Medical Imaging Analysis: Image Registration

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1. The Aim and objective of the homework and solution:

The main objective of the homework is to explore Image registration framework for medical image processing algorithm. In fact, the homework is tuned to help to learn how to setup an image registration framework and to configure different parameters to perform the registration algorithm on a set of given image. The framework shown in Fig.1, which has been already established, will be completed step by step and the result will be demonstrated and discussed. Some results will appear in the current report and will be discussed just in response to the questions while the remaining results and images will be attached to the report.

2. Explanation of the registration framework and its components:

Image registration is an image processing technique used to align multiple scenes into a single integrated image. It helps overcome issues such as image rotation, scale, and skew which are common when overlaying images. Image registration is often used in medical and satellite imagery to align images from different camera or multiple sensor sources. One of the common frameworks for image registration is shown in Fig.1.

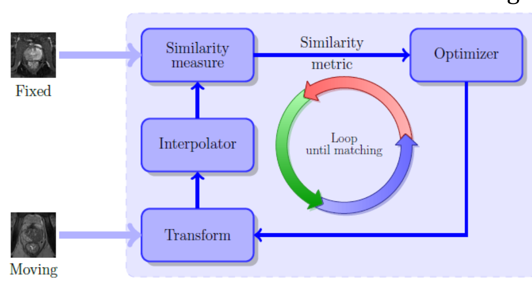


Fig.1 image registration framework

This frame work has following components:

- Input images (fix and moving images)
- Transformation functions (eg. Affine_function.m): by selecting one of the three blow transformation function the coefficient of the transformation will be calculated during the optimization process in the way that the moving image back can be transferred and overlay on the fix image with a minimum error using selected metrics.

  1.Rigid

  $$f_x(x,y) = x\cos\phi + y\sin\phi + t_x$$
  $$f_y(x,y) = -x\sin\phi + y\cos\phi + t_y$$

  2.affine

  $$f_x(x,y) = a_x x + a_y y + t_x$$
  $$f_y(x,y) = b_x x + b_y y + t_y$$

  3.projection

  $$f_x(x,y) = \frac{a_x x + a_y y + t_x}{c_x x + c_y y + 1}$$
  $$f_y(x,y) = \frac{b_x x + b_y y + t_y}{c_x x + c_y y + 1}$$

Note: only affine transformation is used in this homework.

- Optimizer and finding the best transformation parameters(fminunc function)
- Metrics for evaluation of transformation parameters (root mean square, mutual information): two following metrics will be used in this homework.

1. Simple Intensity difference (Root mean squared)

$$RMS(A,B) = \frac{1}{N}\sqrt{\sum_{x=0}^{X}\sum_{y=0}^{Y}(A(x,y)-B(x,y))^2}$$

2. Mutual information

$$C(A,B) = \sum_{i=0}^{I}\sum_{j=0}^{J} p_{AB}(i,j)\log\frac{p_{AB}(i,j)}{p_A(i)p_B(j)}$$

The definition of the components of the mutual information for a given example is shown in Fig.2.

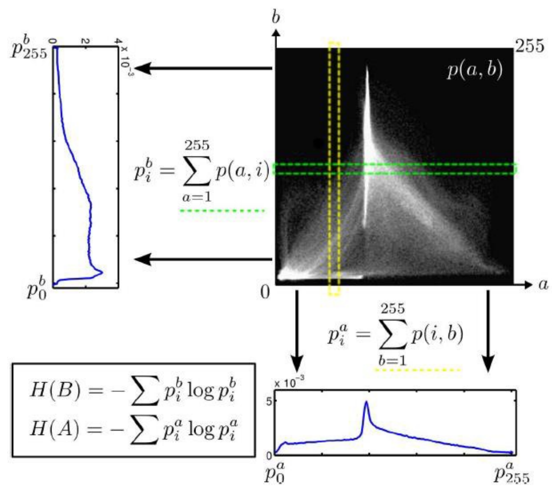


Fig.2 mutual information computation for two given images

The following codes were proposed to calculate the two above metrics:

- Mean root square of intensity

```
% metric computation
switch mtype
    case 'sd' %squared differences
        e=sum((I3(:)-Ifixed(:)).^2)/numel(I3);
    case 'm' %mutual informaiton
        e=Mutualinformation(I3,Ifixed);
    otherwise
        error('Unknown metric type');
end;
```

- Mutual information

```
% metric computation
switch mtype
    case 'sd' %squared differences
        e=sum((I3(:)-Ifixed(:)).^2)/numel(I3);
    case 'm' %mutual informaiton
        e=Mutualinformation(I3,Ifixed);
    otherwise
        error('Unknown metric type');
end;
```

3. Description of the implementation aspects requested in Sections 1-5.

Registration framework

The MATLAB files were read and fully understand as per framework has already been provided in the previous section. The components of an image registration framework were identified as detail in section 2.

components	**transformation**	**interpolation**	**optimization**	**metrics**
filename	Affine_trans.m	Affine_transf_2d.m	Affine_Reg2D.m	Affine_trans.m
Lines#	33-35	55-75	32	40-47

Answer to the follow question is as follows:

• What is the function of the scale vector? It seems the scale vector creates multi-resolution images representative for fully exploring rotation, translation and scale up/down transformation using pyramid scheme. It means, the moving image not only may subject to rotation and translation but might move away or get closer to the sensor. Applying different scale will leads to better transformation. Sometimes, as we will see later, achieving good image registration is possible only using scaling.

• Why is Gaussian smoothing used? The Gaussian smoothing is used to remove the trivial local minimum in the image which helps the faster convergence of the optimization algorithm.

• Where is the center of rotation of the transformation? The center of the rotation is coordinate (n/2, m/2) in image, where n and m are the length the height of the image.

