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PEER ASSESSMENT RATING (PAR) INDEX CALCULATION ON 2D DENTAL MODEL IMAGE FOR OVER JET, OPEN BITE, AND TEETH SEGMENTATION ON OCCLUSION SURFACE

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Abstract

Malocclusion is a clinical symptom, in which the teeth of maxilla and mandible are not located at the proper location. If malocclusion left untreated, it can lead to complications in the digestive system, headache, and periodontal disease disorders. Malocclusion problems involving abnormalities of teeth, bones, and muscles around the jaw are obligation of orthodontic specialists to treat them. The treatments can be varying based on the type of malocclusion, including tooth extraction and tooth braces. To know certain degree of malocclusion experienced by the patient, an assessment method called Peer Assessment Rating (PAR) Index is usually used by the specialist. To help the works of orthodontic specialists in Indonesia, a new automated calculation system based on 2D image of tooth model for PAR Index is being developed. In this paper, the calculation system for over-jet, open-bite, and teeth segmentation is developed. The result of the developed system is then compared with manual assessment done by orthodontic specialist, in order to verify the accuracy of the system.

Keywords: *2D Dental Model Image, Canny edge detection, Open Bite, Over Jet, PAR Index*

Abstrak

Maloklusi adalah gejala klinis dimana gigi pada rahang atas dan rahang bawah tidak terletak pada posisi yang semestinya. Apabila tidak dirawat, maloklusi dapat mengakibatkan komplikasi pada sistem pencernaan, sakit kepala, dan gangguan penyakit periodontal. Masalah maloklusi yang melibatkan kelainan gigi, tulang, dan otot sekitar rahang merupakan kewajiban dokter gigi spesialis ortodonti untuk merawatnya. Perawatan yang dilakukan melingkupi tindakan pencabutan gigi dan perawatan tanpa pencabutan gigi yang biasa dilakukan menggunakan kawat gigi. Untuk mengetahui dengan pasti kasus maloklusi yang dialami oleh pasien, digunakanlah sebuah metode penilaian bernama indeks PAR (Peer Assessment Rating). Untuk membantu meringankan tugas dokter spesialis ortodonti yang jumlahnya masih terbatas di Indonesia (402 dokter spesialis ortodonti se-Indonesia pada tahun 2010 menurut data dari Asosiasi Fakultas Kedokteran Gigi (AFDOGI)), maka dikembangkanlah sistem penghitungan indeks PAR otomatis menggunakan metode computer vision pada citra model gigi 2D. Pada penelitian ini, dikembangkan metode untuk menghitung 2 (dua) buah komponen penilaian indeks PAR, yaitu Jarak Gigit dan Gigitan Terbuka. Selain itu, dikembangkan pula segmentasi gigi untuk model gigi terbuka yang akan digunakan untuk menghitung 6 (enam) buah komponen penilaian lainnya. Hasil penghitungan menggunakan metode computer vision akan dibandingkan dengan penghitungan secara manual oleh dokter spesialis ortodonti untuk mengevaluasi tingkat akurasi perhitungan secara otomatis.

Kata Kunci: *Canny edge detection, citra model gigi, Gigitan Terbuka, indeks PAR, Jarak Gigit, segmentasi gigi*

1. Introduction

Malocclusion is a clinical symptom where teeth on upper jaw and teeth on lower jaw are not located accordingly. Malocclusion happens when both of jaws are in the state of closing. Untreated malocclusion can affect patient's health such as indigestion, headache, and periodontal disease. Furthermore, malocclusion also can affect patient's daily life such as low self-esteem because of abnormal facial structure, oral function disorder because of difficulty in chewing and swallowing, joints disorder in jaws, and other oral diseases like plaque, caries, and gum problems.

Malocclusion can be divided to several dangerous levels. Based on Angle classification [1], malocclusion can be divided into three different types of malocclusion which are Malocclusion Class 1, Malocclusion Class 2, and Malocclusion Class 3 [1]. Malocclusion Class 1 is the most common malocclusion in the world. A person is considered to suffer Malocclusion Class 1 if the upper teeth is located more forward than the lower teeth. Whereas, a person is considered to suffer Malocclusion Class 2 if the the upper teeth is located too forward than the lower teeth. For the last, a person is considered to suffer Malocclusion Class 3 if the lower teeth is located more forward than the upper teeth.

