International Journal of Computer Engineering and Information Technology

VOL. 9, NO. 8, August 2017, 176–180
Available online at: www.ijceit.org
E-ISSN 2412-8856 (Online)

Detecting Temporomandibular Joint Disorder (TMJD) Using Modified Euler Angle in Image Processing With First Aid Application

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ABSTRACT

The rapid increase of Temporomandibular Joint Disorder (TMJD) cases has caught the attention of medical industry. However, only few of these cases has been diagnosed properly due to unawareness of the patients and of the high cost of diagnosis. Today, medical mobile applications is becoming prevalent to aid medical specialists and patients. This research study focused on the methods for self-diagnosing TMJ disorder using symptom questionnaire and mesurement of the maximum mouth opening. With incremental development as a software development tool, the mobile application was programmed using Android Studio. Measurement of the maximum mouth opening through image processing involves detecting face and face landmarks, mouth opened/closed detection, distance measurement, Euler Angle modification and measurement of the actual maximum opening with the aid of Google Vision API. A myofascial exercise recommended for relief of pain associated with TMJ disorder is also included in the mobile application. With an average percent difference of 1.21, there is no significant difference between the manual and the mobile measurement of the maximum mouth opening. Evaluated by TMJ practitioners, the mobile application is recommended for self-diagnosis and first-aid of TMJ disorder.

Keywords: *Temporomandibular joint disorder, image processing, mobile application, self-diagnosis.*

1. INTRODUCTION

Medical diagnosis is the method of identifying a disease or condition that a person is experiencing along with the symptom's and signs. It is based on information from sources like interview, physical examination medical history and laboratory tests. Medical diagnosis directs the course of treatment for individuals and it should be conducted right away to prevent worsening of patient's case.

In dentistry, diagnosing conditions in the oral cavity is also common. One of the most common disorder in the oral cavity that mostly affects woman is the temporomandibular joint disorder [11]. TMJ disorder is associated with symptoms like pain in the jaws, headache and locking of the jaw [7][2][4][8]. The method of diagnosing is conducted manually with the use of clinical tools that with improper use becomes unsafe for the patient. The existing clinical methods are also expensive for ordinary individuals. Well in fact, the method can be conducted through a self-diagnosis with an aid of a mobile application.

Arising technologies aided with applications installed in mobile platforms become evident nowadays because of its portability and usefulness. The latest generations of smartphones are even viewed as devices used for health care purposes. In fact a large number of mobile applications are already available in the market [5]. With the mobility of smartphones, it is not far that these devices can also be used for self-assessment purposes.

Image processing is usefully applied in medical diagnosis. In modern medicine, imaging is the most effective tool for diagnostics, treatment planning and therapy. Digital acquisition techniques with processing of images becomes an important option especially in medical diagnosis [3].

Moreover, the clinical diagnostic procedure for TMJ disorder is costly. In the long run, unawareness or neglecting of early signs and symptoms of TMJ disorder may lead to even costlier clinical treatment.

1.1 Background of the Study

Mobile applications are helpful tools to monitor the health of an individual. Mobile applications or mobile apps are continuously becoming prevalent among medical professionals as stated by [1]12]. In fact, there are already a vast range of mobile applications already being utilized to manage health. These are called as mobile medical apps. As estimated, by 2015, 500 million smartphone users worldwide will be using a medical applications [6]. In 2016, an approximation of 30-50% of

medical professionals will be using these apps for clinical care setting [14].

The huge number of smartphone users in 2016 of 2.1 billion [9] signifies the interest of the users to the use of mobile applications also. On the other hand, the medical apps have huge potential to improve patient practice, system efficiency and communication by providing a quick reference tool accessible at the point of care. Since smartphones can facilitate development and distribution of mobile applications by clinicians and other developers, rapid production of the market will likely continue.

It is significant that all medical applications must be based on scientific methods of how it should work. At least it must be consulted with physicians or should be based on standardized medical procedures. However, most of the medical apps available today lacks expert medical input [10].

Today, mobile applications associated with TMJ disorder has been deployed in the market to inform the user about TMJ disorder background. The basic function of these apps is to give adequate information about TMJ disorder only. Self-diagnosing a TMJ disorder and being knowledgeable on how to apply self-relief can be helpful to assist the users and guide them on how to give a first-aid relief of their conditions.

1.2 Objectives of the Study

The general objective of the study is to detect Temporomandibular Joint Disorder (TMJD) using Modified Euler Angle in Image Processing with First Aid Application

Specific Objectives:

1. Identify the methods used for diagnosing TMJD.
2. Determine the image processing algorithm to detect TMJD.
3. Help the TMJD patients in self-diagnosis and self-therapy of their conditions.
4. Gather reviews of the mobile application's efficacy from TMJ practitioners.

