AR tooth brushing game to promote children's oral care habits through object tracking

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***Index Terms*—Tooth brushing, Children's oral care, Machine learning**

I. Introduction

We should brush tooth while considering easily soiled areas and areas with a lot of polish leftovers [1]. Easily soiled area means that it often have bacteria that is called food residue or plaque. People should brush tooth every day since the tooth started to grow. That is because if we do not brush tooth, our milk tooth may fall out because of tooth decay before permanent tooth grow and change. That phenomenon makes us get crooked tooth because there is a possibility that permanent tooth grows bent or grows in the different place than it should have. Further, the tooth decay in milk tooth may make the environment where tooth decay prone to occurrence. So we should not leave the tooth decay in milk tooth [2]. However Annual report of school health statistics research reminds that the account for 31.16 percent of kindergarten children have tooth decay and that the account for 44.82 percent of elementary school student have them and the account for 19.15 percent of kindergarten children have tooth where no action has been taken and the account for 21.74 percent of elementary school student have them [3]. There account is larger than the one of junior high school students and the one of high school students. The result reminds that the small children do not brush their tooth enough. Also, the account of those who brush their tooth with awareness of periodontal disease, the account of those who brush their tooth with awareness of caries prevention, and those interested in insurance news in dental hygienist second year are larger than ones in dental hygienist first year and students from other departments [4]. The result shows that those who have received education in dental health are increased interest and knowledge about dental health. That means that helping people learn to brush their tooth correctly makes them brush tooth regularly. So we think that the reason that children do not brush enough is that they do not learn how to brush their tooth. However it is difficult that children understand why they should brush tooth because germs are invisible to the naked eye. So we make it a goal that we make children learn correct toothbrushing habits by teaching them why they should brush tooth to interest them in brushing tooth. We have proposed AR tooth brushing system that promotes oral care habits of children [5]. This system detects tooth areas easily soiled from PC camera image in real time using machine learning technique first, and superimposes germs illustrations to show easily soiled areas. By the way, tooth areas easily soiled do not mean tooth soiled in fact. This system enables children to see germs that can not been seen with the naked eye in fact to increase motivation for children to brush their tooth. However even if children brush their tooth by toothbrush while using this system, the germs illustrations can not be erased. The phenomenon may not give the feeling of brushing their tooth. So it is difficult to improve their toothbrushing habits by this system. We improve the system so that it changes the display of germs following the movement of the toothbrush that children have in this study. The improved system also takes PC camera image as previous system, and detects tooth areas easily soiled using machine learning technique first. Then it shows easily soiled areas superimposing germs illustrations same as previous system. Further, easily soiled areas are tracked and if the area of toothbrush overlap them, the illustrations are erased. This improvement is expected to enable children to enjoy brushing tooth by using this sysetm and to increase toothbrushing guidance efficiency.

II. Previous AR tooth brushing system

In our previous study, we have proposed the system that displays the germs illustrations in tooth areas easily soiled to improve their toothbrushing habits. This system detects tooth areas easily soiled from PC camera image in real time using machine learning technique, and superimposes germs illustrations (Fig. 1) to show easily soiled areas. It takes face image (Fig. 2) by a front camera of PC first. Then teeth are detected and extracted, especially molars, the areas between a tooth and gum, the areas between a tooth and another tooth, and the area behind a front tooth. We conducted following three machine learning using library YOLOv3 [6].

- 1st To learn easily soiled areas using the images that include other than mouth
- 2nd To learn easily soiled areas using the images that include only mouth
- 3rd To learn mouth areas using the images that include other than mouth

Table I reminds that f-value of 2st learning is larger than one of 1st learning. So the system detects tooth by the result of 2nd learning after detecting mouth by the result of 3rd learning because that is better than detecting tooth from face image

directly by the result of 1st learning. However if mouth area (Fig. 3) can not be detected from face image by the result of 3rd learning, tooth are tried to be detected directly by the result of 1st learning. Also the height size of superimposed germs illustration is twice as large as the height of the detected tooth area, and it dose not overlap with each other. Also If the system detects too large area to be tooth area, then does not show illustrations because if detected area is too large, that detecting is appears to be a false positive. This system can interest children in brushing their tooth. We got that in the experiment for the family with children (Fig. 4). However while we conducted the experiment for a long time, children were losing interest in the system because the system that just displayed illustrations was boring for children. And children could not really feel it this system because the germs illustrations were not changed even if children brush their tooth. So we improved the system in this study.