Malocclusion which involves abnormalities of teeth, bones, and muscles in the area of jaws is orthodontist's obligation to take care of it. Some treatments that is usually performed by orthodontist are tooth extraction and treatment without tooth extraction. The treatment without tooth extraction is usually done by using braces. Whereas, in extreme case, surgery of jaws has to be done to cure a malocclusion. To know a certain case of malocclusion, there are several methods that can be used by orthodontist. One of them is an index named Peer Assessment Rating (PAR). PAR index is not only used for knowing malocclusion rate, but also can be used to know how good malocclusion treatment has been done.

PAR index was developed by [2] in 1992. PAR Index was developed in order to meet all assessment criteria for all occlusion abnormalities that may be found on the malocclusion. PAR Index was designed to be able to determine all types of malocclusion disorder and the treatment for them, to compare malocclusion before treatment, after treatment, and after retention, as well as to evaluate quality of treatments that have been done. In practice, PAR index can be used to determine orthodontic treatment that are required for particular case, to evaluate the results of orthodontic treatment, as well as to determine the classification of malocclusion based on Angle classification (Class 1, Class 2, and Class 3).

Until now, calculation process of PAR index is usually done manually by orthodontist. Orthodontist has to use a special ruler developed by Richmond et al. [2] in order to calculate PAR index, and it usually needs a long time to calculate PAR index. To get high number of precision, the calculation of PAR index has to be done by orthodontist and it cannot be done by regular dentist. The reason of this is because the calculation process of PAR index is quite complex even for orthodontist. Because of that, if there is a regular dentist want to calculate PAR index, he or she has to be trained intensively by orthodontist to avoid mistakes in the calculation processes.

Another difficulty that has to be faced in malocclussion treatment is all of dental models from before, mid, and after treatments have to be saved in a proper place. All of models will be used for evaluating treatments that have been done to a patient. To keep dental model in its best condition, there is a special place and treatment for the models when it has to be stored.

Indonesia which has more than 17.000 islands in its territory has a particular difficult situation to provide public health services. The population of Indonesia spreads along its archipelago unevenly, and most of specialists are in big cities like Jakarta, Surabaya, and Medan. For dentist itself, there are only 19.000 dentists in Indonesia based on dentist association in Indonesia (Persatuan Dokter Gigi Indonesia or PDGI). Compare to its population that reach 231 million people in 2009, the ratio of dentists and population is only 1:12.000. This ratio is too small compare to World Health Organization's standard that needs to be in 1:2000 ratio between dentists and population in a particular country. This condition is worsen if we compare another data from faculty of dentist assocation (Asosiasi Fakultas Kedokteran Gigi or AFDOGI) that stated only 6% of dentists are ortodontist [3]. Whereas, prevalence of malocclusion in Indonesia achieved 88.58% in 1998 [4][5].

To solve problems that are faced by orthodontist, we proposed some method that can calculate PAR Index automatically by using dental model image. The use of dental model image rather that dental model images refers to the difficulty to store many dental models in real life. Furthermore, we expect to use dental model image in tele-health manner for orthodontist and patient. Dentist, who usually do not have rights to calculate PAR Index because of its complexity, can use a tele-health program that can calculate PAR Index automatically based on dental model image. The results that come from proposed method and then can be verified by orthodontist by using tele-health program. For development, we were using Open-CV [6].

PAR Index

PAR index was developed by [2] in 1992. PAR Index was developed in order to meet all assessment criteria for all occlusion abnormalities that may be found on the malocclusion. PAR index has 11 different components where each of them contains one or more different calculation. All of 11

TABLE 1
11 COMPONENTS OF PAR INDEX

No	Components of PAR Index
1	Upper right segment
2	Upper anterior segment
3	Upper left segment
4	Lower right segment
5	Lower anterior segment
6	Lower left segment
7	Right buccal occlusion
8	Over-jet
9	Overbite
10	Centre-line
11	Left buccal occlusion

TABLE 2
OVER-JET ASSESSMENT

Score	Discrepancy
0	0 – 3 millimeter
1	3.1 – 5 millimeter
2	5.1 – 7 millimeter
3	7.1 – 9 millimeter
4	Over 9 millimeter

TABLE 3
CROSS-BITE ASSESSMENT

Score	Discrepancy
0	No discrepancy
1	One or two teeth *edge to edge*
2	Cross-bite on one tooth
3	Cross-bite on two teeth
4	Cross-bite on more than two teeth

TABLE 4
OPEN-BITE ASSESSMENT

Score	Discrepancy
0	No open-bite
1	≤ 1 millimeter
2	1.1 – 2 millimeter
3	2.1 – 3 millimeter
4	> 3 millimeter

TABLE 5
OVERBITE ASSESSMENT

Score	Discrepancy
0	No abnormality
1	One or two teeth *edge to edge*
2	Cross-bite on one tooth
3	Cross-bite on two teeth

