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# Rigid Registration of Reduced Dimension Images using 1D Binary Projections

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***Abstract*—**The purpose of this work is to present a method for rigid registration of medical images using 1D binary projections when a part of one of the two images is missing. We use 1D binary projections and we adjust the projection limits according to the reduced image in order to perform accurate registration. We use the variance of the weighted ratio as a registration function which we have shown is able to register 2D and 3D images more accurately and robustly than mutual information methods. The function is computed explicitly for n=5 Chebyshev points in a [-9,+9] interval and it is approximated using Chebyshev polynomials for all other points. The images used are MR scans of the head. We find that the method is able to register the two images with average accuracy 0.3degrees for rotations and 0.2 pixels for translations for a y dimension of 156 with initial dimension 256. For y dimension 128/256 the accuracy decreases to 0.7 degrees for rotations and 0.6 pixels for translations.

***Keywords*—**binary projections, image registration, reduced dimension images.

## I. INTRODUCTION

IMAGE registration is the process of geometrically aligning two images so that corresponding voxels/pixels can be superimposed on each other. There are several applications of image registration [1]. Examples include remote sensing, medicine, cartography, and computer vision.

Several techniques for signal intensity projection based image registration have been developed [2,3,4]. The most relevant work to this report is the method presented in Khamene et al [2]. In this work the registration problem is analyzed into the sub-problems of registering, using signal intensity based algorithms and criteria, the rendering projections of the two volumes along the three axes and adjusting the two volumes according to the projection-based computed registration parameters.

This paper presents the 2D rigid registration experiments performed between medical images with non-overlapping segments. We use 1D binary projections and we adjust the projection limits according to the reduced dimension image in order to perform accurate registration. We use the variance of the weighted ratio as a registration function which we have shown is able to register 2D and 3D images more accurately and robustly than mutual information methods. The function is computed explicitly for n=5 Chebyshev points[5] in a [-9,+9] interval and it is approximated using Chebyshev polynomials for all other points. This iteration loop is the basic idea for all registration methods which are developed as part of this work.

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In this context, the motivation is the need to produce a well engineered registration system of methods for 3D-3D rigid body registration (volume and projection based), 2D- 3D registration and non-rigid body registration.

## II. METHOD

The images used are MR scans of the head. We crop one of the two scans at two different levels and we perform registration experiments of the full scan which is T2 weighted to the cropped scans which are proton density. We cut the noise using thresholding and a threshold of 40. The images show in figure 1.

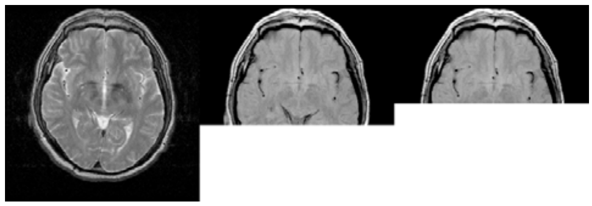

Fig. 1 Left: The reslice T2 weighted image. Middle: The reference image cropped at a ydim=156. Right: The reference image cropped at a ydim=128

The 2D registration method using 1D projections and reduced dimension images works in the following way:

After preprocessing, the contour pixels of the two images are projected along the x- and y-axes giving two sets of x- and y-projections. They are then rotated by θ degrees and projected onto the x-axis giving a set of θ degree projections. The projection of the reslice image is part of the iteration loop whereas the projection of the reference image is performed only once. Projections are incorporated into the geometric transformation function. The minimum and maximum values of x- and y-coordinates of the nonzero pixels of the geometrically transformed data set are computed and the 1D projections are created by padding the in-between ranges [xmin, xmax], [ymin, ymax], [xθmin, xθmax] with a standard non-zero value. The projections have double the dimension of the image in order to cope with the out-of-the-imaging area rotations and translations. For registration of translations the sum of x- and y-projections is used whereas for the registration of the xy-plane rotation the θ degree projections are used. The registration function is the 1D equivalent of the volume based definition given above. The way that we compute the projections allows us to avoid the use of interpolation within the geometric transformations. Instead of interpolation a computation of minimum and maximum x- and y-dimensions is performed.

The reduced dimension image is defined as the reference image. The other image is aligned to the reference and is referred to as the reslice image because in the 3D registration case it has to be resliced after alignment

The main iteration loop is entered and one of the N=3 geometric transformation parameters is adjusted with each iteration.