TABLE I: Learn for tooth

Learning	Precision	Recall rate	f-value
1st	0.25	0.53	0.34
2nd	0.35	0.65	0.45
3rd	0.98	0.98	0.98

Fig. 1: Germs illustrations

III. Improved AR tooth brushing game

We aim for that the system interests children in brushing their tooth by showing that germs illustrations exist in their mouth and by erasing germs illustrations depending on the movement of the toothbrush that they have in hand. The system takes face image by a front camera of PC first. And it detects mouth and tooth areas easily soiled as same as previous method. We conducted machine learning for nose using library YOLOv3 and 256 face images (Fig. 5). The result is Table II. The system detects nose using this result (Fig. 6).

Fig. 2: Face image taken by a PC camera

Fig. 3: The area of mouth

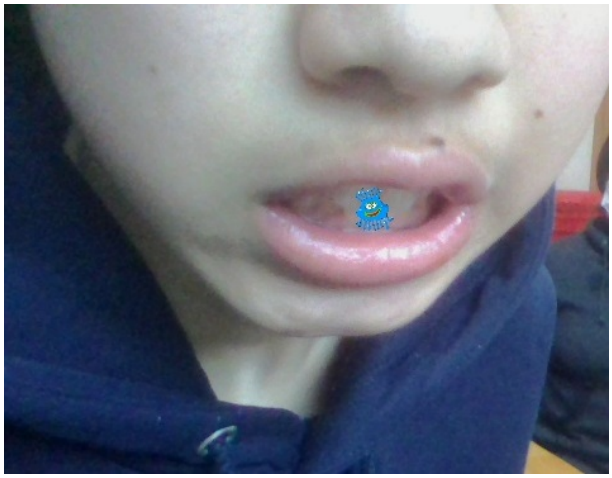


Fig. 4: Previous experiment

Each detected area is tracked according to the algorithm flow (Fig. 7). The same thinning process is also used. The position of brush part of toothbrush is also obtained. Also if toothbrush exists in the area that is detected as mouth area, the system may not be able to track the toothbrush because toothbrush prevent tooth from being visible. So the system calculated the position and size of the tooth areas easily soiled from

the position and size of the nose that is not prevented from being visible by the toothbrush that children have in hand. The position of the tooth areas easily soiled if toothbrush exists in the area that is detected as mouth area are as follows.

$$Pt = Pn \times Sn \frac{Ppt - Ppn}{Psn} \quad (1)$$

The size of the tooth areas easily soiled if toothbrush exists in the area that is detected as mouth area are as follows.

$$St = \frac{Pst \times Sn}{Psn} \quad (2)$$

Where Pt is the position of the tooth, Pn is the position of nose, Sn is the size of nose, Ppt is the position of tooth before brush of toothbrush enters the area of mouth, Ppn is the position of nose before brush of toothbrush enters the area of mouth, Psn is the size of nose before brush of toothbrush enters the area of mouth, St is the size of the tooth, and Pst is the size of tooth before brush of toothbrush enters the area of mouth. Next, the system displays germs illustrations on the tooth areas easily soiled that are tracked. The system processes to germs illustration depending on the positional relationship between the toothbrush and germs illustration (Fig. 8). Then the system records the number of times that brush of toothbrush overlaps the germs illustrations on the tooth areas easily soiled that are tracked. And if the number of times recorded exceeds a certain level, the system records the germs illustrations as the illustration that should be erased. Also when brush of toothbrush overlaps the germs illustrations on the tooth areas easily soiled that are tracked, the germs illstration that is overlaped is permeance. And the germs illustrations that are not recorded as the germs illustraion that should be erased are superimposed in real time (Fig. 9). Also if when a certain amount of time has passed since the system starts tracking the tooth areas easily soiled, mouth, and nose, the system records the informations of germs illstrations that are not erased then. The informations of germs illstrations that are not erased are the position, the germs illstrations, and the number of times that brush of toothbrush overlaps the germs illustrations on the tooth areas easily soiled that are tracked. When the system detects the tooth areas easily soiled next, the system records the information of germs illstrations that are not erased. If each position is recorded, the system record the position and do not detect the positon newly. Also when a certain amount of time has passed since the system starts tracking the tooth areas easily soiled, mouth, and nose, the system records the postion of nose and one of mouth. We used the library named OpenCV for object tracking of the tooth area easily soiled, the area of mouth, and the area of nose. To measure the position of brush part of toothbrush, we used AR marker (Fig. 10) that is one of the image recognition technique. Also if the system can not track the areas when the mouth is closed, etc. and if the illustrations that should be displayed, the system obtains face image from PC camera image and detect their tooth areas easily soiled, mouth, and nose from the image. We expected that the sytem enables children to enjoy brushing their tooth and reminds them that brushing can remove germs. This makes children brush their tooth regularly.