TABLE 6
NUMBER OF DOTS IN 1 MILLIMETER BOX
BEFORE AND AFTER PRE-PROCESSING PROCESS

No	Original Size	After Pre-Processing
1	12 x 13	2 x 2
2	13 x 13	2 x 2
3	13 x 13	2 x 2
4	13 x 13	2 x 2
5	12 x 12	2 x 2
6	13 x 13	2 x 2
7	11 x 11	2 x 2
8	9 x 9	1 x 1
9	12 x 12	2 x 2
10	11 x 11	2 x 2
11	9 x 9	1 x 1
12	10 x 10	2 x 2
13	10 x 11	2 x 2

components can be seen in Table 1. In this paper, we only created automatic calculation for over jet component and over bite component. Therefore, in this paper, there will be these two components' explanations only.

Overjet is horizontal distance between labial surface of lower incisor and palatal surface of upper incisor. There are two calculations of assessment that are complement to each other named overjet and crossbite. Overjet assessment scores can be seen in Table 2, and crossbite assessment scores can be seen in Table 3.

Overbite

Overbite is vertical distance between upper incisor and lower incisor. There are two calculations that are complement to each other named openbite and overbite. Openbite assessment scores can be seen in Table 4, and overbite assessment score can be seen in Table 5.

Dental Model and Calibration

Dental models that have been printed will be sized 1:1 according to the shape and size of the patient's jaw and teeth. Each model, both before and after treatment ,should be kept in order to be evaluated continuously. Some of stored models are selected randomly, but in accordance with the limitations of research that has been described previously.

To get the image of model, each model that have been selected will be scanned with 300 dpi (dots per inch) quality. Each model will be scanned from many sides. This is accomplished because it is impossible to count all of PAR index components by using only one side of dental model image.

We took six dental images from different six sides for every dental models which we named: 1) the front side of the dental models, 2) the left side of the dental models, 3) the right side of the dental models, 4) the occlusal surface of the dental models, and 5&6) the front side of dental models with upper and lower jaws apart. To facilitate the calibration process for resulted images, millimeter box was affixed on the scanner around the dental models. Resulted image from this process can be seen in Figure 1.

Calibration is done by comparing the size of a box of 1 millimeter from millimeter box produced in the process of image data collection with a box of 1 millimeter from millimeter box that has been processed in pre-processing process. The number of dots or points from origin 1 millimeter

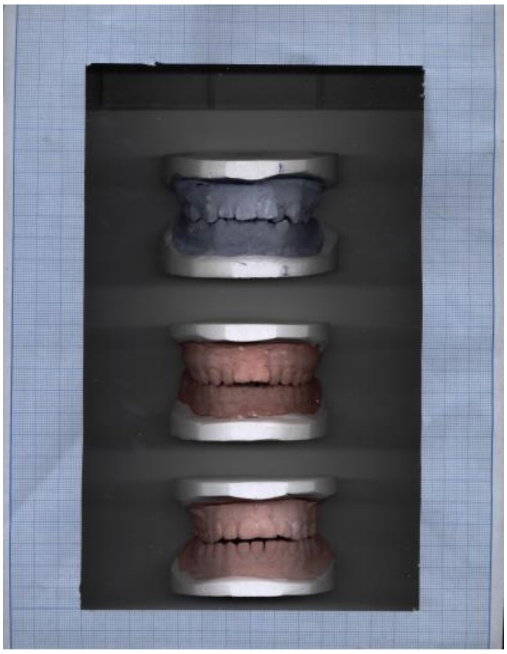

Figure 1. Example of resulted dental image [7].

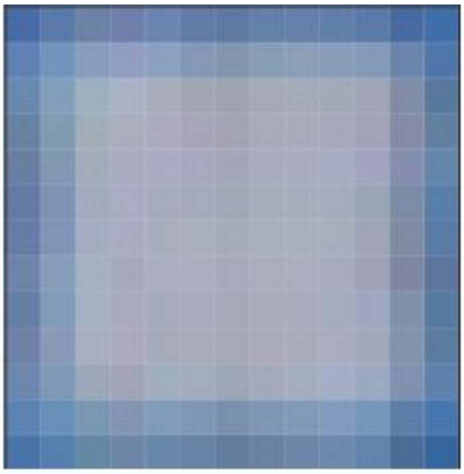

Figure 2. Original 1 millimeter box before pre-processing which has 12x12 dots.

box are compared with a box that has been processed in pre-processing processes. The results then will be used as the calibration value. The origin of 1 box of millimeter box can be seen in Figure 2. From this calibration process, resulted values that is shown in Table 6 were produced. From the table, we can see that most of 1 millimeter boxes that are used in calibration process will have 2x2 points of box. Therefore, we can say that 2x2 points of box will be the same as 1 millimeter in the origin size.

