban actors using TensorFlow Lite and TensorFlow mobile models. The authors confirm advances in artificial intelligence because it is now possible to use Neural Networks for detection and classification within a device with limited hardware. Here the performance of Deep Neural Networks is compared (DNN). Their default model is a Single Shot Detector (SSD), which has been retrained, and the frameworks are TensorFlow mobile and TensorFlow light, respectively. The default model has 80 different object classes, while their re-trained model has only 6 different classes based on urban actors (car, bus, truck, bicycle, motorcycle, person). Their main purpose is to use an Android cell phone to create an object tracker for urban transportation.(Campoverde and Barros, 2020)

Ankita Saxena, Deepak Kumar Jain and Ananya Singhal worked on a hand gesture recognition application that uses android mobile platform.

The key features used are the hand centroid, the presence of the thumb and the number of peaks in the gesture of the hand. The algorithm is based on shape-based characteristics, taking into consideration that, except in some cases, the shape of the human hand is the same for all human beings. Artificial neural network among back propagation algorithms is the recognition approach used in this paper. This methodology can be very easily adapted to a real-time framework. Frames are sent to the server and edge detection of the video is performed after image were captured using android device inbuilt camera. Statistical analysis or artificial intelligence techniques are used to interpret these gestures. (Saxena, Jain and Singhal, 2014)

Sapan Thakker and Prof. Harsh Kapadia presents "Innovative approach towards design, developing, and implementation of image processing-based application using embedded vision platform". The image processing-based algorithm can be implemented on Android devices by using the OpenCV library. It is possible to build OpenCV with an Android embedded vision-based system, which can be replaced by a machine vision-based system. The embedded vision device based on Android reduces the system size and also offers a cost-effective solution for industries. Basic operations such as color transformations, edge detection, morphological operation etc. are carried out by the android application introduced in this paper. (Thakker and Kapadia, 2015)

"Android-Based Object Recognition for the Visually Impaired" paper presents about an Android-based object detection application that developed to help the blind better understand their surroundings. This application is based on the extraction of the local characteristics of the object of interest, which are then compared to the corresponding characteristics of the objects saved in the previously generated knowledge base. Using image processing technology, local characteristics are checked against more than one method of classification and the findings are analyzed. This system is evaluated using a dataset specially developed for this purpose when the application is deployed on an android device. The dataset used includes over 600 images of twelve objects under different distortions and shifts in viewing conditions. (Saeed, Salem and Khamis, 2013)

Seyed Mohammad Alizadeh and Ali Mahloojifar present how to identify skin cancer named Melanoma early, using image processing technology. The authors proposed an application for early detection of melanoma using Android Studio applications, Java programming language, and OpenCV library image processing methods and pattern recognition algorithms. The Android smartphone was used to perform all the detection measures. A computer was also used for better performance in the classification stage, in addition to the smartphone. This software is user-friendly and, on average, the measured precision, sensitivity and specificity are 95%, 98% and 92.19%. (Alizadeh and Mahloojifar, 2018)

DONG Ranran and others present an image matting system that uses the Android platform. Digital Image Matting refers to cutting out the part of a natural digital image that you are interested in while retaining the full edges. The aim of this paper is to add a convenient type of human-computer interaction and high process speed to the design and implementation of an Android image matting application. Second, on the basis of the Android graphics API and Android touch API, we get the user's interactive inputs. Then, to process images, we use a new matting algorithm based on the improved Grab-cut and targeted Filter. If the consumer is not pleased with the matting result, some scribbles may be applied as additional constraints to the result. Then, the matting result will again be processed by the matting algorithm suggested. Image segmentation technology is used in this application for cut the image that user is interested. (Dong et al., 2015)

"The aim in this paper is to utilize the advancement in mobile technologies to foster knowledge on plant species around us." In this paper it is proposed to create an application to classify plant species on android operating system. To detect the edges of the leaf from a plain white background, we use contour-based edge detection, and centroid classification is also done. The feature vector obtained should be independent of any contour scaling, rotation or translation. In the past, Fourier descriptor was

commonly used by these types of applications to compare object shapes and object textures, now we use Maximally Stable External Regions (MSER) detector and FD's represent the external shape. (Deepak and Vinoth, 2014)