TABLE II: Learning for nose

Precision	Recall rate	f-value
0.94	0.95	0.95

(a) Nose image **(b)** Labeling

Fig. 5: Nose image

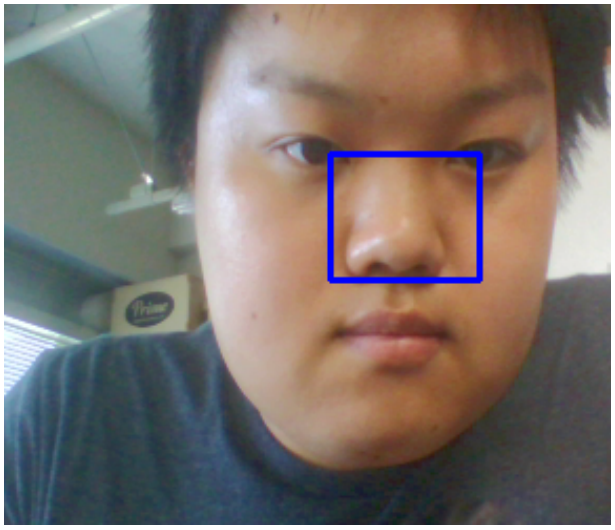


Fig. 6: Detecting nose

IV. EXPERIMENT

This system displayed the illustration of germs and erased them following the movement of the toothbrush that children have in hand (Fig. 11(a)). Also the system can trace tooth areas easily soiled even if user moves face position (Fig. 11(b)). The refresh rate is 22.11fps. The refresh rate is enough to promote children's oral care habits. Also we experimented for a elementary school student and her parent to make sure that the system can promote children's oral care habits. First, we explained them the way to use this system. Next they used this system and answered a questionnaire (Fig. 12, 13). We asked a elementary school student the following questions.

- Were you interested in this system?
- Did you feel like brushing your teeth in the future?

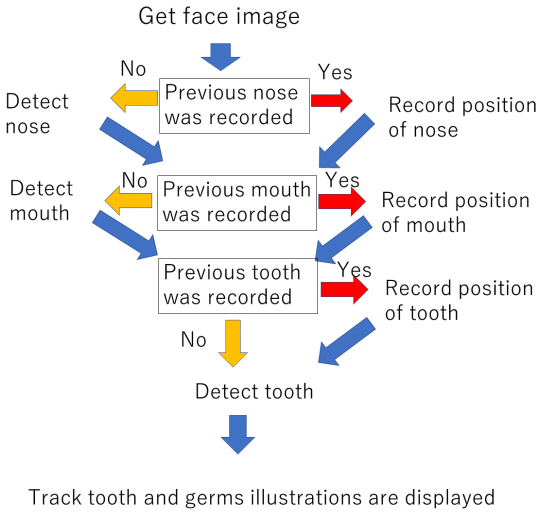


Fig. 7: System behavior from getting face image to tracking object

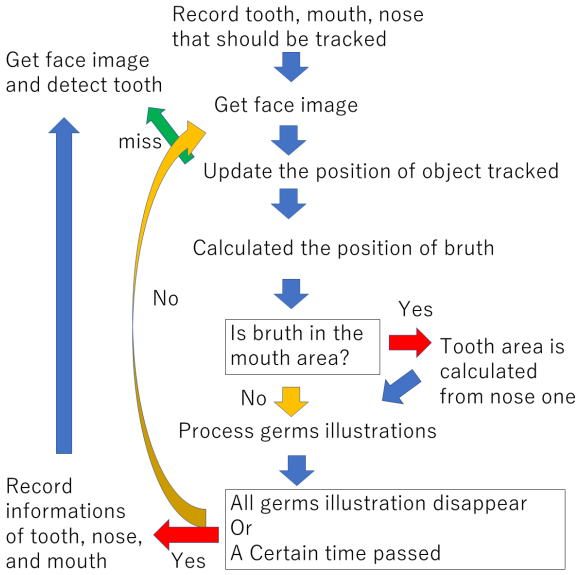


Fig. 8: System behavior from starting to track object to processing germs illustration

We asked her parent the following questions.

