Medical Image Registration Based on SURF Detector

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Abstract—A quick method of 2D global registration of CT images in different series of studies of one patient is suggested in this work. The distinguishing feature of this approach is the use of image registration based on the SURF (Speeded Up Robust Features) detector, which has proved efficient in computer vision.

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INTRODUCTION

One of the most important tasks of analysis of images is their registration: bringing two or more images into a united system of coordinates for their subsequent analysis. This task is important in cartography for updating maps by satellite images; in applications of computer vision for stereo reconstruction; in capturing and analyzing movement; in medicine for diagnosing and revealing changes in different series of images of medical scanning of the patient or even for conducting operations [1, 8], as well as in many other areas.

At present, there are many approaches to solving this task, many of which are quite universal [2], while there are also specialized methods for registering medical images [3–9].

The algorithms of medical registration can be conventionally divided into subclasses by the following criteria: automatic or interactive; pixel (intensity-based) [6, 9] or feature-based [7–9]; model-based [8] or in the general case; working in a frequency or spatial range; rigid, affine, or projective by the type of admissible transformations; unimodal and multimodal approaches [7] (use of several various species of input data upon registration), and others.

As for the feature-based registration, radically differing characteristics may be used here with reference to medicine. For example, it can be interactive points, anatomical features [8], or geometrical and other local particularities. This study suggests an algorithm of image registration based on a SURF (Speeded Up Robust Features) descriptor developed by H. Bay et al. [10]. The suggested approach is used for quick leveling of CT layers of one patient taken at different times (an example of two pictures of the same patient taken at different times is given in Figs. 3a, 3c). This procedure is very important for accurate diagnosing, searching for changes, estimating the regression of new formations, etc., since it is not always possible to track small changes in tissues in an interactive regime without preliminary processing and accurate combining of CT images.

At first glance, medical images can be combined using rigid registration. As a matter of fact, the information about the scale of the CT layer of the study is registered in the title of the DICOM file and to combine them, all that remains is to select its optimum turn and shift. However, due to the particularities of our area of study (the organs of the mediastinum and retroperitoneal space), this approach gives poor results since the areas of scanning are easily deformed (another phase of respiration or change in the position of the organs of the abdominal cavity).

So it is necessary to solve the more complicated task of determining elastic transformation, which is quite labor-intensive in terms of calculations.

In this work, we suggest using a simplified approach based on registering part of an image: the area of interest. Registration in the area of interest is accomplished by searching for a promising transformation, which would combine the points of interest areas of the two images in the best way possible. Practical trials have shown the competence of this assumption. To calculate the optimum perspective transformation, the method of registering based on a SURF detector [11], which has proved its validity, is used.

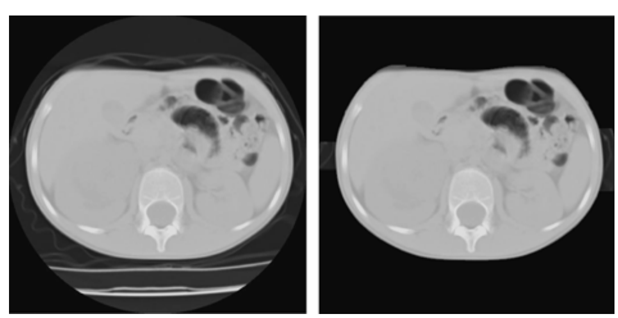

Fig. 1. Source CT image (left) and the result of morphological body region segmentation (right).

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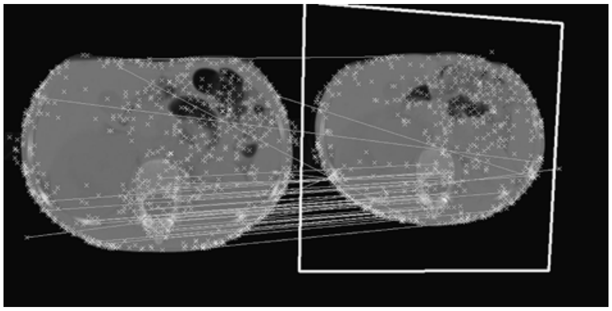

Fig. 2. Control points (indicated by white crosses), the determined point pairs (shown with lines), and the result of determining perspective transformation (bounding rectangle).