2. Methods

Feature Extraction of Over-jet

Figure 3. Example of resulted cropped dental image.

Figure 4. Example of resulted images (from left to rig-ht: grayscale, binary, and after morphology processes).

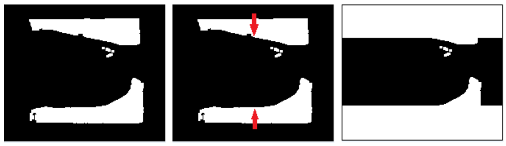

Figure 5. Example of midpoint location and mask for prediction of teeth location.

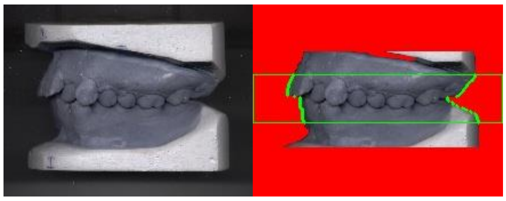

Figure 6. Example image of over-jet feature extraction.

The first thing to do is manually cutting a dental model base of the full image dental models as shown in Figure 1. Cutting is done manually because it does not belong to the scope of the study. Cutting is done randomly or not to follow a rule. Example image after manually cutting are shown in Figure 3.

The resulted cropped image further will be reduced up to 1/15 of its original size. Once the size is reduced, the resulting image is converted from RGB color model to grayscale color model. Image grayscale color model thresholding process is then performed to create a binary image color model. Furthermore, morphological process will be used to eliminate the noise from the binary image. Morphological processes that are carried out is a combination of morphological technique of opening, dilation, and erosion. Example of the resulted images from these processes can be seen in Figure 4.

The results of base segmentation of dental

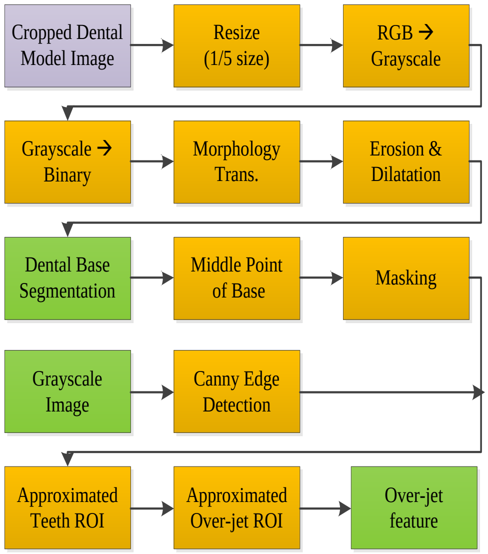

Figure 7. General flowchart for over-jet feature extraction.

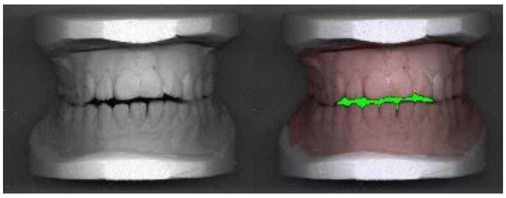

Figure 8. Example image of open-bite feature extraction.

model will be used as an input to predicting the location of the teeth as well as location of over-jet. The next process is to predict the midpoint of the base model of the teeth. The midpoint can be fo-und by finding the midpoint of the base. After th-at, we make a mask on the midpoint to overlay the unnecessary space or background. Examples of the resulting mask masking process to predict the location of the tooth can be seen in Figure 5.

After getting the teeth location, the next thi-ng to do is to find bounderies between teeth, mo-del, and the background. To get teeth indentati-on boundaries, Canny Edge Detection is used. To cla-rify the boundaries of the teeth and remove noise that might occur, morphological dilation, erosion, and Hole Filling Algorithm [8] is used. Image of teeth boundaries will then be combined with the mask so that only the part of teeth prediction loca-tion will be appeared. The remaining part of the background on the left and the right gear models will then be merged with the mask. Outermost bo-undary between the background with teeth then will be used as an PAR Index value of over-jet. To improve the predicted value of over-jet, location of teeth are divided into four equally locations where the two most central area of them are the

