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AN IMPROVED MATHEMATICAL MODEL AND ALGORITHM FOR TOOTH BORDER SEGMENTATION FROM X-RAY DENTAL IMAGES

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***Abstract**. Mathematical machine learning model for dental disease diagnosis plays an important role in medicine with high accuracy, speed and personalization capabilities. This allows to increase efficiency not only for patients, but also for medical personnel. Therefore, in this paper, an improved mathematical model and algorithm are developed for effective detection of dental diseases.*
***Key words:** Segmentation, diagnosis, X-ray, dental diseases, deep learning model, models.*

I. INTRODUCTION

Another important step for diagnosing X-ray images is the segmentation process. Segmentation of teeth from dental radiographs by template matching[1]. Recent advances in deep learning-based segmentation and object detection algorithms[2]. Automatic segmentation of the mandible in panoramic radiographs[3]. Segmentation of teeth in panoramic dental radiographs using mask regional convolutional neural network[4]. segmentation[5].Visualization framework for tooth segmentation in panoramic radiographs[6].

The above-mentioned research and scientific studies show that this process is an important process in improving the accuracy of X-ray diagnosis and achieving an effective result.

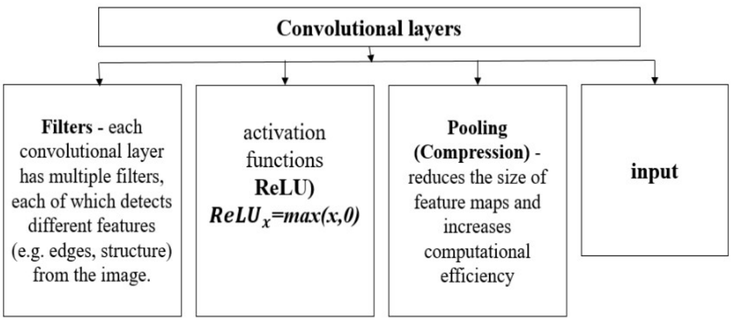

Figure 1. A convolutional layer segmenting tooth boundaries in X-ray images.

The Sobel filter is widely used in image boundary detection. It determines the boundaries by calculating the gradient of the image. The purpose of the Sobel filter is to calculate the gradient of the image. The gradient indicates the color change of the image, and higher values indicate boundaries.

The Sobel filter has two main convolution surfaces, one for the horizontal gradient (Gx) and one for the vertical gradient (Gy).Gx (horizontal gradient) is calculated using the formula below.

$$G_X = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad (1)$$

Gy (vertical gradient) threshold definition formula.

$$G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad (2)$$

The process of applying the Sobel filter is done by convolution. The image let us denote by I(x,y). The process of applying the Gx and Gy matrices to the image is calculated using the following formula.

If there is an image input I(x,y), the horizontal gradient G_X is calculated by the formula (3)

$$G_x(i,j) = \sum_{m=-1}^{1} \sum_{n=-1}^{1} I(i+m, j+n) \cdot G_x(m+1, n+1) \qquad (3)$$

If there is an image input I(x,y), the vertical gradient G_y is calculated by the following formula (4) when the filter collapses.

$$G_y(i,j) = \sum_{m=-1}^{1} \sum_{n=-1}^{1} I(i+m, j+n) \cdot G_y(m+1, n+1) \qquad (4)$$

The gradient values for each pixel are calculated using these formulas. To calculate the total value of the gradient, Gx and Gy are combined with the following formula.

$$G = \sqrt{G_x^2 + G_y^2} \qquad (5)$$

Here G is the total value of the gradient. To determine the direction of the border, the following formula (5) is used.

$$\theta = \text{atan}\left(2G_{y,}G_X\right) \qquad (6)$$

These mathematical processes of the Sobel filter are important in image segmentation and object boundary detection. This method is widely used in computer vision and X-ray image analysis.

Activation functions play an important role in computing the output of neurons in artificial neural networks (ANNs). They determine the output value by transforming the values calculated on the inputs of the neuron.

The sigmoid function allows the input value to be normalized between 0 and 1, which is useful for representing probabilities. The sigmoid function is expressed in the following formula.

$$\sigma(x) = \frac{1}{1+e^{-x}} \quad (7)$$

Here e is Euler's number (approximately 2.71828), x is the input value, and the sigmoid function gives the output value in the interval (0, 1). σ(0)=0.5 at x=0 This point shows the symmetry of the function, the function has the highest slope at x=0, where $\sigma'(0)$=0.25. The slope decreases as the value of x increases.

The derivative of the sigmoid function is expressed in the following formula.

$$\sigma`(x) = \sigma(x) \cdot (1 - \sigma(x)) \quad (8)$$

where s(x) is the value obtained in the function itself.