For this parameter the reslice image is transformed at n=5 Chebyshev points in the transformation units interval [-A, +A] and for these points the registration function is computed explicitly. The transformation units are degrees for rotations and pixels for translations. The approximated function has a point of minimum which is considered as the adjustment value of the geometric transformation parameter. Using this value, the reslice image is transformed.

The adjustment values computed for each transformation parameter in different iterations are summed to give the final adjustment value. Convergence for a transformation parameter is achieved when two iterations which adjust this transformation parameter give adjustment values less than one transformation unit.

It is clear from the above that the value of θ which registers the 2D rotation is a parameter of the algorithm. Extensive experiments showed that the value is not steady for all initial transformations and should be varied and the registration results compared in order to get the best registration result. The range of the variation of this angle used for the results in this report is 40 to 50 degrees for the usual orientation of the reference image which is parallel to the y-axis. If the reference image is significantly rotated relative to the y-axis, then a measurement of the angle of the rotation of the axis of symmetry of the image is performed and the θ range is adjusted accordingly.

Eleven angles in the range 40-50deg separated by one degree (40, 41, 42,…,50) are used to evaluate the best θ.

The algorithm used is:

*Algorithm 1: 2D image registration using binary projections and repetitive execution*

*For θ = 40,50 degs with step 1deg*
*Step 1 : Define A (cropped image) as reference image and B as reslice image*
*Step 2: Compute x,y and θ deg projections for A*
*For each of xy rotation, x translation, y translation:*
*Step 3 : Transform B at n Chebyshev points positions.*
*Step 4 : For each Chebyshev point:*
*compute x , y and θ deg projection of B*
*compute the registration function*
*End For (Chebyshev Points)*
*Step 5 : Approximate using Chebyshev polynomials and compute the point of minimum*
*Step 6 : Adjust reslice image to the point of minimum*
*Step 7 : With 2 less than one adjustments per transformation exit.*
*End For (transformations)*
*End For θ*
*Choose the best registration of all thetas.*

## III. RESULTS

From the beginning of this registration related work the evaluation of the accuracy is performed using a standard set of geometric transformation parameters. We de-register the reslice image and we bring it back into register using the registration algorithm. In this paper we use a standard set of 10 2D rigid transformations for the evaluation of the accuracy. The limits of the transformations are -10 deg to +10 degs for rotations and -10 pixels to +10 pixels for translations. The set of transformations are shown in Table 1.

TABLE I STANDARD SET OF 10 2D RIGID TRANSFORMATIONS

| Transf # | XY rotation(degrees) | X translation(pixels) | Y translation(pixels) |
|---|---|---|---|
| 1 | 7.35 | 2.35 | 1.44 |
| 2 | -5.14 | 8.77 | 7.33 |
| 3 | -8.67 | -2.44 | -2.66 |
| 4 | 8.33 | 7.11 | -3.75 |
| 5 | -0.95 | -1.63 | -3.14 |
| 6 | -9.14 | -9.21 | 8.42 |
| 7 | -5.85 | -6.87 | -8.05 |
| 8 | 2.24 | -3.92 | 5.63 |
| 9 | -3.6 | 0.45 | -2.97 |
| 10 | 4.1 | 9.23 | 8.05 |

After the image is de-registered we perform 11 registration experiments and we visually compare the final results in order to choose the most accurate one. This can also be done with the use of the full area criterion with the registered images. Table 2 gives an example of the results for all thetas for transformation # 1 and with the ydim=156.

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TABLE II EXAMPLE OF CHOICE OF THE Θ (PROJECTION ANGLE) WHICH REGISTERS ACCURATELY THE IMAGES WITH ydim=156 (transformation #1)

| θ (degrees) | XY rotation error(degrees) | X translation error(pixels) | Y translation error(pixels) |
|---|---|---|---|
| 40 | -0.27 | -0.06 | -0.19 |
| 41 | 0.57 | 1 | 0.20 |
| 42 | 0.32 | 0.83 | 0.31 |
| 43 | -2.4 | -0.74 | 0.25 |
| 44 | 0.65 | 0.83 | 0.25 |
| 45 | -0.49 | 0.6 | 0.25 |
| 46 | -0.27 | 0.43 | -0.24 |
| 47 | 0.93 | 0.88 | -0.02 |
| 48 | -2.43 | -0.74 | 0.25 |
| 49 | 0.99 | 1.11 | 0.14 |
| 50 | -0.6 | 0.38 | 0.25 |

Based on this result we chose the value of θ=40 to be the most accurate.