2. METHODOLOGY

This research study is classified as a qualitative research type as it determines the acceptability of the mobile application for TMJ disorder diagnosis through survey questionnaires that must be answered by TMJ practitioners.

2.1 Data Gathering

The first part in the research process conducted is the data gathering. Reading of articles and related journals from the internet was conducted to get details about TMJ disorder, its signs and symptoms, number of TMJ disorder cases and the methods of diagnosing and treating it. Interviews with TMJ specialists and practitioners were conducted to alleviate the initial findings

2.2 Analysis of the Best Algorithm for Image Processing

With evident findings on how to diagnose TMJ disorder through questions and measurement, the next step conducted was to design the algorithm for the self-diagnosis of TMJ disorder. A set of Computer Vision frameworks were referred to and tested the possibility of building the algorithm using them. Google Computer Vision API was tested in the development of the algorithm. The libraries and documentation of this framework were analyzed on to which of these can provide simplest yet most effective mechanism of getting the measurement of an image focusing on mouth.

2.3 Software Development

Incremental development is the software development life cycle used as a reference for developing the model as shown in Figure 1. Incremental development is a method for software development where the product is designed, implemented and tested incrementally until the product is finished. The product is defined as finished when it satisfied all of its requirements [13]. Symptom questionnaire based on RDC/TMD and the image processing method as shown in Figure 1 were developed using Android Studio.

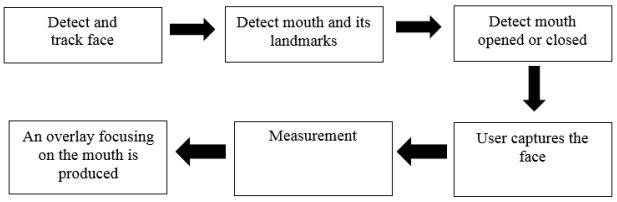

Fig. 1. Process of Detecting Estimated Maximum Mouth Opening

3. RESULTS AND DISCUSSION

3.1 Method of Self-Diagnosing TMJ Disorder

TMJ disorder detection can be done in various ways. It can be conducted using clinical procedures. The most

common medical diagnosis is to ask the patient of the signs and symptoms of TMJ related to pain, headache and jaw joint disorders and measure the mouth opening. Two methods were used to self-diagnose a TMJ disorder – the TMJ related questions to pain, headache and jaw problems and the measurement of the maximum unassisted mouth opening. Questions were based on the Diagnostic Criteria for Temporomandibular Disorders Symptom Questionnaire.

3.2 Image Processing Tool

The most applicable image processing method is to utilize the Google Vision API to get the estimated mouth opening is composed of five (5) steps namely face detection, face landmark detection, opened or closed mouth detection, measurement of the distance and measurement of the mouth opening as shown in Figure 2. To get the estimated maximum mouth opening, the user should position the mobile phone approximately 210 mm away from the face. The distance can be estimated through a distance reflected in the mobile application. The acceptable face distance is 210 + or - 10 mm away from the phone to get the nearest value compared to the manual.

3.2.1 Face and Face Landmark Detection/ Mouth Opened or Closed Detection

Figure 2 shows the real time tracking of the mouth in front view. The landmarks are constantly tracked. The green box refers to the face detected. The green button shows the center of the forehead. Circles are drawn to the landmarks needed for the measurement. The yellow circle points to the upper mouth, cyan circle points to the right mouth, blue circle points to the left mouth and the white circle points to the bottom mouth. Mouth is also detected if it is opened or closed.

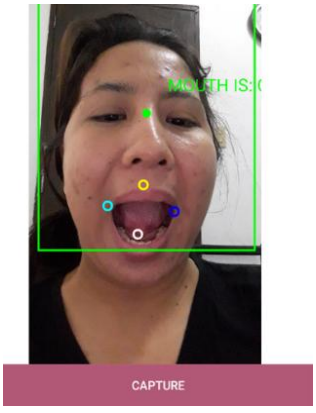

Fig. 2. Face/Face Landmark Detection and Mouth Opened/Closed Detection

3.2.2. Euler Angle Modification

The only available landmarks detected by Google Vision API in terms of Euler Angle Y does not include the upper mouth.The nose base was used as a point of reference to locate the upper mouth about 30mm downwards.

