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Image Registration for a Series of Chest Radiograph Images

Omar Mohd. Rijal*, Norliza Mohd. Noor†, Shee Lee Teng*
* Institute of Mathematical Science, University Malaya
†Diploma Program Studies, Universiti Teknologi Malaysia

Abstract :- To investigate the effect of treatment, a study on the progress of an MTB patient is carried out. One approach is to compare a series of chest radiographs taken at three different time points. For each radiograph a subset of the image representing the diseased area is derived, and henceforth monitoring is defined as the activity of comparing the three corresponding subset image. The elements of each subset image of dimension $(n \times n)$ is treated as n^2 numbers from which, five statistics are calculated (min, first quartile, median, third quartile, max). In other words, the box – plot of each subset image is derived. The total numbers of statistics that show a left – ward shift (decrease in magnitude) is an indication of patient's progress. However, before comparing a pair of box – plots, the corresponding pair of images needs to be resized and registered. This study shows that a combination of resizing and registration can improve the pair – wise comparison.

Key Word:- Chest Radiograph, Mycobacterium Tuberculosis, Image Registration, Correlations, Box-plot

1 Introduction

The common radiograph film is still an important tool in the diagnostic process for lung ailment despite rapid advances in medical imaging technology, see Middlemiss [1] and Moores [2]. In Malaysia, government hospitals perform the major part of detection using radiographs films simply out of economic considerations. Problems associated with the visual interpretation (and comparison) of standard chest radiograph films are well known [3]. These remarks motivate a need to create objective methods in particular for comparing two or more digital radiograph images.

Before a pair of radiograph images may be compared they need to be registered, and in some cases resized as well. Image registration and resizing is necessary because conditions vary when the series of X-ray films are taken. In this study the steps involved are (i) crop the region of interest that is the lung area, (ii) apply a method called 7-control points registration (SCPR) which is use for image registration, and (iii) resize the image using affine transformation (a MATLAB function).

After registration and resizing it is still necessary to check whether the images are properly 'overlapping'. This is done by estimating correlation ($R_F{}^2$ and $R_S{}^2$ [4], [5]) as well as MSE and PSNR.

In this study, let {*I*(*i*,*j*); *i* = 1, …, M, *j*= 1, …, N} represent the digital X-ray image of a patient on his first visit to the hospital. Let {*K*(*i*,*j*); *i* = 1, …, M, *j*= 1, …, N} represent the same patients image at a later prescribed time point.

2 Seven control point registration (SCPR)

Let $A = (x_A, y_A)$, $B = (x_B, y_B), \ldots,$ $G = (x_G, y_G)$ be 7 selected points on the lung area. Given two images (two time points) we have,

$$1^{st} \text{ image} \equiv \{ A, B, C, D, ..., G \}$$

$$2^{nd} \text{ image} \equiv \{ A', B', C', D', ..., G' \}.$$

The following distances were calculated:

$$D_{AA'}, D_{BB'}, ..., D_{GG'}$$

where for example

$$D_{AA'} = \sqrt{(x_A - x_{A'})^2 + (y_A - y_{A'})^2}$$

It can be shown that $D_{AA'} = 143.8367$ (for 1st and 2nd image) and $D_{AA'} = 118.3089$ (for 1st and 3rd image). Hence fore each pair of images was registered as follows; calculate

$$T_{xA} = (x_A - x_{A'})$$
$$T_{xB} = (x_B - x_{B'})$$
$$\vdots$$
$$T_{xG} = (x_G - x_{G'})$$

and let $T_x = median\{T_{xA}, T_{xB}, \ldots, T_{xG}\}$.

Similarly calculate

$$T_{yA} = (y_A - y_{A'})$$
$$T_{yB} = (y_B - y_{B'})$$
$$\vdots$$
$$T_{yG} = (y_G - y_{G'})$$

and let $T_y = median\{T_{yA}, T_{yB}, \ldots, T_{yG}\}$.

Treating the 1st image as a reference image, then the 2nd and 3rd image were subject to a vertical and horizontal translation show by (T_{xA}, T_{yA}).

The images are said to be properly registered if the distances $D_{AA'}, D_{BB'}, \ldots, D_{GG'}$ are minimized.

