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Multiple Regression Analysis of Computed Radiography

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INTRODUCTION

The FCR7000 computed radiography system (CR) is a digital imaging system that outputs images by image processing. This image processing system is composed of two types of processing: gradation processing and frequency processing. In order to obtain output images, we must set parameters to the items of CR. Even if there are only four gradation items and three frequency items, the number of combinations of gradation and frequency values is enormous. On the basis of its experience with the screen-film system and trial and error, each hospital determines its own CR parameters in order to obtain good images. However, subjectivity in the determination of parameters using these methods is inevitable. In this study, we tried to determine the best combination of CR parameters by utilizing multiple regression analysis.

METHOD

In this study, the quality of a processed image was treated as a response variable and the CR parameters as explanatory variables. Response variables must be numerical data in multiple regression analysis; however, numerical expression of clinical image quality is very hard. Consequently, we used an RMI156 phantom in this study. This phantom is authorized by the American College of Radiology, and objects within the phantom simulate calcifications, fibrous calcifications in ducts, and tumor masses. The number of recognition of imitation objects can be expressed numerically by the use of this phantom.

In order to avoid difficulties in the experiment and in data analysis, we only examined gradation processing in this study. Gradation type (GT), which cannot be expressed as numerical data, was set at GT=O and gradation shift (GS), which defines sensitivity, was set at GS=0.30. These GT and GS values are used daily in our hospital. Therefore, the explanatory variables were the amount of rotation (GA) and the center of rotation (GC).

An x-ray photograph of the phantom was taken by x-ray apparatus usually used for mammography. As we did not examine frequency processing, the frequency emphasis (RE) in the frequency parameters was set at RE=0.0.

Gradation processing was performed by using all combinations of GA=0.6, 0.9, 1.2, 1.5, 1.8 and 2.1 and GC=0.6, 1.0, 1.4 and 1.8. The images were observed on a

mammographic viewing screen (nominal luminous intensity: 30000 lux). The observed value of the phantom (response variable) is the recognizable imitation object number.

The calculation of multiple regression analysis was made from GA groups. The method of grouping successively shifts; i.e., GA=0.6, 0.9 and 1.2, GA=0.9, 1.2 and 1.5 and so on. All the GA groups are combined with all the values of GC (GC=0.6, 1.0, 1.4 and 1.8).

Thus, multiple regression analysis is performed for each group, and then the partial regression coefficients of GA and GC are obtained. If the sign of the partial regression coefficient of GA or GC is positive, the value, which is greater than the maximum value of GA or GC, makes the theoretical value of the response variable greater. On the other hand, if the sign of the partial regression coefficient of GA or GC is negative, the value, which is fewer than the minimum value of GA or GC, makes the theoretical value of the response variable greater. The theoretical value can be calculated from the following multiple regression equation.

$$y=ax_1+bx_2+c \ ,$$

where y is a response variable, x_1 is the explanatory variable GA, x_2 is the explanatory variable GC, a is a partial regression coefficient of GA, b is a partial regression coefficient of GC, and c is a constant.

The method of determining the optimum image is as follows:

(1) Some groups are selected from the groups having a coefficient of determination of more than 0.5

(2) The group having the maximum observed mean value of the phantom is selected from the above set of groups.

(3) The values of GA and GC are determined from the sign of the partial regression coefficient.

RESULTS

Table 1 shows the results of the multiple regression analysis. On the basis of the coefficients of determination shown in Table 1, groups 1, 2 and 4 were selected and group 3 was rejected. The group with the highest observed mean value is group 4. The signs of the partial regression coefficients of GA and GC are both negative in group 4. Therefore, GA=1.4 and 1.3 and GC=0.5, 0.4 and 0.3 were adopted. Because GA=1.2 is already used and GC=0.2 and 0.1 cannot be adopted in this system.

DISCUSSION

Using F-distribution, we tested whether the multiple regression analysis for group 4 could be utilized as an estimate of a response variable. Consequently, utilization for an estimate was useful with hazard rate 1 %. As described above in METHOD and

Table 1 Results of multiple regression analysis

Group No.	GA	GC	PRC of GA	PRC of GC	COD	OMV
1	0.6, 0.9, 1.2	0.6, 1, 1.4, 1.8	2.50	0.50	0.85	8.50
2	0.9, 1.2, 1.5	0.6, 1, 1.4, 1.8	3.13	0.29	0.85	9.38
3	1.2, 1.5, 1.8	0.6, 1, 1.4, 1.8	1.46	0.17	0.36	9.92
4	1.5, 1.8, 2.1	0.6, 1, 1.4, 1.8	-0.83	-0.63	0.70	10.13

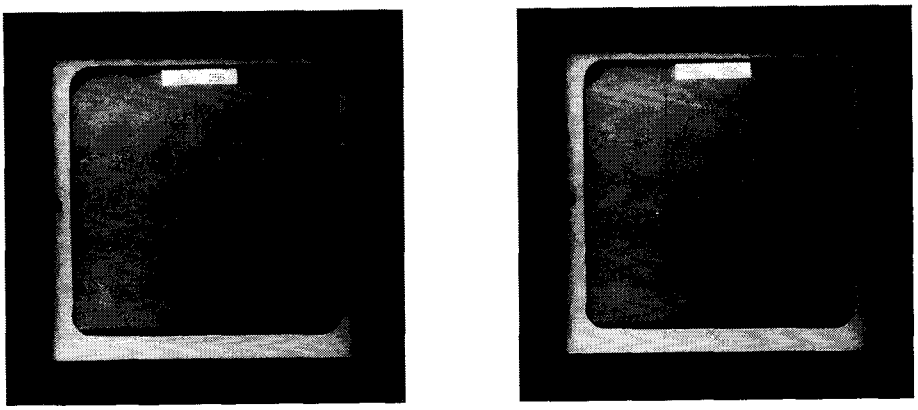
- PRC : Partial regression coefficient
- COD : Coefficient of determination
- OMV : Observed mean value

RESULTS the highest theoretical values were GA=1.3 and GC=0.3. The image created by these parameters is the optimum image. Fig. 1(1) shows this image. Fig. 1(2) shows the image obtained by the conditions used daily in our hospital (GA=1.3, GC=0.6, RN=9, RE=0.5 and RT=P). The images are almost the same.

Fig. 2 shows the clinical images by parameters used in this study and in our hospital. These images are almost indistinguishable.

CONCLUSION

We used multiple regression analysis in order to determine the best combination of parameters for gradation processing. The maximum theoretical value of image quality was obtained for values of GA=1.3 and GC=0.3. The observed value of this image was 10.5. This was the same value as that of the image obtained by trial and error. In conclusion it is very important in CR image processing that the parameters for gradation processing not be determined subjectively, but be derived statistically.



(1)Created in this study (2)Created in our hospital

Fig. 1 Phantom images

(1)Created in this study

(2)Created in our hospital

Fig. 2 Clinical images