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AUTOMATIC DETECTION OF SPINAL DEFORMITY BASED ON STATISTICAL FEATURES FROM THE MOIRE TOPOGRAPHIC IMAGES

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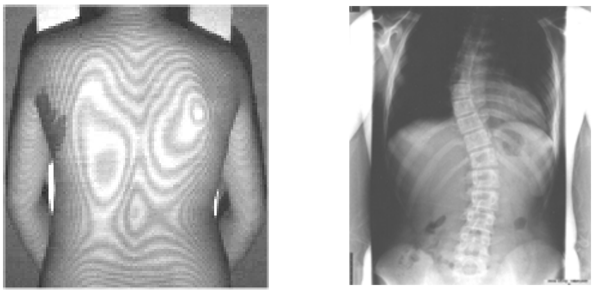
Abstract: *Spinal deformity is one of a disease mainly suffered by teenagers during their growth stage particularly from element school to middle school. There are many different causes of abnormal spinal curves, but all of them are unknown. To find the spinal deformity in early stage, orthopedists have traditionally performed on children a painless examination called a forward bending test in mass screening of school. But this test is neither objective nor reproductive, and the inspection takes much time when applied to medical examination in schools. To solve this problem, a moire method has been proposed which takes moire topographic images of human backs and checks symmetry/asymmetry of their moire patterns. In this paper, we propose a method for automatic judgment of spinal deformity which is obtained moire topographic images based on statistical features on the moire image. Statistical feature of asymmetry degrees are applied to train employing the classifier such as Artificial Neural Network, Support Vector Machine, Self-Organization Map and AdaBoost.*

Keywords: *Moire Topographic Image, Spinal Deformity, SVM, ANN, SOM, AdaBoost.*

1. INTRODUCTION

Spinal deformity is one of a serious disease, mainly suffered by teenagers. It is tends to run in families and is more common in females than males during their growth stage. There are many different causes of spinal deformity such as congenital, kyphosis (curvature of the spine with the convexity pointing toward the back), but all of them are unknown. Although the spine does curve from front to back side it should not curve lateral. A side-to-side called scoliosis and it may take the shape of an ‘S’ or ‘C’ character. The difficulty because of not accompanied by the subjective symptom such as pains the early stage detect and the early treatment becomes a problem. When one suffers from a spinal deformity, in severe case, it is associated with pain and it requires surgical treatment. The treatment of spinal deformity depends on the location and degree of curvature. Slight curves usually require no treatment, but as the curve progresses the treatment is required because the size of chest cavity diminish, it causes pain and decrease in lung.

To find the spinal deformity in early stage, orthopedists have traditionally performed a painless examination which called the forward bending test in mass screening of school. In the forward bending test, mainly medical doctor checks 5 points such as rib hump, lumbar hump, and asymmetric degree on the shoulder and west line. But this test is neither objective nor reproductive, and the inspection takes much time when applied to medical examination in school screening. To solve such various problems, a moire method [1-2] has been proposed which takes moire topographic images of human subject backs and checks symmetry/asymmetry of the moire patterns in a two-dimensional way. Fig. 1 shows an abnormal moire and its X-ray image. Asymmetrical moire patterns are appear on the subject backs. By using the moire image, the diagnosis efficiency of spinal deformity in the mass screening improved. However, the burden of the doctor who diagnoses a large amount of moire image is still remained. Then, the necessity of the image diagnosis support by using a computer is requested from the medical site. In order to achieve efficiency in diagnostic work by reducing reading time and to improve the accuracy, many systems were proposed nowadays. To detect the spinal deformity, some algorithms are proposed [3-8]. To improve the accuracy and efficiency of the primary visual screenig for the detection of spinal deformity of early stage, coputer aided dianosis (CAD) is still required.



(a) (b)

Fig. 1 – An example of moire image and its X-ray image; (a) shows an moire image, (b) shows obtained a X-ray image of (a).