- Can this system be used for children's tooth-brushing education?

As a result, she told us that this system made her interest bushing her tooth and she wanted to brush tooth every day and her parent told us that this system can be used to teach children how to brush their tooth. So the result showed that the system was so valid that children learn good tooth brushing habit.

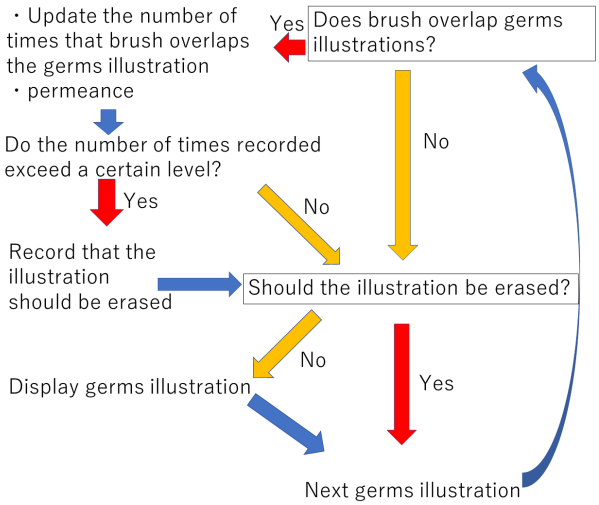


Fig. 9: System behavior from processing germs illustration to displaying it

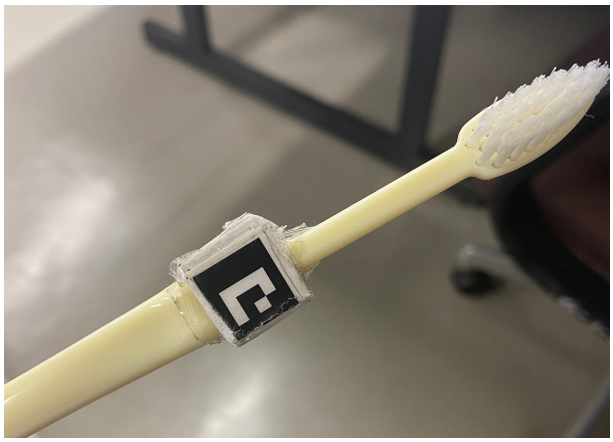


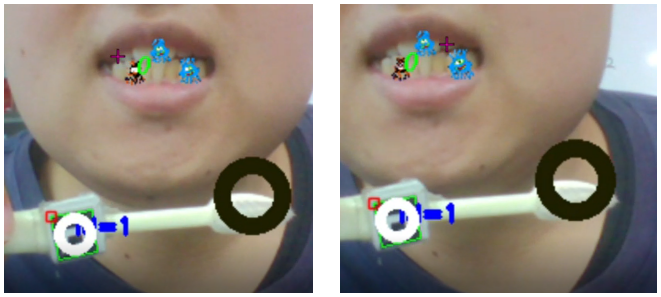
Fig. 10: Toothbrush with AR marker

V. CONCLUSION

In this study, we proposed the improved system that looks like video game to detect tooth areas easily soiled in real time using machine learning technique, superimpose germs illustrations to show easily soiled areas, and change the display of germs following the movement of the toothbrush. Also we experimented that the system is so useful that it promotes oral care habits of children. As future works, we would like to improve the system as considering the time and frequency of brushing until the germs disappear. Additional experiments are also expected for more homes or kindergarten to confirm usefulness.

ACKNOWLEDGMENT

This work was supported in part by JSPS KAKENHI Grant Number JP20K11918 and JP22K12337.



(a) Before moving **(b)** After moving

Fig. 11: Tooth area tracking

Fig. 12: Appearance of experiment

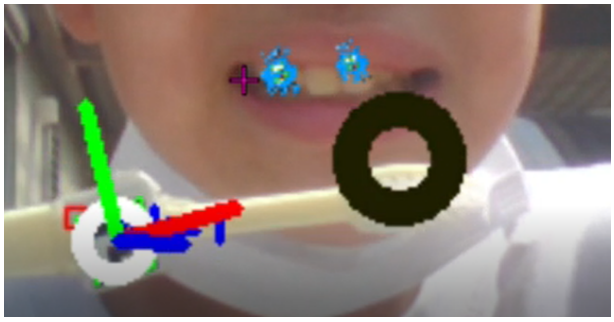


Fig. 13: Display with test labels

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