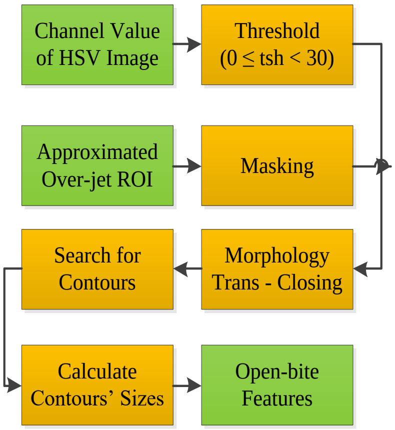

Figure 9. General flowchart for open-bite feature extraction.

location of over-jet malocclusion. Example of re-sulted image from this process can be seen in Fi-gure 6. Whereas, general flowchart for over-jet fe-ature extraction can be seen in Figure 7.

Feature Extraction of Open-bite

PAR Index feature extraction of open-bite is done by changing the original color model of dental model image (Red-Green-Blue color model) into Hue-Saturation-Value (HSV) color model [10]. HSV color models is used to make manipulation and interpretation of an image easier. For open-bite, only value color channel of the HSV color model is used to extract the required features. This is because channel value of HSV color model is used to represent lighting level, so the extraction feature of open-bite that rely on shadow between teeth will be more easy to be done.

Prediction of teeth location that were used in over-jet feature extraction wil be reused in open-bite feature extraction. Prediction of the location of the teeth is used to make sure that the area to be analyzed is an area between upper jaw teeth and lower jaw teeth. Threshold process will be carried out in this area with threshold value is $0 \leq$ *threshold* < 30. These two values are predicted va-lues which represent shadow for holes of open-bite. Example of resulted image from this process can be seen in Figure 8.

Once resulted image of masking and thres-holding processes has been produced, morpholo-gical process of opening is performed to remove noise that might arise. Noises that arise from the previous process are the pixel dots that have the same value of open-bite shadow on the image but do not have a partner nearby. These kind of pixel is classifed as noises. After that, contour detection will be performed on the resulted image. Contour detection is performed to count number of objects

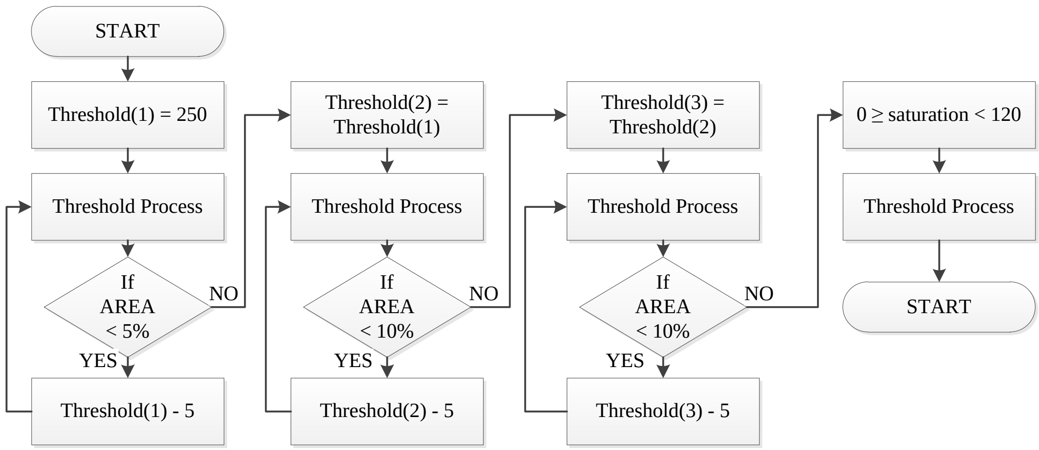

Figure 10. Adaptive Multiple Threshold (AMT) that is used in teeth segmentation.

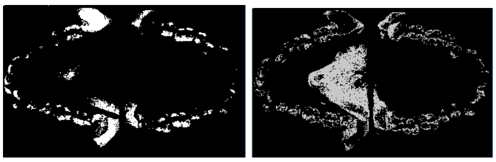

Figure 11. Example of resulted image of AMT from the first and second levels.

Figure 12. Example of resulted image of AMT from the third and final levels.

in the resulted image.

In this process, there will be information for the number of existing contour in the image, the location of the contour in the image, and the size of the contour.

This information then will be used in the assessment process of PAR Index's open-bite. In general, general flowchart for open-bite feature extraction can be seen in Figure 9.