In the present paper, we propose a technique for automatic detection of spinal deformity from moire topographic images by using statistical feature on the moire image. In the first step, once the original moire images is fed into computer, the middle line of the subject's back is extracted on the moire image employing the approximate symmetry analysis[9]. Regions of interest (ROIs) are automatically selected on the moire image from its upper part to the lower part and the middle line of the subject's back. Then the four asymmetry degrees are calculated from obtained ROIs. Numerical representation of the degree of asymmetry, displacement of local centroids and difference of gray value, are calculated between the right-hand side and the left-hand side regions of the moire images with respect to the extracted middle line. Feature of four asymmetry degrees (mean value and standard deviation from the each displacement) from the right-hand side and left-hand side rectangle areas apply to train the artificial neural network (ANN), support vector machine (SVM), self-organization map (SOM) and AdaBoost. In general, their algorithms can be easily introduce to classify unknown data and also can yield higher classification accuracy when the features used are not well separated. We have already proposed some techniques for automatic classifying the spinal deformity by using linear discliminant function (LDF). To increase the classification rates and avoiding the misclassification, we introduce the classifiers by using statistical features from the moire images.

2. EXTRACTION OF MIDDLE LINE

Generally, the moire stripes show symmetric patterns on the normal subject's backs. But when one becomes spinal deformity, asymmetric moire pattern appears on the moire image. In the diagnostic of imaging by using the moire method, asymmetry degree are evaluated on the moire images, so it is effective to make the asymmetry degree on the moire image in the visual screening.

To analyze the asymmetric of moire pattern, the middle line is extracted based on approximately symmetry analysis technique [9]. The approximate symmetric axis can be found by superposing the original and the reflected original image (mirror image). The best position of the superposing is determined, by evaluating the difference image which is obtained from the original and the mirror image. We adjusted to the position in which the difference of the density of a pixel values are minimized. The approximate symmetric axis is represented by the perpendicular bisector of the center of gravity of the original and the mirror image.

We assume an original moire image is $f(x,y)$,$(x,y) \in R$, and its reflected image is represented by $f^r(x,y)$, $(x,y) \in R^r$. The $f^r(x,y)$ is superposed onto the $f(x,y)$ by parallel translation $c=(c_x,c_y)$, T is a rotation transform and rotation θ to find the best match in eq.(1). In this paper, we assume that θ=0 in eq.(2), because the moire images are captured normally straight using position-supporter so that their middle lines remain vertical.

$$D_{axis} = \min_{T} \sum_{(x,y)\in R\cup R^r} \left| f(x,y) - Tf'(x,y) \right| \tag{1}$$

$$T = \begin{pmatrix} \cos\theta & \sin\theta & c_x \\ -\sin\theta & \cos\theta & c_y \\ 0 & 0 & 1 \end{pmatrix} \tag{2}$$

3. EXTRATION OF ASYMMETRIC FEATURES

The ROIs are selected by using pre-processing technique for extracting the asymmetrical features by the following way.

Within the region R and at a certain position $y=j$, two rectangle areas are defined, as shown in Fig.2, at symmetric locations with respect to the middle line $x=m$. The width R_x of the rectangle area is defined by,

$$R_x = \min(m-l, r-m) . \tag{3}$$

Here m is the middle line which is extracted above mentioned, l and r are minimum frequency of the left- and right-hand side on the histogram, respectively. On the other hand, height of the area is defined empirically.

Let us denote the rectangle areas of the left-hand side and right-hand side at $y=i$ by A_i^l and A_i^r, respectively (See Fig.3). Here i=1,2,…,N. The centroids of A_i^l and A_i^r are denoted by $G_l(x_l,y_l)$ and

$G_r(x_r,y_r)$, respectively. The centroid $G_l(x_l,y_l)$ is reflected with respect to the middle line $x=m$ into the region A_i^r and denoted by $G_l^*(x_l^*,y_l^*)$. The distance E between $G_l^*(x_l^*,y_l^*)$ and $G_r(x_r,y_r)$ is calculated by,

$$E = \sqrt{\left(x_l^* - x_r\right)^2 + \left(y_l^* - y_r\right)^2} \,. \tag{4}$$

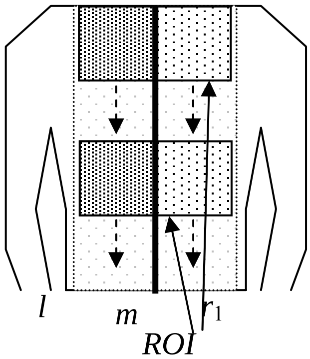


Fig. 2 – Rectangle areas in the region of interest.