Kanghun Jeong and Hyeonjoon Moon worked object detection on smartphone platforms. They suggested a method for real-time object recognition in smartphone environments. The proposed framework for object recognition consists of two main modules: extraction of features and recognition of objects. Feature detectors such as Scale Invariant Feature Transform (SIFT) and Speeded Up Robust Feature (SURF) are good techniques that deliver high-quality functionality, but they are too computationally intensive for any complexity to use in real-time applications. Smartphone platforms have limited resources relative to PC platforms, so computation-intensive SIFT and SURF descriptors in such resource-limited environments are less available. The FAST corner detector is utilized in this paper, which provides faster feature computation by extracting only corner information. The number of corners identified by the FAST corner detector varies, so to change the extracted corners to the same number, normalization is applied. Training for the efficient recognition of objects is carried out on the basis of normalized corner information, support vector machine (SVM) and back propagation neural network (BPNN). The suggested object recognition method based on the FAST corner detector yields increased speed and low performance degradation on smartphones compared to traditional SIFT and SURF algorithms. (Jeong and Moon, 2011)

Akhmad Qashlim and others researched about image segmentation using OpenCV Library. This research describes the use of mobile technologies to help fisheries. Specifically, authors developed an Android application that uses an internet-connected camera to detect and then convert RGB image artifacts to HSV and gray scale. The digital tool that provides fish detection results in the form of length, width, and weight used to decide the price of fish will be addressed in this paper using Android-based mobile technology using image processing methods. This application was developed to generate binary images using features provided by the OpenCV library. To build the user interface, the contour-active method was used to divide and separate image objects from the context, while the clever edge method was used to enhance the outline appearance of objects, three key challenges highlighted during application design, including C++ QT. On the Android platform, both approaches are introduced and use mobile cameras as an identification tool. (Qashlim et al., 2020)

III METHODOLOGY

Toothcare app is an all-new app for mainly identifying toothbrush condition. Also, the app consists of another two main features. Suggest a suitable toothbrush for users and notify the time period that user has to change their existing toothbrush. The app is developed using android studio and it's compatible with android API level 25 and above.

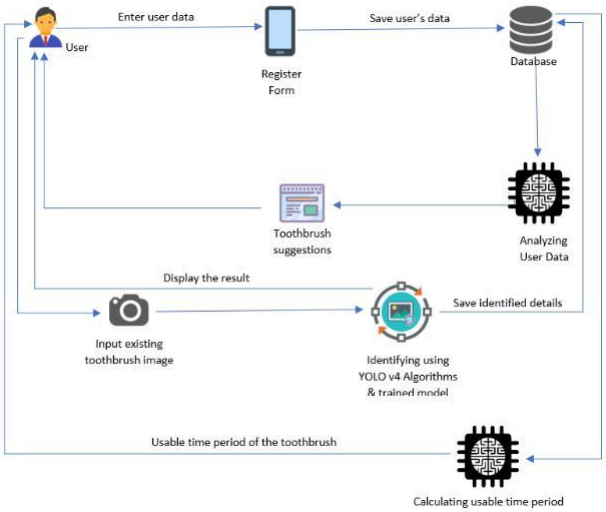

Figure 2 – Application Work Flow

Source – Toothcare Documentation

Firebase is used as the database and Python and TensorFlow are used for model development. Figure 2 depicts the basic process of toothbrush quality identifying app.

A. Toothcare App

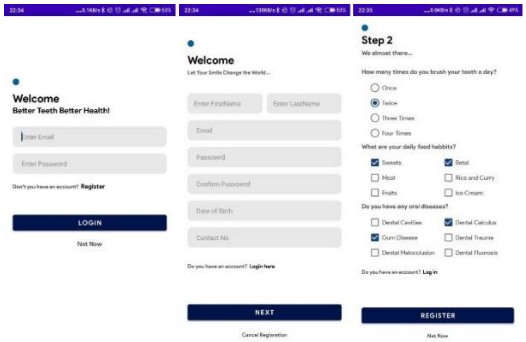

Figure 3 – Login and Registration Interfaces

Source – Toothcare App

Here in figure 3 presents login and registration interfaces. User needs his email and password to login to this app. In the registration process user needs to enter some private data and these data are used for the functionality of this app.