3. Results and Analysis

Teeth Segmantation on Occlusal Surface

To calculate six components of PAR Index; (1) upper right segment, (2) lower right segment, (3) upper left segment, (4) lower left segment, (5) upper anterior segment, and (6) lower anterior segment, we need dental model image taken on its occlusal surface. As performed in previous methods, each model will be cropped manually to obtain images of individual occlusal surface dental

Figure 13. Example of resulted mask before (left) and after (right) noise reduction using morphological transformation.

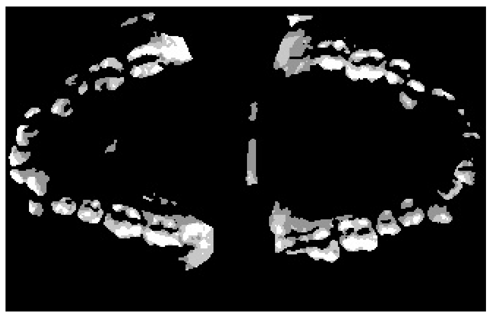

Figure 14. Example image of final resulted image of occlusal surface of dental model.

models. Each image will then be converted from RGB color model into HSV color model. From three existing channels of HSV, saturation channel is used for thresholding process based on the saturation value of each point or pixel.

Threshold process on the teeth segmentation process is done by multiple adaptive thresholding method where threshold value for the saturation value is divided into four levels. Multiple adaptive thresholding is performed by limiting the number of image regions that dental models can fit into an image thresholding results. This threshold system is proposed to reduce noise and also ensures that resulted teeth region is not too large. Flow chart of multiple adaptive thresholding can be seen in Figure 10.

The first level in the process of multiple

TABLE 7
DIFFERENCES BETWEEN MANUAL CALCULATION AND AUTOMATIC CALCULATION FOR OVER-JET FEATURE FROM RIGHT SIDE OF DENTAL MODEL

No	Model's Name	DRM-1 (mm)	DRM-2 (mm)	DRM-3 (mm)	DRA (mm)	DIFF-1 (mm)	DIFF-2 (mm)	DIFF-3 (mm)
1	A1-Right	5	5	6	6.5	1.5	1.5	0.5
2	A2-Right	10	10	10	9.5	0.5	0.5	0.5
3	A3-Right	5	5	4	6	1	1	2
4	B1-Right	9	9	9	6	3	3	3
5	B2-Right	4	4	5	5	1	1	0
6	B3-Right	8	7	7	8	0	1	1
7	C1-Right	3	1	2	3	0	2	1
8	C2-Right	3	1	2	2	1	1	0
9	D2-Right	5	4	5	5	0	1	0
10	D3-Right	3	3	4	3	0	0	1
					Average	0.8	1.2	0.9

TABLE 8
DIFFERENCES BETWEEN MANUAL CALCULATION AND AUTOMATIC CALCULATION FOR OVER-JET FEATURE FROM LEFT SIDE OF DENTAL MODEL

No	Model's Name	DRM-1 (mm)	DRM-2 (mm)	DRM-3 (mm)	DRA (mm)	DIFF-1 (mm)	DIFF-2 (mm)	DIFF-3 (mm)
1	A1-Left	5	5	6	5.5	0.5	0.5	0.5
2	A2- Left	10	10	10	10	0	0	0
3	A3- Left	5	5	4	5	0	0	1
4	B1- Left	9	9	9	5.5	3.5	3.5	3.5
5	B2- Left	4	4	5	5	1	1	0
6	B3- Left	8	7	7	8.5	0.5	1.5	1.5
7	C1- Left	3	1	2	2.5	0.5	1.5	0.5
8	C2- Left	3	1	2	2.5	0.5	1.5	0.5
9	D2- Left	5	4	5	4	1	0	1
10	D3- Left	3	3	4	4.5	1.5	1.5	0.5
					Average	0.9	1.1	0.9

TABLE 9
DIFFERENCES BETWEEN MANUAL CALCULATION AND AUTOMATIC CALCULATION FOR OVER-JET FEATURE FROM RIGHT SIDE OF DENTAL MODEL

No	Model's Name	ACC	TNR	FNR	FPR	TPR	PRC	GM
1	A1	0.87	0.91	0.35	0.09	0.66	0.55	0.60
2	A2	0.84	0.86	0.25	0.14	0.75	0.49	0.61
3	A3	0.84	0.83	0.15	0.17	0.85	0.52	0.66
4	B1	0.82	0.82	0.21	0.18	0.79	0.49	0.62
5	B2	0.83	0.84	0.19	0.16	0.81	0.51	0.64
6	B3	0.81	0.80	0.18	0.20	0.82	0.46	0.61
7	C1	0.86	0.87	0.20	0.13	0.80	0.54	0.66
8	C2	0.86	0.88	0.25	0.12	0.75	0.48	0.60
9	D1	0.84	0.87	0.35	0.13	0.65	0.46	0.55
10	D2	0.87	0.89	0.23	0.10	0.77	0.54	0.65
11	D3	0.87	0.90	0.27	0.11	0.73	0.60	0.67
Average		0.85	0.86	0.24	0.15	0.76	0.51	0.62