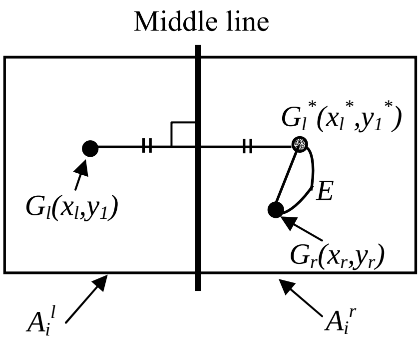


Fig. 3 – Calculation areas for local centroids.

The mean μ_E and standard deviation σ_E of the values E $(i=1,2,\ldots,N)$ are employed as some of the features representing the degree of asymmetry of the moire image in calculation rectangle area. The expressions are shown as follows.

$$\begin{cases} \mu_E = \dfrac{1}{N}\displaystyle\sum_{i=1}^{N} E \\ \sigma_E = \sqrt{\dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\left(E - \mu_E\right)^2} \end{cases} \tag{5}$$

Furthermore, in the same rectangle area in figure 3, the difference of gray value D on the right- and left-hand side are calculated by,

$$D = \left| r_d - l_d \right| . \tag{6}$$

Here, r_d and l_d are shown the mean value of the gray value on the right- and left-hand side in the region in figure 3, respectively. The mean μ_D and standard deviation σ_D of the difference of gray values D $(i=1,2,\ldots,N)$ are employed as the other features representing the degree of asymmetry of the moire image in calculation rectangle area. The expressions are shown as follows.

$$\begin{cases} \mu_D = \dfrac{1}{N}\displaystyle\sum_{i=1}^{N} D \\ \sigma_D = \sqrt{\dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\left(D - \mu_D\right)^2} \end{cases} \tag{7}$$

4. CLASSIFICATION METHOD

The mean value and the standard deviation of the difference of the center of gravity and difference of gray value on the right-hand and left-hand side area are obtained as the statistical features. In order to detecting the unknown moire image, we have tried the ANN, SVM, SOM and AdaBoost techniques. We compared the classification performance of the four pairs.

ANN is used a useful technique for the pattern classification. This technique provided a method for the automatic spinal deformity. It is necessary for input layers, which extracted numerical feature. In order to classify the unknown moire image, the four features (mean values and standard deviation in eq.(5), (7)) which is obtained above mentioned are used for training by using the back propagation in ANN. Our ANN is consist of three layers, which include four inputs neurons, three hidden neurons and two output neurons for training by using back propagation on ANN. Finally, unknown moire images are discriminated as normal or abnormal case automatically.

The SVM [10, 11] is a supervised learning technique from the field of machine learning applicable to both classification and regression. The SVM is a set of related supervised learning methods used for classification. It is an optimization algorithm for the problem of pattern recognition. Some free software also provided methods for assessing the generalization performance efficiently. It was worked out for linear two-class classification with margin, which has the minimal distance from the separating hyper- plane to the closest data points. SVM learning machine seeks for an optimal separating hyper plane, where the margin is maximal. In this method, to classify the unknown moire images, we implement the SVM technique employing four statistical feature vectors from the left-hand side and right-hand side of rectangle areas by using the eq.(5) and eq.(7).

SOM [12] is a data visualization technique invented by T. Kohonen which reduces the dimensions of data through the use of self-organizing neural networks. In this study, we applied our method to the SOM for clustering the normal and abnormal moire image. In our method, in order to detect the unknown moire images, we implement the SOM technique employing four feature vectors from the left-hand side and right-hand side of rectangle areas (in eq.(5) and eq.(7)).