Let's look at the graph of the sigmoid function. The graph extends along the x-axis and lies between 0 and 1 along the y-axis. converges asymptotically. When the slope of the sigmoid function is small, the backpropagation process can have a very small gradient, which slows down the learning process. Since the output values are between 0 and 1, this can cause problems in some cases.

The sigmoid function plays an important role in artificial neural networks and statistical modeling. Its unique properties and applications make it useful in learning processes and probability calculations. However, it is important to consider its shortcomings and choose other activation functions if necessary.

The ReLU (Rectified Linear Unit) activation function comes in handy when checking tooth color images. The ReLU function is simple and effective, mainly for manual validation of deep learning models.

The ReLU function is defined

$$f(x) = \max(x, 0) \quad (9)$$

Here f(x) is the result of the ReLU function, x is the input argument of the function.

Features of the ReLU function

- $x > 0 \ if \ f(x) = x$
- $x \leq 0 \ if \ f(x) = 0$

Dental X-ray images are often high-dimensional data, and deep neural networks are used to classify them. The ReLU function is used for data processing in these networks.

For example, there is N-dimensional input data. In each layer, the convolution operation is performed as follows.

$$y = W \cdot x + b \quad (10)$$

Here y is the output, W is the weight, x is the input, and b is the input. Then, the ReLU function is applied.

$$f(y) = \max(0, y)$$

The ReLU function preserves the non-zero parts of the output values and converts the non-zero parts to 0. This activation function allows the model to reduce uncertainty and loss.

Gradient calculation is very important during training with the ReLU activation function. The gradient of ReLU.

$$Agar\ x > 0\ bo`lsa, f'_{(x)} = 1$$

$$Agar\ x \leq 0\ bo`lsa, f'_{(x)} = 0$$

These gradients are used, for example, in the backpropagation process and ensure that this process is efficient in training the model.

The ReLU activation function is very effective in diagnosing X-ray dental images. It is widely used in deep learning models due to its simplicity, speed and gradient availability. The use of this function speeds up the process of extracting features from images and classifying them.

In order to further improve the accuracy of the ReLu function

$$f(x) = \max(x, 0)$$

Features of the ReLU function.

$$\begin{cases} x > 0\,, f(x) = x \\ \beta \cdot x \leq 0\,, f(x) = 0 \end{cases} \quad (11)$$

Here b is any (-) negative value.

Properties of the ReLU function: If the value of x is positive, it returns the value of x. If the value of x is negative, instead of returning a value of 0, multiplying some b (-) by a negative value and returning the value of x will increase the accuracy, but it will lose time due to the increase in calculations.

For example, suppose you have the following values of X.

$$x = \begin{bmatrix} -5 \\ 10 \\ -8 \\ 15 \end{bmatrix}$$

We calculate input values for X1=-5, X2=10, X3=-8, X4=15 using the formula (2.30). b=-0.5

$$f(-5) = max(-0.5) \cdot (-5) = 2{,}5$$

$$f(-8) = max(-0{,}5) \cdot (-8) = 4$$

$$f(15) = max(0{,}15) = 15$$

$$f(10) = max(0{,}10) = 10$$

By collapsing the ReLu function, the following output will have positive values. b=(-0.5) negative value allows negative values to be returned as positive values without returning them as 0.

$$x = \begin{bmatrix} -5 \\ 10 \\ -8 \\ 15 \end{bmatrix} \quad y = \begin{bmatrix} 2{,}5 \\ 4 \\ 15 \\ 10 \end{bmatrix}$$

If we take into account that the accuracy of x-ray images in the field of medicine is in the first place, the above formula (2.30) can be considered the most effective. Accuracy is achieved at the expense of time.

Pooling layers are used in artificial neural networks to reduce image size and extract important features. The most common pooling methods are max pooling and average pooling.

Max pooling uses the following formulas and concepts to reduce image dimensions and select the largest value.

Max pooling, the following formula is used to find the largest value in a k×k area of a given matrix.

$$P(i,j) = \max\left\{ I(m,n) \middle| \begin{matrix} m \in [i \cdot s, i \cdot s + k), \\ n \in [j \cdot s, j \cdot s + k) \end{matrix} \right\} \quad (12)$$

Here P(i,j) is the value in the result matrix, row i and column j. I(m,n) is the value in the input matrix, k is the size of the pooling area, s is the stride (for example, 2), which defines how many pixels to shift in each step.