adaptive thresholding is to get the highest value of saturation in the image of occlusal surface of dental models but the region will be ranged between 5-10% only. The second level is the second highest value of saturation in the image of occlusal surface of dental models and the region that will be taken from is ranged between 10-15%. The third level is the third highest saturation value in the image of occlusal surface of dental models and the region that will be taken from is ranged between 10-15%. As for the last level is to get the lowest saturation value where saturation value is $0 \geq saturation < 120$.

From the first level to the third level in the process of multiple adaptive thresholding, gradual reduction of the threshold value is performed. Initial value of the threshold on the first level is 250, and the threshold value will continue to decrease in the scale of 5 until the first level thresholding condition is not met. The first level condition is the number of the resulted region should be less than 5% compared to the origin dental model image. If the resulted region is greater than 5%, then the first level of thresholding process will be terminated. The last value of threshold used in the first level will be the initial threshold value on the second level. The process in the first level then will be performed in the second and third levels.

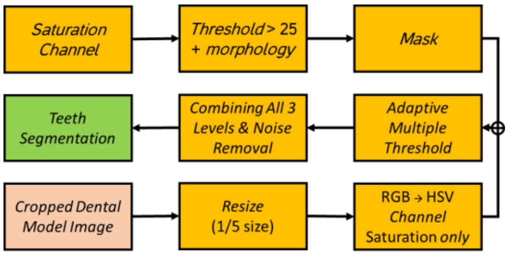

Figure 15. General flowchart for teeth segmentation.

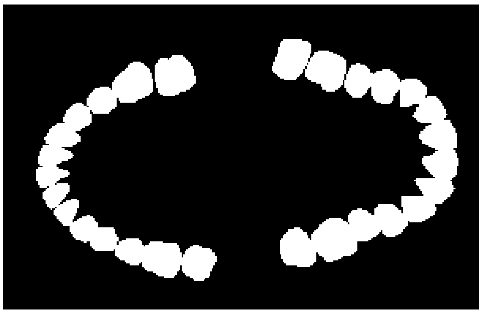

Figure 16. Example image of ground truth.

The differences between these levels are the conditions of resulted image that should be less than 10% over the entire region of origin image model. Examples of multiple adaptive image thresholding results 4 levels can be seen in Figure 11 and Figure 12.

From the above segmentation results, we obtained enough information to determine position of each tooth. However, there are still many noises that come from adaptive multiple thresholding. Therefore, a mask and some morphological transformation are used to get rid these noises.

To make the mask, we use the saturation channel of HSV color model with a threshold value 25. With value of 25, we will get all regions that have saturation values greater than 25 which are estimated teeth region. To eliminate noises in the mask, morphological transformation of closing is used several times so that the regions are close to each other and make a larger region. Examples mask resulting from thresholding and morphological transformation can be seen in Figure 13.

After mask is used, the first, second, and third levels are combined to build a final image of teeth segmentation. To reduce noises, Hole Filling Algorithm [7] is used in the final process. The final image from these process can be seen in Figure 14. Whereas, general flowchart of these processes can be seen in Figure 15.

We used 10 dental models that have been taken their images for all experiments. All models have been manually calculated their PAR Index by three different orthodontists. We compared manual results with automatic results by using proposed methods that have been previously discussed.

TABLE 10
EXAMPLE FEATURE VALUES FOR OPEN-BITE BY PROPOSED METHOD FROM DENTAL MODEL D2-RIGHT

No	Column Min, Max	Row Min, Max	Delta Distance, Height
1	107, 107	86, 86	0, 0
2	98, 98	89, 89	0, 0
3	98, 98	89, 89	0, 0
4	95, 95	88, 88	0, 0
5	71, 72	94, 94	1, 0
6	114, 115	87, 87	1, 0
7	62, 70	87, 92	8, 5
8	127, 136	76, 84	9, 8

Over-jet Feature Extraction

As explained in the previous section that PAR Index value for over-jet obtained by finding the closest point on the boundary image (minimum) to the furthest point from the image limit (maximum). Comparison of results between manual calculation and automatic calculation from the right side of dental models can be seen in Table 7 while calculations for the left side of dental models can be seen in Table 8.