AdaBoost [13, 14] is one of the most successful and popular learning algorithms as the useful Boosting technique which is a classification algorithm designed to construct a strong classifier from a weak learning algorithm. It is a meta-algorithm which can be used in learning algorithms to improve their performance. The algorithm achieved good performance as a classifier for face detection on pattern recognition field [15]. Boosting makes a learning machine different as the weight of the exercise is changed one after another, the technique which composes the learning machine that these are combined and accuracy is high. In AdaBoost algorithm when the weight of the learning machine is updated, weight to the training sample misclassified with the learning machine increases, and weight to the training sample correctly classified decreases. Therefore, it might become difficult to see the whole image because data with a difficult distinction is emphatically learned.

5. EXPERIMENTAL RESULTS

Experiment was done employing 1200 real moire images which is 600 of abnormal and normal, respectively. The employed moire images are separated into two groups such as training and test data sets. As a training data for this study, we have selected randomly 400 (200 normal and abnormal cases, respectively) moire images. Three subsets containing normal cases are denoted by $G_i(i=1,2,3)$ and those containing abnormal and normal cases are denoted by $S_i(i=1,2,3)$. A set S_i is defined as $S_i = S_{ni} \cup S_{ai}$ (i=1,2,3), (S_{ni} is normal cases and S_{ai} is abnormal cases). Then, according to the leave-out method, the set $S_j(j=1,2,3)$ is chosen as a training set and the set $S_k \cup S_l \ (k \neq j, l \neq j, k \neq l)$ as a test set. The leave-one out is a method of applying the obtained criteria to the data group of the remainder for two data groups, doing the evaluation to which data is not biased.

The employed moire topographic image size is 256X256 pixels with 256 gray levels. Fig.4 illustrates experimental result by using only the SVM because other method could not output visually. In Fig.4, '◊' and '■' shows normal and abnormal data which is plotted feature space, respectively, which is obtained by SVM. Furthermore, a horizontal line shows the data number which consist of 400 of data set (1 to 200 of data number is normal set and 201 to 400 of data number is abnormal set). On the other hand, a vertical line shows the classification results. In our implemented SVM, '-' classified as normal and '+' classified as abnormal.

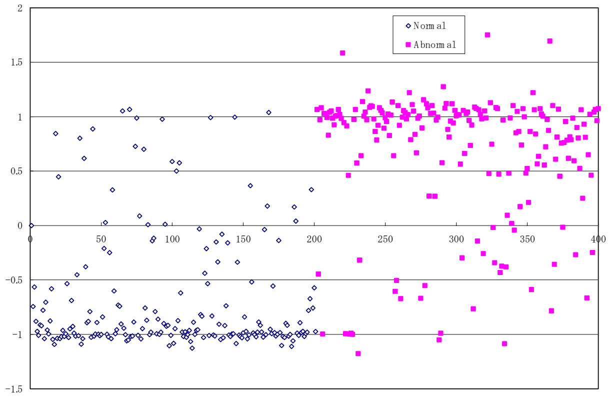
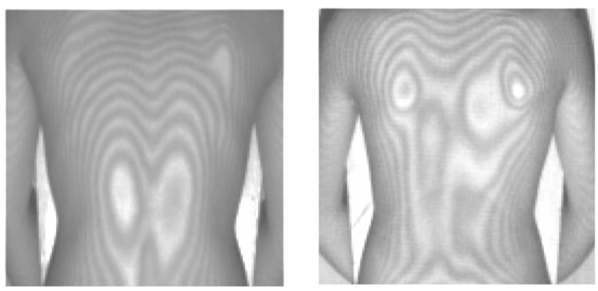


Fig. 4 – The feature space and the classified 400 data, corresponding to the G1 by using SVM in Table 1.