Let's say that the input is a 4x4 size image and there is a 2x2 size MaxPooling function.

$$I = \begin{bmatrix} 1 & 3 & 1 & 5 \\ 5 & 6 & 8 & 9 \\ 3 & 4 & 6 & 7 \\ 6 & 7 & 5 & 4 \end{bmatrix} \qquad X1 = \begin{bmatrix} 1 & 3 \\ 5 & 6 \end{bmatrix}$$

$$X2 = \begin{bmatrix} 1 & 5 \\ 8 & 9 \end{bmatrix}$$

$$X3 = \begin{bmatrix} 3 & 4 \\ 6 & 7 \end{bmatrix} \qquad X5 = \begin{bmatrix} 6 & 7 \\ 5 & 4 \end{bmatrix}$$

MaxPooling 2x2 pooling (X1,X2,X3,X4) MaxPooling performs the calculation by selecting the largest value of the layers from which the feltir is derived.

X1={1,3,5,6}=6, X2={1,5,8,9}=9,

X3={3,4,6,7}=7, X4={6,7,5,4}=7

$$I = \begin{bmatrix} 1 & 3 & 1 & 5 \\ 5 & 6 & 8 & 9 \\ 3 & 4 & 6 & 7 \\ 6 & 7 & 5 & 4 \end{bmatrix} \quad \Rightarrow \quad \text{MaxPooling} \quad \Rightarrow \quad I = \begin{bmatrix} 6 & 9 \\ 7 & 7 \end{bmatrix}$$

A 2x2 MaxPooling filter is applied to the input image I, and the main boundaries of the image are determined. This process reduces the size of the image and preserves the important features.

The output layer is the last layer of artificial neural networks. It plays an important role in the preparation and classification of the final results of the model.

The task of the output layer is to process the data received from the input layer and make final decisions.

If the output layer has N classes, each neuron represents the probability of N classes. Softmax activation function is used for this.

$$Y_i = \frac{e^{zi}}{\sum_{j=1}^{N} e^{zj}} \qquad (13)$$

Here Y_i is the i-th class of the output, z_iesa is the output of the neuron.

If the output predicts a single real value (eg, price), the output layer has only one neuron, and usually no activation function is used.

$$Y = wx + b \qquad (14)$$

The output layer is an important element of artificial neural networks. It prepares model outputs and outputs results for classification or regression tasks. The configuration of the output layer and the activation function will depend on the specific task of the model.

The segmentation process for X-ray images is important in medicine. This process is used in many fields such as diagnostics, treatment planning, image analysis, artificial intelligence training and statistical research. With the help of segmentation, accurate and efficient results can be achieved, which will serve to provide the best treatment options for patients.

There are several problems and disadvantages in tooth border segmentation from X-ray dental images. Noise or low-quality images in X-ray images make it difficult to determine the boundaries of the tooth. reduce the accuracy of segmentation results, differences between teeth, differences between different teeth (for example, hardness, color of teeth) can cause problems in the segmentation process. Sometimes the teeth are very close to each other, making it difficult to separate them. Existing egmentation algorithms cannot accurately reflect the complex tooth anatomy. Algorithm uncertainties and incorrect parameters may result in incorrect segmentation, if various dental problems (e.g., caries, infections) are present in the dental x-ray images, these conditions may be ignored in the segmentation process. , segmentation algorithms may not perform well due to insufficient data or incorrect data in the learning process, integration with external software or interfaces may have problems, which may hinder the implementation of tooth segmentation. makes it difficult. The process of tooth border segmentation from X-ray dental images faces several challenges. However, with the help of modern technologies and more advanced algorithms, these problems can be reduced.

The following architecture and algorithm

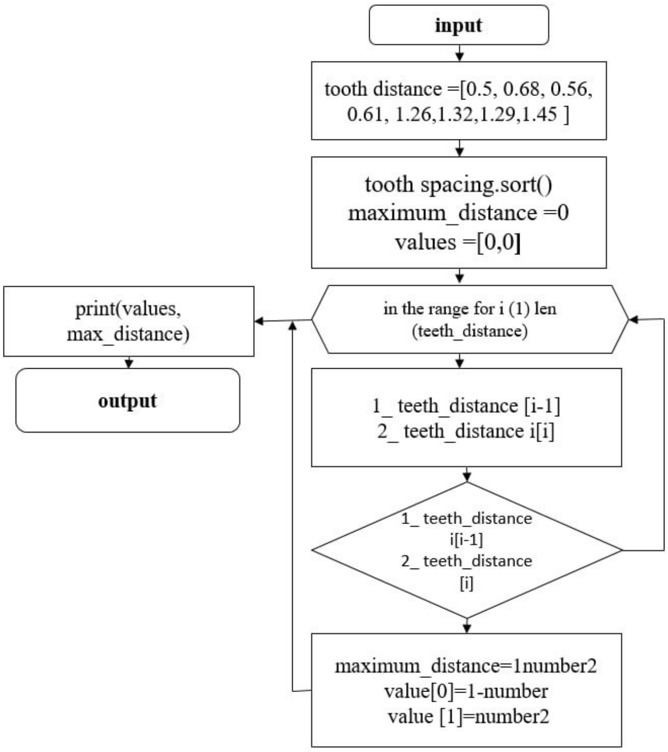

Figure 2. Algorithm for segmentation of tooth boundaries from X-ray images.