3 Resizing

A view of the original image shows that a significant area of the image is taken – up by the irrelevant background. Further Figure 1 shows that the three images are of different size, and this may have a significant effect on comparison of images. This study proposes that the image be resized as follows;

A) The image is cropped such that the remaining image is essentially the lung area.

B) Then an affine transformation is carried out using the MATLAB command

$$\text{MAKETFORM ['affine', } \begin{pmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{pmatrix} \text{]}$$

where for example in Figure 4, $C_x = \frac{1489}{1885} \approx 0.78$.

and $C_y = \frac{1536}{1844} \approx 0.83$. C_x and C_y is the required percentage for resizing. The program will then interpolate the new pixel value using the bilinear interpolation.

4 Brief Review of ULFR and R_F^2

Re-label the observations (or experimental values) of $\{I(i,j);\ i = 1, \ldots, M, j= 1, \ldots, N\}$ as $y_1, y_2, \ldots, y_{MN}$, the observations of $\{K(i,j);\ i = 1, \ldots, M, j= 1, \ldots, N\}$ as $x_1, x_2, \ldots, x_{MN}$, and the true $I(i,j)$ and $K(i,j)$ values will be denoted by $Y_1, Y_2, \ldots, Y_{MN}$ and $X_1, X_2, \ldots, X_{MN}$, respectively. We look at two regression models to study the relationship between y_i and x_i.

We first look at the ordinary simple linear regression (SL) model [6] of the dependent variable, y_i and explanatory variable, x_i:

$$y_i = \alpha_s + \beta_s x_i + \varepsilon_i, \quad i = 1, 2, \ldots, MN \qquad (1)$$

where the maximum likelihood estimators (MLE) and COD are given as follows:

$$\hat{\alpha}_s = \bar{y} - \hat{\beta}_s \bar{x}, \quad \hat{\beta}_s = \frac{S_{xy}}{S_{xx}}$$

and $R_s^2 = \frac{\hat{\beta}_s S_{xy}}{S_{yy}}$ (2)

where the R_s^2 is the proportion of variation explained by explanatory variable x and

$$\bar{y} = \frac{\sum y_i}{MN}, \bar{x} = \frac{\sum x_i}{MN},$$
$$S_{yy} = \sum (y_i - \bar{y})^2,$$
$$S_{xx} = \sum (x_i - \bar{x})^2$$

and $S_{xy} = \sum (x_i - \bar{x})(y_i - \bar{y})$.

However, as pointed out by [5], the assumption that the explanatory variable can be measured exactly may not be realistic in many situations. The estimates of explanatory variable may contain measurement error arising from the techniques or instruments used or trying to quantify a variable that has no physical dimension. In these cases, the explanatory variable is subject to error.

Suppose that now the X and Y are two linearly related unobservable variables (see [4] and [7])

$$Y_i = \alpha + \beta X_i \qquad (3)$$

and the two corresponding random variables x and y are observed with error δ and ε respectively

$$\left.\begin{aligned} x_i &= X_i + \delta_i \\ y_i &= Y_i + \varepsilon_i \end{aligned}\right\} \quad i = 1, 2, \ldots, MN \qquad (4)$$

where δ_i and ε_i are mutually independent and normally distributed random variables. Equation (3) and (4) are known as the ULFR model when there is only one relationship between the two variables *X* and *Y*. It can be shown that the maximum likelihood estimators when the ratio of the error variances is equal to one, $\frac{\sigma_\varepsilon^2}{\sigma_\delta^2} = \lambda = 1$, are given as follows:

$$\hat{\alpha}_F = \bar{y} - \hat{\beta}_F \bar{x} \quad (5)$$

$$\hat{\beta}_F = \frac{(S_{yy} - S_{xx}) + \{(S_{yy} - S_{xx})^2 + 4S_{xy}^2\}^{1/2}}{2S_{xy}} \quad (6)$$

$$\hat{\sigma}_\delta^2 = \frac{1}{MN-2}\left[\sum (x_i - \hat{X}_i)^2 + \frac{1}{\lambda}\sum (y_i - \hat{\alpha} - \hat{\beta}\hat{X}_i)^2\right] \quad (7)$$

and $$\hat{X}_i = \frac{x_i + \hat{\beta}(y_i - \hat{\alpha})}{\lambda + \hat{\beta}^2} \quad (8)$$