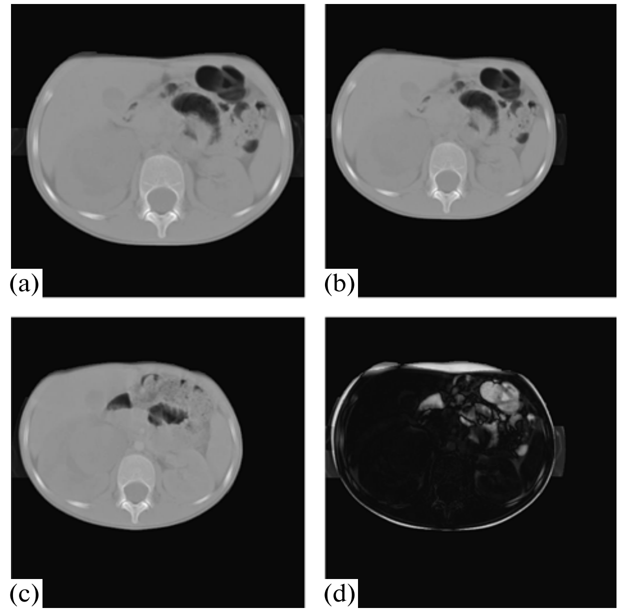

Fig. 3. (a) Original and (b) transformed images; (c) template for registration; and (d) the difference between the template and the image obtained during the registration.

DESCRIPTION OF THE ALGORITHM

Since the DICOM images contain not only the information about the density of the patient's body tissues at the cut but also some extraneous components, for example, parts of the CT scanner, the patient's clothes, special sensors, etc., preprocessing of the image should be the preliminary stage. The area occupied by the patient's body is distinguished at this stage and further comparison will be conducted only for this area.

To do this, morphological and threshold operations are used. The listing of the algorithm in a pseudocode is given below (Listing 1). The result of its operation is given in Fig. 1b.

Listing 1. Body region segmentation algorithm

```
// Loading DICOM Image
image = LoadImage("Source");
// Cloning DICOM Image
imCpy = CloneImage(image);
// Morphological Opening (Radius=10)
image = Opening (image, 10);
// Morphological Closing (Radius=30)
image = Closing (image, 30);
// Thresholding by DICOM Levels
image = Threshold (image, 50);
// Mask&Source Image Conjunction
image = And (image, imCpy);
// Saving Resulting Image
SaveImage("Result", image).
```

After distinguishing the body area and rejecting the extraneous components, registration of two layers of images from different series is conducted. Special points are calculated in each image, and their descriptors are determined. After this, the descriptors of the two images should be compared and the nearest correspondence found using one of the well-known fast methods (for example the KD-tree–based nearest neighbor search [12]). Only after calculating all matching pairs (part of which can be false matches) can the optimum transformation, which converts the points of the first image into those of the second, be determined.

As was mentioned above, the registration by the proposed model uses a global type of transformation. Such a transformation can be determined using the models of rigid, affine, perspective, and elastic deformation.

The first two models cannot provide satisfactory correspondence quality, while the elastic deformation is too complicated and time-consuming. For this reason the perspective transformation model was used. To search for the corresponding feature-based perspective transformation, the well-known stochastic method RANSAC (RANdom Sample Consensus) was used [13]. Its fast implementation can be taken from the OpenCV open source software package [14].

A more detailed explanation of the algorithm is suggested in Listing 2. The computed feature points, matched features, and resulting perspective transformation are shown in Fig. 2.

Listing 2. SURF-based registration algorithm

```
// Load 2 Slices with Body Region
img1 = LoadImageBody("Slice01");
img2 = LoadImageBody("Slice02");
// Calculate Keypoints&Descriptors
KeyPt1 = SURF(img1);
KeyPt2 = SURF(img2);
// Find Corresponding Point Pairs
Pairs = FindPairs(KeyPt1, KeyPt2);
// Find Homography Matrix
H = FindHomography(Pairs);
//Calculate Image Transformation
```

```
imgWarp =WarpPerspective(img2, H);
// Save Transformation Result
SaveImg("Warp.png", imgWarp);
// Calculate Two Images Difference
imgDiff = AbsDiff(img1, imgWrp);
// Save Difference Result
SaveImg("Diff.png", imgDiff).
```

TRIALS

The results of the restoration and comparison using the suggested method are given in Fig. 3. The original and transformed images of the first layer are given, as well as the difference between the images obtained through registration.