1.step. a scanned X-ray tooth image is entered; one condition is entered for the distance between teeth [0.5, 0.68, 0.56, 0.61, 1.26, 1.32, 1.29, 1.45].

2. step. The value of the tooth gap in X-ray dental images is entered as a limit [0,0].

3.step. condition is entered for i in the range (1) line tooth distance

4.step4. 1_tooth_distance[i-1],2 _tooth_ distance[i] define the distance between the first and second teeth.

5.step. Rechecks if the distance between the teeth in the x-ray dental images exceeds the limited sphere, if the distance between the teeth in the x-ray dental images satisfies the specified condition, the algorithm goes to the next step and the algorithm is finished. The following database was obtained for the experiment conducted using the above algorithm.

1 table.

Data set for the experiment

1	training	validation	test	Health image
2	500	275	200	150

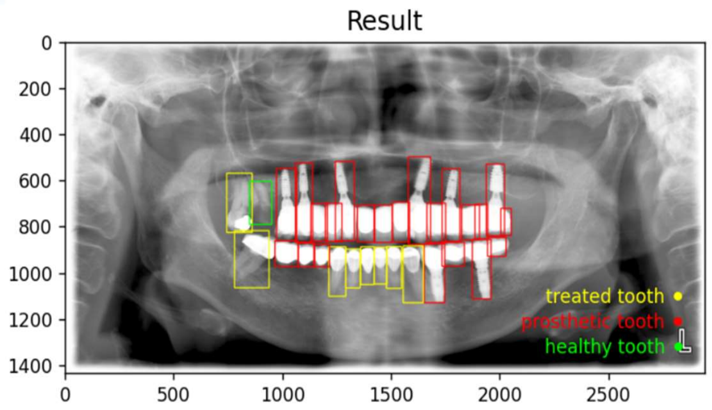

Figure 3. X-ray dental imaging diagnosis.

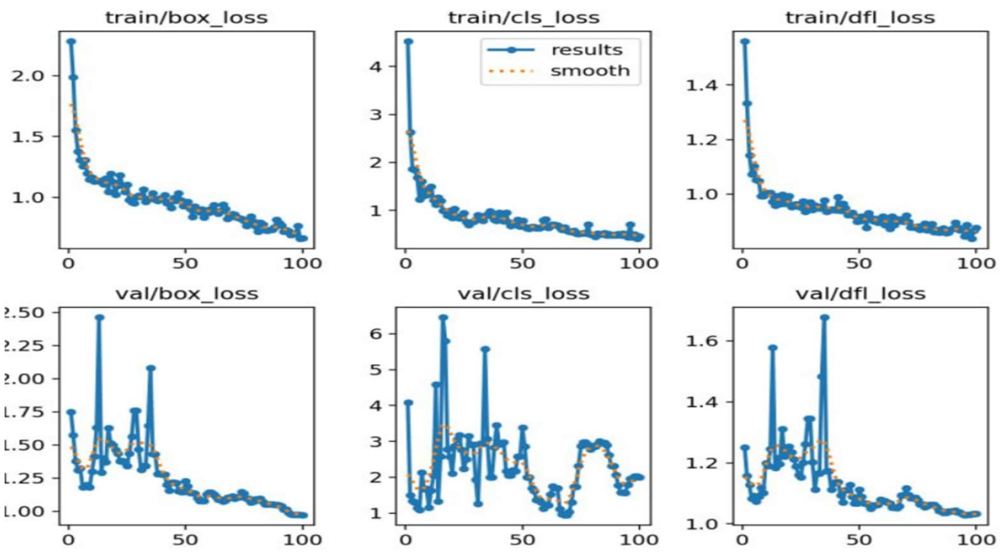

Fig. 4. Checking the accuracy of the proposed model.

CONCLUSION

Improved algorithms for segmentation of tooth boundaries from X-ray images help to solve the following problems. For more accurate segmentation, better identification of vague boundaries between the object and the background, more accurate separation of small and complex structures of teeth, reduction of noise in images and increase of segmentation accuracy, segmentation of teeth of different sizes and shapes with the same accuracy, located close to each other or partially overlapping problems of correct separation of superimposed teeth, better detection of tooth boundaries in low-contrast images can be solved using the above architecture and algorithm. An improved algorithm can be effective in solving these problems in deep learning networks.

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