Figure 4 - Home Screen Interface

Source – Toothcare App

In the home screen we can access to the main features of the app and also, we can access profile details, notifications and settings. The app gives ability to edit user data and upload a profile picture for the user account. And in the settings section user have permission to on or off notifications that we generate to notify the user about time period that user need to replace the toothbrush. In the notification section the app displays all the past and current notifications.

In the home screen three main features are displayed. When the user opens "Explore Toothbrushes" it displays the suitable toothbrushes for the user. The other button is "Scan Your Toothbrush" here user have two options "New Toothbrush" and "Previously Scanned Toothbrush". user have to select whether it's a previously scanned toothbrush through the app or a new toothbrush that needs to scan for the first time. The third button in the home screen is "Toothbrush Usage" from here user can view all their previous usage data, how much time they used previous toothbrushes and how much time they scanned those toothbrushes.

B. Identify Toothbrush Condition

The main feature is identifying the quality and condition of the toothbrush. Image processing model is used for identifying the toothbrush condition and quality. The model is developed using image classification technique. Here we use TensorFlow, keras, cv2, NumPy, matplotlib and pickle libraries for develop this model. We use grayscale images to train our model because the colour of the toothbrush doesn't need for identify the quality and condition and we can reduce the processing power by not using colour images. We classify the input image into two classes, suitable for use and not suitable for use. To train this model we used a dataset that includes 900 images, 450 images for each class. We are using Convolutional Neural Network algorithm to train the model. It uses 2D convolutional layers to process the images. To train this model we used 25 epochs, 32 images for a batch and validation split as 0.1. The model accuracy was 83.48%.

The input image classified through the model and outputs the result if the toothbrush is usable or not. After deciding the toothbrush is usable or not these usable or not usable percentage is saved in the database with the date. These saved data will be used for predicting the toothbrush usable time period. Anaconda Navigator was used to access and manage libraries and Jupyter Notebook was used as the model development IDE.

C. Suggesting Suitable Toothbrushes

Another feature is suggesting suitable toothbrushes for the user. When registering to the app we are requesting some personal data from the user. Age, Food habits, Frequency of brushing teeth for a day and previous dental diseases are the data we request. By using these data, we categorize users into four categories.

Age, food habits, previous dental diseases are the main parameters considered when categorizing users. According to these categorise we suggest users what toothbrush is most suitable for them, whether it's a kid's toothbrush, adult soft, medium or hard toothbrush.

D. Notifying the User

Another main feature is notifying the user when the existing toothbrush needs to replace. For this feature we used existing toothbrush's usable time period and brushing frequency for a day as parameters. From these parameters we categorize users into several time periods starting from

three weeks to three months. We save each and every toothbrush's scan date and current toothbrush quality percentage for calculate usable time period of a toothbrush. Then we can use previous toothbrush usable time periods for predict more accurate date.

This notification procedure has 2 stages. First stage is notifying user to buy a new toothbrush when the existing toothbrush can only use 7 more days. Second stage is to notify user to replace the damaged toothbrush that is not suitable to use. This notification will occur until user scan the new toothbrush using Toothcare app.

IV. RESULT & DISCUSSION

Toothcare is a toothbrush quality identifying app that uses machine learning and image processing libraries and algorithms for identifying toothbrush quality and condition. Here we use a TensorFlow Lite CNN model that uses TensorFlow, Keras, cv2, NumPy, matplotlib and pickle libraries. We use a manually created dataset that includes 900 images, 450 each two classes. When training the model, we ran 25 epochs including 32 images for a batch and validation split as 0.1. Finally, the model reaches 83.48%. of accuracy.

We tested the model accuracy manually by identifying whether the toothbrush is usable or not with the help of dental doctors and by scanning the toothbrush through the app. From this testing procedure we got 84% of overall accuracy by testing 50 toothbrushes.