In Fig.5, (a) shows a normal moire image and (b) shows an abnormal moire image. Table 1 shows obtained classification rates. In the table, G_i (i=1,2,3) shows data sets, "*Normal*" shows classification rates which normal cases were classified correctly, and "*Abnormal*" shows classification rates which abnormal cases were classified correctly. Finally, "*Average*" shows the average classification rate obtained from each data group, "Ave." shows the entire average classification rate. That is, the paragraph of G1 shows the identification rate when G2 and G3 are learned as learning data, and the result of obtaining is applied to G1. As a result, on the total average, classification rate of 85.2%, 85.3%, 71.8%, and 85.6% were achieved in the ANN, SVM, SOM, and AdaBoost, respectively.



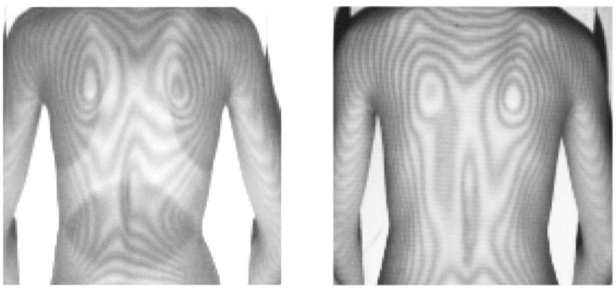
(a) normal (b) abnormal

Fig. 5 – Experimental results

5. CONCLUSIONS

In this paper, we proposed a new automatic classification method for the spinal deformity detection by using ANN, SVM, SOM, and AdaBoost method which is extracted asymmetry degree. The middle line of the subject's back is extracted on moire image employing the approximate symmetry analysis, and ROIs are automatically selected, then the asymmetry degree is calculated. Four asymmetry degrees from the right-hand and left-hand side rectangle areas which is selected as ROIs apply to train the ANN, SVM, SOM, and AdaBoost. The total average shows the classification rate of 85.2%, 85.3%, 71.8%, and 85.6% in the ANN, SVM, SOM, and AdaBoost respectively in the experiment employing 1200 moire image. In the experimental results, there is no significant difference between the performance of three classifiers such as ANN, SVM, and AdaBoost excepting SOM.

Fig.6 illustrates examples of misclassification result. In Fig.6, a normal case is classified into abnormal in (a), whereas an abnormal case is classified into normal in (b). In Fig.6, sunburn trace appears on the waist part in (a). In Fig. 6 (b), gray values subtly differ in the vicinity of an edge particularly on the shoulder part. All of the misclassified normal cases are found asymmetry of moiré patterns. This is because gray values distribution in the rectangle regions unfortunately affected symmetrically when the features were calculated. To escape from this difficulty, some other asymmetry features such as asymmetric of shoulders line or asymmetric of angle on a waist line might be taken into account in conjunction with it. These issues remain for further study.



(a) (b)

Fig. 6 – Examples of misclassification: (a) Classified normal to abnormal; and (b) Classified abnormal to normal.

In this paper, we present a computer aided detection algorithm by using statistical features for detection of spinal deformity of early stage. The ANN, SVM, SOM, and AdaBoost classifier are used in the classification task with the extracted features. In the experimental results, the classification rates which abnormal cases were classified correctly are higher than the classification rates which normal cases were classified correctly. Generally, medical doctor checks the symmetric shape of right-hand and left-hand side such as waist line and shoulder line of human back. In the normal case, waist line shows almost symmetric shapes. On the other hand, in the abnormal case, asymmetric moire patterns are appeared on the waist line. To improve the classification rate in the future, we introduce a new feature such as waist line and shoulder line for the new features. That still remained as a future works.

Table 1. Classification rates [%]

	G_1	G_2	G_3	*Ave.*
ANN				
Normal	75	79.5	76	75
Abnormal	96.5	90	94	94
Average	85.8	84.8	85	85.2
SVM				
Normal	76	78.5	73	75.8
Abnormal	98	91	79.5	94.8
Average	87	84.8	84.3	85.3
SOM				
Normal	68	74.5	74	72.2
Abnormal	75	67.5	71.5	72.9
Average	71.5	71	72.8	71.8
AdaBoost				
Normal	75.5	81	80	78.8
Abnormal	95.5	90	91.5	92.3
Average	85.5	85.5	85.8	85.6

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