As can be seen from the difference between the aligned images, the spine region at the matched sections in the two images is almost identical and does not contribute to the difference. The areas in the upper right-hand part of the image, which represent the changes, can be seen well in the image.

To implement and test the proposed methods, the OpenCV [14] library and its Python programming language bindings PyOpenCV [15] were used.

The time spent on body region segmentation is about 93 ms, and the registration time is around 390 ms. Thus, the rate of the implementation of the algorithm is quite high even though it is performed using a script interpreter. The proposed method is expected to be introduced in the developing system of diagnosing mediastinum organ disorders in children under the ISTC B-1489 project.

The application of this approach can also be transferred to 3D medical registration.

It is also planned to study the possibility of increasing the accuracy of the algorithm through using feature points of original 16 bit DICOM images.

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REFERENCES

1. R. C. Susil, J. H. Anderson, and R. H. Taylor, "A Single Image Registration Method for CT Guided Interventions," in *Proc. 2nd Int. Conf. on Medical Image Computing and Computer–Assisted Intervention (Sept. 19–22, 1999)*, Ed. by C. Taylor and A. C. Colchester (Springer–Verlag, London, 1999), Vol. 1679, pp. 798–808.
2. B. Zitova and J. Flusser, "Image Registration Methods: a Survey," Image Vision Comp. **21**, No. 11, 977–1000 (2003).
3. D. L. G. Hill, et al., "Medical Image Registration," Phys. Med. Biol. **46**, No. 3, R1–R45 (2001).
4. J. Martinez and M. Viergever, "A Survey on Medical image Registration," Med. Image Anal. **2**, No. 1, 1–36 (1998).
5. A. Goh and R. Vidal, "Algebraic Methods for Direct and Feature Based Registration of Diffusion Tensor Images," in *Proc. ECCV,* Ed. by A. Pinz (Graz, 2006), Vol. 3, pp. 514–525.
6. X. Y. Wang, D. D. Feng, and J. S. Jin, "Elastic Medical Image Registration Based on Image Intensity," in *Selected Papers from 2001 Pan–Sydney Area Workshop on Visual Information Processing (VIP2001)*, Ed. by D. D. Feng, J. Jin, P. Eades, and H. Yan (Sydney, 2001), pp. 139–142.
7. Liao Shu and A. C. Chung, "Multi–Modal Image Registration Using Orbital Features and Multidimensional Mutual Information," in *Proc. Biomedical Imaging: From Nano to Macro. 4th IEEE Int. Symp. on Digital Object Identifier* (Washington, 2007), pp. 5–8.
8. G. C. Sharp, et al., "Anatomic Feature–Based Registration for Patient Set–up in Head and Neck Cancer Radiotherapy," Phys. Med. Biol. **50**, No. 19, 4667–4679 (2005).
9. R. A. McLaughlin, "Intensity–Based Registration Versus Feature–Based Registration for Neurointerventions," in *Medical Image Understanding and Analysis,* Ed. by R. A. McLaughlin, J. Hipwell, G. Pennym, K. Rhodes, A. Chung, A. Noble, and D. Hawkes (The Univ. of Birmingham, Jul. 16–17 2001).
10. H. Bay, "SURF: Speeded up Robust Features," in *Proc. Computer Vision and Image Understanding*, Ed. by H. Bay, A. Ess, T. Tuytelaars, and L. Van Gool (2008), Vol. 110, No. 3, pp. 346–359.
11. V. Pimenov, "Fast Image Matching with Visual Attention and SURF Descriptors," in *Proc. 19th Int. Conf. on Computer Graphics and Vision, GraphiCon'2009* (Moscow, 2009), pp. 49–56.
12. A. Moore, "An Introduction Tutorial on kd–Trees," Tech. Rep. No. 209 (Computer Laboratory, Univ. of Cambridge, Carnegie Mellon Univ., 1991).
13. M. A. Fischer and R. C. Bolles, "Random Simple Consensus: a Paradigm for Model Fitting with Applications to Image Analysis and Automated Cartography," in *Readings in Computer Vision: Issues, Problems, Principles, and Paradigms*, Ed. by M. A. Fischler and O. Firschein (Morgan Kaufman Publ., Los Altos, CA, 1987), pp. 726–740.
14. http://sourceforge.net/projects/opencvlibrary
15. Python Bindings for OpenCV 2.x Using Boost.Python and NumPy, Available from: http://code.google.com/p/pyopencv