Similarity metric: Mutual information

New similarity metric, mutual information was added to framework. Following function was developed in MATLAB.

```
%image dimention
dimen = size(J,1);
x = numel(J);
t = 1:x;
xx = J(:)+1;
yy = dimen*K(:);
xx = xx + yy;
xx = sort(xx);
yy(1:x-1) = xx(2:x);
zz = yy - xx;
zz(x) = 1;
zz = t(zz ~=0);
yy = xx(zz);
t = numel(zz);
zz(2:t) = zz(2:t)-zz(1:t-1);
xx = zz/x;
%histgram
jhist = zeros(dimen);
jhist(yy) = xx;
% joint entropy
jent = -sum(xx.*log2(xx));
%mutual information calculation between two image J and K
xx = sum(jhist);
yy = sum(jhist,2);
xx(xx>1e-12) = (xx(xx>1e-12)).^-1;
yy(yy>1e-12) = (yy(yy>1e-12)).^-1;
xx = ones(dimen,1)*xx;
yy = yy*ones(1,dimen);
MI = xx.*yy.*jhist;
MI = sum(jhist(:).*log2(MI(:)+(MI(:)<=1e-12)));
```

Transformation: Affine transformation

The framework has been modified to be able to deal with full affine 2D transformations. Following parameters were set for initialization:

Table.2: parameter initialization

parameters	M	interpolation	scale	metric	registration
possibility	any	See table.3	1-10	‘sd’/’m’	‘r’/’a’
setting	0	Bilinear/replicate	1.0	sd	‘r’

Table.3: Interpolation parameters

Option	interpolation	boundary
0	bilinear	replicate
1	bilinear	zero
2	bicubic	replicate
3	bicubic	zero
4	nearest	replicate
5	nearest	zero

The above settings were applied to the given set of medical images and following result were achieved (Fig.2).

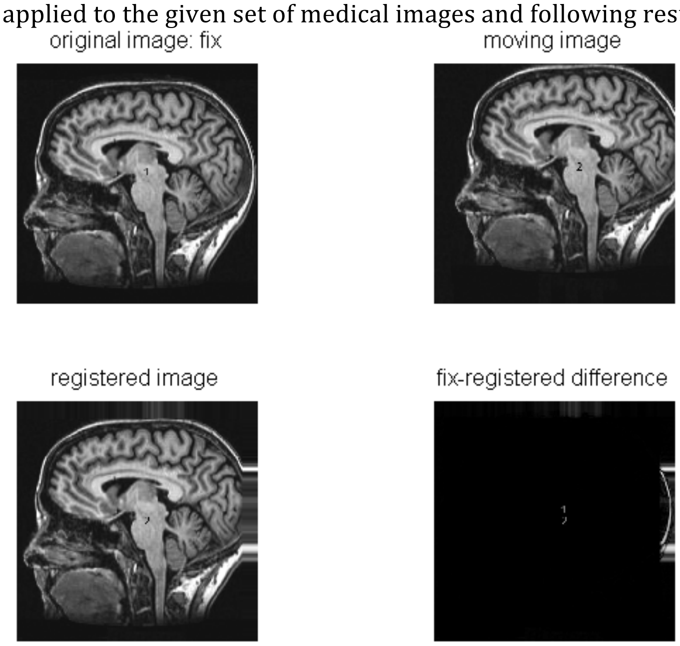


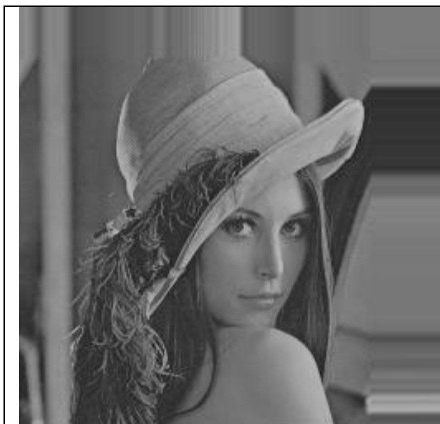
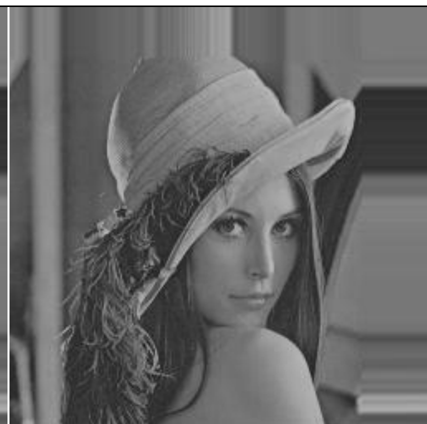
Fig.2 two top images are fixed and moving images and two bottoms are registered image and the different between registered and fix image.

Multi-resolution

The above modifications were implemented and transferred under a multi-resolution registration framework. In this framework, the resolution (step between each resolution) and the number of resolutions are the parameters of the framework. To initialize a multi-resolution framework, first a single resolution is established. Then, different resolution is generated by modifying multi-resolution parameters. Looking at the results, we will see that this framework has drawbacks and advantages. The main drawback is that the computation time will grows while on the other hand the accuracy are significantly improved which is a grate benefit.

Fig.3 two top images are fixed and moving images and two bottoms are registered image (scale vector: [1,2,2]) and the different between registered and fix image.

For instance, two following images (Fig.3 top) were selected as Fix and moving images and the registered image and the difference between registered and fixed images were found as two bottom images. For other resolution see attached folder multi-resolution result. All the MATLAB code and result is attached.

		
[1,2,2]	[1,2,3]	[1,2,8]
		
[1,3,6]	[1,5,4]	[1,5,8]