To test the user experience and feedback, the app was presented for some users randomly to conduct the testing process. Also, a questionnaires were provided to these participants to get the feedback of the app whether it needs to improve features or satisfying users. Testers were briefed about the functionality of the app after that tester start to test all the features that include in Toothcare. According to testers' feedback the features are all useful features. And the app UI also attractive and simple. The simplicity of UI is a must when we considering the userbase of the app. Toothcare has no age limit from child to older persons should have ability to use the app. That requirement was successfully achieved in Toothcare. And according to the questionary most of the testers don't have an idea when to change their existing toothbrush and what is the most suitable toothbrush for them. Not knowing these can cause serious oral diseases. Toothcare provide the solution for those too. And another problem that testers had was forgetting to replace their existing toothbrush because most of them forgot to buy a new toothbrush and some forgot to replace it.

The notification feature was useful when considering above problem. We remind users to buy a new toothbrush and replace it when existing one is not suitable for use. And users can view their previous usage history through the app. It also a useful feature for uses who wish to trach their toothbrush usage and app usage.

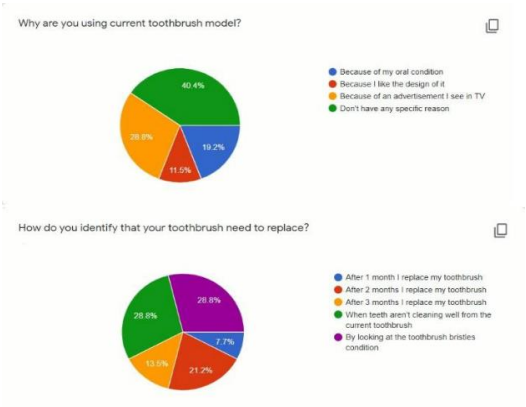

Figure 5 Survey Results
Source – Google Form

Through this testing procedure it confirms that the Toothcare app is a useful app for every human being who use a toothbrush and it is easy to use because of simple UI design.

V. CONCLUSION AND FURTHER WORKS

This app can be used by all the humans who brush their teeth. There are no age limits for using this app. A human starts to brush teeth when 6 months old. So, parents can make a profile for their children and monitor their toothbrush condition through Toothcare. Users only have to scan toothbrush that they use and Toothcare will decide whether it's usable or not and when should user change the existing toothbrush.

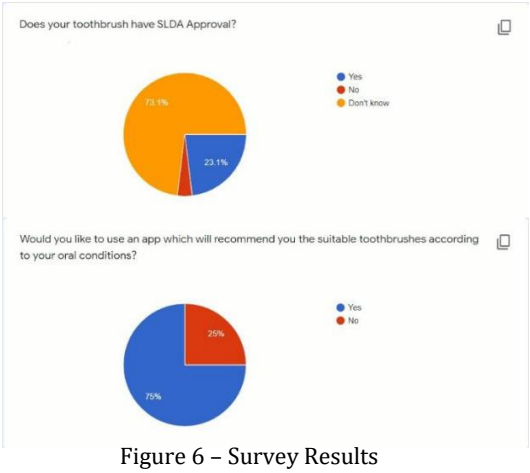

Figure 6 – Survey Results
Source – Google Form

According to the survey done by using 150 participants 73% don't know whether their toothbrush is under SLDA standards. 80% don't have a specific reason about why they use current toothbrush model. 71% don't have an idea when they should change their current toothbrush. Further, 75% like to use a app that can manage their toothbrush usage and recommend them suitable toothbrushes. According to these survey data we can conclude that Toothcare will be a useful app for society to maintain their oral health and prevent from oral diseases that cause by using damaged toothbrushes.

Further this app will be developed for iOS & Huawei platforms too. Also, Toothcare will introduce for toothbrush manufacturing companies for advertise the advantages of brushing teeth properly and manufactures can also introduce & educate about their toothbrushes through Toothcare. Also, in the future we are planning to improve Toothcare as an online store where users can purchase products related to oral care.

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