3.2.3 Distance Measurement

Facing the user, the mobile phone camera, must be estimated to be 210 mm away. This can be achieved by looking at the guide in the mobile phone that shows the estimated distance. Distance computed is based on Euclidean distance shown in Equation 1 and Figure 3.

$$\text{dist}(A,B) = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \quad (1)$$

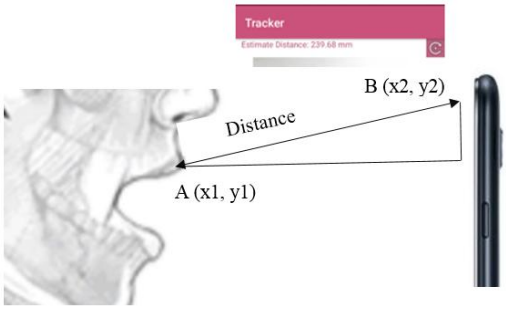

Fig. 3. Measurement of the Distance

3.2.4 Measurement

The real height of the mouth is computed based on Equation 2. The distance is fixed to 210 mm, the object height is computed by Google, the sensor height is 2.7, the focal length is 1.9 and the image height is 2560 pixels.

$$\text{Real height} = \frac{(\text{distance} * \text{object height} * \text{sensor})}{f * \text{image height}} \quad (2)$$

$$= \frac{210\text{mm (X pixels) (2.7 mm)}}{1.9\text{ mm (2560 pixels) (2)}}$$

3.2.5 Analysis of the Self-Diagnosis

Answers to the questions related to pain, headache and jaw problems are analyzed. A single yes answer in the diagnostic criteria for temporomandibular disorders means that the user has TMJ disorder. If the person has headache or pain in the jaw, ears and temple area the patient, TMJ disorder occurs to the user. If the patient experiences aching of the jaw or temple areas during eating, yawning or talking, the user is described as a TMJD patient already.

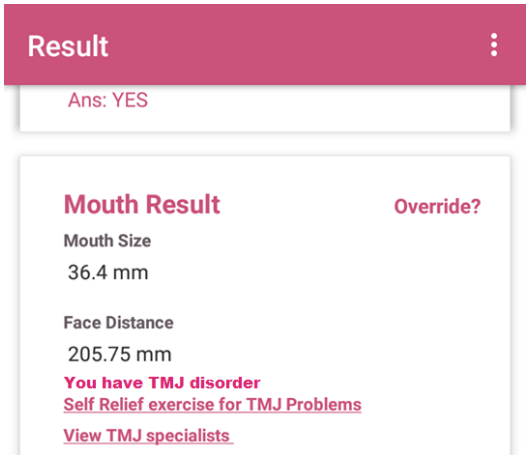

Fig. 4. Analysis of TMJD self-diagnosis

When the self-diagnosis is completed and analyzed, a recommended self-exercises or therapeutic activities will show. These are called Myofascial Release Exercises recommended for Self-Relief of TMJ related problems. The myofascial release is alternative to medicine for eliminating pain and restore motion by relaxing contracted muscles at the jaw, temple and mandible.

4. TESTING FOR THE ACCURACY

To test the accuracy of the mouth measurement, TMJD patients from Cavite and Laguna were requested that their unassisted maximum mouth opening be measured manually with the use of a calibrated ruler. Then the mobile application was installed in a smartphone with a front camera of 5 megapixels that was used to measure the maximum mouth opening. Table 2 shows the measurements taken manually and using the mobile application. The percent difference was calculated to determine how close the values are in the manual and mobile measurements

Table 1: Manual and Mobile measurements of the mouth opening with percent difference

TMJD Patient	Gender	Estimated Mouth size (Manual) (mm)	Estimated Mouth size (mobile) (mm)	Distance (mm)	% Difference
1	M	44.17	43.34	201.20	1.09
2	F	39.20	39.68	208.06	1.22
3	F	38.30	38.71	214.64	1.07
4	F	39.06	38.50	204.51	1.45
Average Percent Difference					1.21

5. CONCLUSION

The two methods used to self-diagnose a Temporomandibular Joint Disorder are the symptom questionnaire and the measurement of the maximum mouth opening. The symptom questionnaire is composed of questions related to headache, pain in the ear, temple and mandible and opened and closed locking of the jaw.
The image processing to measure the maximum mouth opening is composed of five steps, the face and face landmark detection, opened or closed mouth detection, distance measurement, Euler Angle modification and computation of the maximum mouth opening. With a mouth opening of less than 45 mm, the user is diagnosed to have TMJ disorder. An analysis of the user's TMJ related condition has been generated. After the user diagnose their TMJ-related conditions, a self-therapy for first aid relief of TMJD related pain has been provided.
Altogether, the method of self-diagnosing TMJ disorder, the image processing algorithm for measuring the mouth opening and the self-therapy guide instructions were embedded into the mobile application. The percent difference between manual measurement and the measurement calculated by the mobile device was computed. With an average of 1.21%, there is no significant difference between the manual and the mobile measurement.
Thereafter, the TMJ self-diagnosis mobile application was evaluated by two TMJ practitioners. The mobile application for TMJD self-diagnosis is high-tech and a breakthrough in dentistry. The method used for diagnosing TMJ disorder is appropriate and analyzed the diagnosis properly. The mobile application is very easy to follow and even general practitioners could use it. With the technology of science which goes on a fast pace, this mobile application can cope up with the technology especially in the dental field.

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