With more reduced value of ydim=128 the errors increase for all thetas. Table 3 gives an example of the results for all thetas for ydim=128 and transformation #1.

TABLE III EXAMPLE OF CHOICE OF THE Θ (PROJECTION ANGLE) WHICH REGISTERS ACCURATELY THE IMAGES WITH ydim=128 (transformation #1)

| θ (degrees) | XY rotation error(degrees) | X translation error(pixels) | Y translation error(pixels) |
|---|---|---|---|
| **40** | **-0.55** | **1.22** | **0.03** |
| 41 | 0.45 | 2.23 | 0.03 |
| 42 | -0.13 | 2.4 | -0.24 |
| 43 | -0.27 | 1.61 | -0.3 |
| 44 | 0.26 | 2.01 | 0.03 |
| 45 | 0.13 | 2.4 | -0.24 |
| 46 | -0.07 | 2.01 | -0.07 |
| 47 | -0.44 | 1.95 | 0.14 |
| 48 | -1 | 1.33 | -0.13 |
| 49 | -0.27 | 1.67 | -0.24 |
| 50 | 0.54 | 2.57 | 0.25 |

Based on these results we chose the value of θ=40 for the correct result.

We perform the above experiments repetitively for all transformations. Tables 4 and 5 show the results for each transformation for ydim=156 and ydim=128 respectively. We get average rotational accuracy 0.3degrees and average translational accuracy 0.2pixels for ydim=156. For ydim=128 we get average rotational accuracy 0.69degrees and average translational accuracy 0.59pixels.

TABLE IV ERRORS FOR ydim=156

| Transf # | XY rotation(degrees) | X translation(pixels) | Y translation(pixels) |
|---|---|---|---|
| 1 | -0.27 | -0.06 | -0.19 |
| 2 | -0.24 | 0.05 | 0.07 |
| 3 | -0.63 | 0.09 | -0.12 |
| 4 | -0.67 | -0.09 | -0.09 |
| 5 | 0.2 | 0.39 | 0.23 |
| 6 | 0.28 | 0.35 | -0.01 |
| 7 | 0.22 | 0.44 | 0.21 |
| 8 | -0.06 | 0.58 | -0.05 |
| 9 | -0.5 | 0.22 | -0.04 |
| 10 | -0.00 | 0.51 | 0.23 |

TABLE V ERRORS FOR ydim=128

| Transf # | XY rotation (degrees) | X translation(pixels) | Y translation(pixels) |
|---|---|---|---|
| 1 | -0.55 | 1.22 | 0.03 |
| 2 | -0.24 | 0.05 | 0.07 |
| 3 | -0.68 | 1.32 | -0.12 |
| 4 | -0.67 | 1.42 | -0.09 |
| 5 | -0.97 | 1.18 | -0.10 |
| 6 | -0.67 | 1.19 | -0.01 |
| 7 | -1.35 | 0.89 | 0.05 |
| 8 | -0.57 | 1.31 | 0.00 |
| 9 | 0.39 | 1.12 | 0.01 |
| 10 | -0.79 | 1.41 | 0.23 |

We run the experiments on a High Performance Computing server iceberg which is the Sheffield node of the White Rose Computing Grid. Iceberg has 96 Sun X2200 nodes. We use one node which has 4 cores and 16 Gbytes of RAM. The processing time per experiment per θ is between 0.3 and 1 sec.

## IV. DISCUSSION

We have presented a method for registration of 2D cropped images using 1D binary projections. The registration uses the variance of the weighted ratio as a registration function and achieves registration by minimizing this function using a Chebyshev polynomial based iteration loop. We avoid the use of interpolation with the use of a geometric transformation routine which does not incorporate interpolation. Instead we compute the minima and maxima of the transformed images along the lines of projections and we pad the in between values in order to compute the projections.

We have applied the method for the registration of cropped images. The modification with the use of cropped images is that we always use the cropped image as a reference and we limit the computation of the registration function based on the projections of the cropped image. In order to achieve acceptable accuracy we modify the projection angle θ between 11 values (40,41,42,…,50) we execute the program repetitively and we choose the most accurate result.

For the testing of the method we cropped the reference image at two levels along y-dimension, at ydim=156 and ydim=128. We get accuracy better than 0.5degrees and 0.5pixels for ydim=156. The accuracy decreases for ydim=128.

The method can be extended to 3D for registration of surfaces of full or missing data. We can treat the surfaces as a stack of contours and use 1D projections for the registration of the contours.

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