**Hidden Markov Model report**

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Toothbrushing is one of the most important measures against oral diseases (especially dental problems) [1]. Proper toothbrushing is very important for reducing plaque and other dental problems. The American Dental Association (ADA) recommends to brush the teeth twice a day for two minutes using the Bass technique [2]. But compliance to the proper toothbrushing technique is a major issue and various studies suggest that many people brush their teeth incorrectly without following the standard procedure. There is very limited technology to assess the compliance of toothbrushing at home. Even though electric toothbrushes are available in the market nowadays, the problem is not solved completely as it still relies on the users to move their hands properly to reach all the surfaces of the teeth. Most of these toothbrushes cannot detect the compliance to proper toothbrushing techniques in terms of duration and coverage. Therefore, there is a need for technology-based solutions to monitor the toothbrushing.

Toothbrushing monitoring is my current research field. Therefore, I would like to choose the paper named “Toothbrushing Monitoring using Wrist Watch” [3] for this report.

In the paper, a system is built to monitor the brushing quality on all 16 tooth surfaces using a manual toothbrush and an off-the-shelf wrist watch. The toothbrushing activity consists of a series of gestures for maneuvering a toothbrush to scrub teeth.

In order to recognize toothbrush gestures, they construct toothbrushing gesture models based on underlying basic motions (wrist flextion/extension, forearm rotation, elbow flexion/extension, and shoulder flextion/extension).

They also develop a **Hidden Markov Model (HMM)** to learn the **order of toothbrushing** **surfaces**, as shown in Figure 2, which varies from person to person.

Hidden Markov

Model

A diagram of a diagram showing how to use a toothbrush

Description automatically generated

As regards tooth surfaces, there are 16 major surfaces of the teeth that we brush, as shown in Figure 3. The labial and buccal surfaces are sides of the teeth that are adjacent to the inside of the lips or the cheek. In this paper, they refer them as outer surfaces. The occlusal surfaces of the teeth are the surfaces that come in contact with those in the opposite jaws during biting or chewing. They refer them as chewing surfaces. The palatal and lingual surfaces of the teeth are those next to one’s tongue. They refer them as the inner surfaces of the teeth.

A diagram of teeth and teeth

Description automatically generated

The main aim of utilizing a **HMM** in their work is to **improve the recognition accuracy**.

People usually have set toothbrushing habits. One such habit is the order of brushing the 16 tooth surfaces. With the data they collected, they observed that users had certain patterns in the order of toothbrushing. Therefore, they develop a **HMM** to learn the probability distribution of the user-specific brushing order, **which allows them to estimate the current brushing surface based on previously brushed surfaces**. They then use it to **correct false recognition results from motion models**. Combined with their gesture recognition algorithms, this improves the accuracy of their brushing gestures recognition solution.

As an example, they analyzed 22 toothbrushing sessions for one of the users, and computed the transition probability matrix of the brushing order in Figure 11. They found that there was a strong pattern in the toothbrushing order. From this matrix, they can see that the transition probabilities from FUO to FLO, from FLO to LLO, from FUI to FLI, and from FLI to RLO, are 100%. Besides, for all the surfaces, the transition probabilities for the most likely next surface are all greater than 70%.

A graph of a graph with numbers and symbols

Description automatically generated with medium confidence

They design a simple algorithm that can be easily integrated with their system. The algorithm maintains a surface transition probability matrix . The algorithm is invoked only when the Bayes based surface classifier makes a prediction that is different from the previous prediction.

* If the classification confidence is greater than an ambiguity threshold , it means the predication is accurate, and the new prediction value will be used to update the matrix .
* On the other hand, if the classification confidence is smaller than , the algorithm will find out the most likely next surface given the previous surface from the transition matrix . Then the algorithm computes the weighted probability and .
  + The algorithm will return if .
  + Otherwise, return .

**References**

[1] H. Loe. “Oral hygiene in the prevention of caries and periodontal disease”. In: *International Dental Journal* 50.3 (2000), pp. 129–139.

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[3] H. Huang and S. Lin. “Toothbrushing monitoring using wrist watch”. In: *Proceedings of the 14th ACM Conference on Embedded Network Sensor Systems CD-ROM*. 2016, pp. 202–215.