As we can see two tables that the difference between manual calculation and automatic calculation is quite small. The average difference is ranged from 0.8 mm to 1.2 mm for right side dental model and from 0.9 mm to 1.1 mm for left side dental model. As for minimum and maximum difference between two calculations are 0 mm and 3 mm for the right side dental model and 0 mm and 3.5 mm for the left side dental model.

Open-bite Feature Extraction

From the results of open-bite feature extraction, it appeared that the holes between teeth that become the focus of open-bite calculation can be well identified. As seen in Figure 7 that the holes was drawn by green color. However, not all green holes that appeared in experiments are open-bite malocclusion disorder. In general, there are three possible outcomes from open-bite feature extraction. They are; 1) marked regions are open-bite malocclusion; 2) marked regions are shadows made by upper teeth and lower teeth; and 3) marked regions are *cusp-to-cusp regions*. From these three possibilities, only the first is open-bite.

In the process of open-bite feature extraction, some information was stored from each dental models. The information stored were: (1) number of regions; (2) location of maximum and minimum points in the region of column; (3) location of maximum and minimum points in the region of row; (4) maximum distance of each region; and (5) maximum height of each region. Example of information obtained from an image of dental model can be seen in Table 10.

From Table 10, we can classify the data into three different classes that have been introduced before. First, data that have distance and height 0, which are dots, and data that have height 0, which are lines, will be classified as class a_0. Second, data that are shadows made by upper teeth and lower teeth will be classified as class a_1. Lastly, data that are open-bite will be classified as class a_2. From all 10 dental models, we got 155 regions where 95 of them are class a_0, 49 of them are a_1, and 11 of them are class a_2. We tried this data in classification by using Generalized Learning Vector Quantization (GLVQ). By using this algorithm, we got 89.68% of accuracy and 0.7989 of kappa statistic in 10-fold cross validation problem. The features that were used are distance and height.

Teeth Segmentation

To see how well teeth segmentation that has been developed, we used confusion matrix [9],[11] to an-alyze the results. The results can be seen in Table 9. ACC, TNR, FNR, FPR, TPR, PRC, and GM stand for accuracy, true negative rate, false nega-tive rate, false positive rate, true positive rate, pre-cision, and geometric mean [9]. This calcula-tion were made by using ground truth images that have been made manually. Example of ground tru-th image can be seen in Figure 16.

From Table 9, we can see that the results for teeth segmentation are quite good. Accuracy of segmentation could achieve 85%. However, because the negative value (black dots) of dental model image are far greater than the positive value (white dots) which each 20:80 in ratio, we have to calculate geometric mean to see the true accuracy [12]. Geometric mean (GM) can be calculated by using formula below where TPR stands for True Positive Rate and PRC stands for precision.

$$GM = \sqrt{TPR \times PRC} \quad (1)$$

$$TPR = \frac{True\ Positive}{False\ Negative + True\ Positive} \quad (2)$$

$$PRC = \frac{True\ Positive}{True\ Positive + False\ Positive} \quad (3)$$

In confusion matrix, true positive rate explains proportion of positive data samples that are correctly classified by the classification system. On the other hand, precision explains proportion of positive data sample compare to all data that are classified as positive. In consequence, geometric mean will explains how well the result is based on true positive rate and precision. From the geometric mean results, we can see that the method only could achieve 62% of accuracy. This low result was caused because almost all results for precision are still comparably low (46%-60%). This indicates that the teeth segmentation needs improvement in precision.

4. Conclusion

In this paper, methods to calculate over-jet, open-bite, and teeth segmentation have been proposed. Over-jet and open-bite of PAR Index feature extraction have been successful developed, and teeth segmentation for other six PAR Index components has also been developed. We used 10 dental models with various colors of dental model with red and blue as the most common colors. From the experiments, there was not any big difference results between each color for all experiments.

Over-jet automatic calculation achieved average difference from 0.8 mm to 1.2 mm for right side dental model and from 0.9 mm to 1.1 mm for left side dental model. For open-bite, automatic calculation could achieved 85% accuracy of classification by using GLVQ algor-ithm. Whereas, teeth segmentation have 62% of accuracy by using geometric mean. This low result was caused because almost all results for precision are still comparably low (46%-60%). This indicates that the teeth segmentation needs improvement in precision.

From these results, we still have to improve the automatic calculation so that it will have lesser differences with manual calculation. Furthermore, teeth classification also need improvement so that it will be easier for automatic calculation on other six components of PAR Index. However, in general, this research has achieved the origin objective to create automatic calculation for some PAR Index components which are over-jet and open-bite.

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