The equation in (3) and (4) can be written as

$$y_i = \alpha_F + \beta_F x_i + (\varepsilon_i - \beta_F \delta_i)$$
$$= \alpha_F + \beta_F x_i + V_i \quad \text{for } i = 1, \ldots, MN \quad (9)$$

where the error of the model, V_i is normally distributed. The residual sum of squares and the regression sum of squares are given as follows:

$$S_E = \frac{S_{yy} - 2\hat{\beta}S_{xy} + \hat{\beta}^2 S_{xx}}{1 + \hat{\beta}^2}$$

and

$$S_R = S_{yy} - S_E$$
$$= S_{yy} - \frac{S_{yy} - 2\hat{\beta}S_{xy} + \hat{\beta}^2 S_{xx}}{1 + \hat{\beta}^2}$$

Therefore, the COD for ULFR can be defined as

$$R_F^2 = \frac{S_R}{S_{yy}} = \frac{\hat{\beta}_F S_{xy}}{S_{yy}} \quad (10)$$

and it can be shown that $0 \le R_s^2 \le R_F^2 \le 1$.

5 MSE and PSNR

Two other indicators of proper registrations are the MSE and PSNR defined as follows:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} \| I(i,j) - K(i,j) \|^2$$

where *I* is second visit image and *K* is the first visit image,

and $$PSNR = 20 \times \log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right)$$

where $MAX = 2^B - 1$, $B = bit$. The digital image is coded using 12bit DICOM format, therefore $MAX = 2^{12} - 1 = 4095$.

6 Comparing Two Images

Since only a small section of the original image is to compared, the image histogram is a potential tool for comparison. However, a simpler way of comparing two distributions is in fact the comparison of two box-plot [8].

7 Descriptions of the Experiments

For each patient, his series of visits to the hospital and consequently the chest x-ray images obtained are labeled A, B and C. The minimum treatment period for MTB is 6 months and the progress is monitored every 2 months via clinical test (usually the sputum test) and chest x-ray images. In this study the chest x-ray images are compared pair-wise, for three time points, that is first and the second chest x-ray (AB), first and last chest x-ray (AC)

The X-ray films were scanned into 12 bit DICOM file using Kodak LS 75 X-ray film scanner.

Two major experiments were carried out;

(a) The images were subjected to SCPR (see Fig. 2). Then the subset images were obtained. Fig. 3 gives the relevant box-plot.

(b) The images were subjected to both resizing and SCPR, see Fig 4 and Fig. 5 before the subset images were obtained (see Fig. 6). The corresponding box-plot was given in Fig. 7.

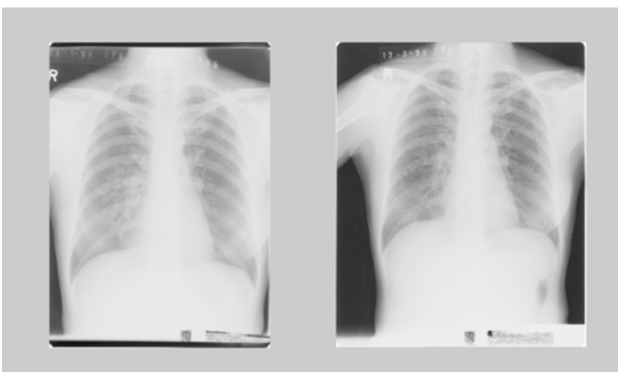
7 Results And Discussion

Fig. 1 show images of different sizes. The images are registered using SCPR and the subset image obtained as given in Fig. 2. The box-plot of Fig. 3 shows a general shift to the left indicating a positive patient progress.

The effect of resizing and SCPR are illustrated in Fig. 5 and 6. Again the box-plot shows similar result.

The effectiveness of SCPR is clearly shown by comparing the first two columns of Table 1 which show that $D_{AA'}$, $D_{BB'}$, ... , $D_{GG'}$ were reduced.

To show the effect of resizing, the increase of ${R_F}^2$ and ${R_S}^2$ and the decrease in MSE as shown in Table 2 shows that resizing is important. Finally Table 2 shows that the PSNR is not sensitive to the effect of resizing. In conclusion image registration and image resizing should both be carried out to achieve some improvement in the pair-wise comparison (compare Fig.3 and Fig. 7).



(a) 1st visit
Size: 2800×2048

(b) 2nd visit
Size: 2500×2048

(c) 3rd visit, Size: 2769×2048

Fig. 1 Three original images of the same patient taken at three different time points.

(a) 1st visit (b) 2nd visit (c) 3rd visit

Figure 2: Subset image with registration only after SCPR.

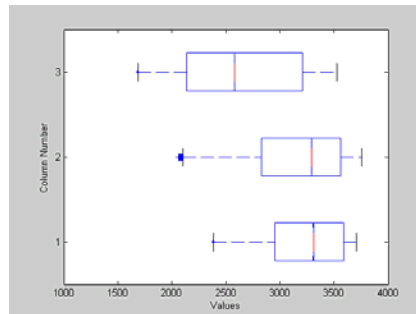


Fig. 3 Lowest box-plot corresponds to subset image from the 3rd visit similarly top-most box-plot is for the last visit. The subset image is image after registration only.

(a) 1st visit 1885×1844 (b) 2nd visit 1489×1536 (c) 3rd visit 1823×1844

Fig. 4 Cropping the region of interest – lung area.

(a) 1st visit 1489×1536 (b) 2nd visit 1489×1536 (c) 3rd visit 1489×1536

Fig. 5 Image after affine transformation.

(a)1st visit (b)2nd visit (c) 3rd visit

Fig. 6 Subset image with resizing and registration image after SCPR.

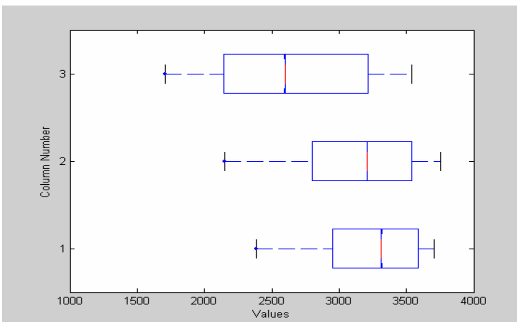


Figure 7 Lowest box-plot corresponds to subset image from the 3rd visit similarly top-most box-plot is for the last visit. The subset image is the image with resizing and registration after SCPR.

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Table 1: Distance Between 7 control points for SCPR for 1st and 2nd image.

	(Before translation) (1st and 2nd)	(After translation) (1st and 2nd)	(T_x, T_y)
$D_{AA'}$	8.9443	17	(8,-21)
$D_{BB'}$	12.00	21.3776	
$D_{CC'}$	22.4722	31.7805	
$D_{DD'}$	39.1152	25	
$D_{EE'}$	25.00	8.9443	
$D_{FF'}$	33.1210	11.3137	
$D_{GG'}$	33.00	14.4222	

Table 2: Comparison of the similarity measures between registrations without resizing and registration with resizing.

Patients	R_F^2		R_S^2		PSNR		MSE $(\times 10^4)$	
	1st and 2nd visit		1st and 2nd visit		1st and 2nd visit		1st and 2nd visit	
	Without resizing	With resizing	Without resizing	With resizing	Without resizing	With resizing	Without resizing	With resizing
1	0.8339	0.9720	0.6325	0.9352	23.9710	28.4604	6.7206	2.3904
2	0.6623	0.8559	0.4564	0.7501	14.6850	16.1452	57.018	40.737
3	0.7010	0.7856	0.4684	0.5681	17.2641	18.1213	31.484	25.845
4	0.9549	0.9421	0.7141	0.6389	12.9149	12.8348	85.708	87.302
5	0.6913	0.8528	0.6133	0.7987	16.8619	17.4395	34.539	30.239
6	0.9392	0.9377	0.8342	0.8294	23.0122	22.8633	8.3809	8.6731
7	0.8629	0.8707	0.7053	0.7305	22.4012	22.9449	9.6469	8.5116
8	0.6570	0.8311	0.2251	0.4815	21.2024	22.0052	12.714	10.568