Local Rigid Registration: A tumour localization application

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Abstract

We present a fast, interactive local rigid registration application to localize tumour's position for radiotherapy. The aim of the application is to automatically localize in a therapy CT dataset the target volume marked in a plan CT before applying a therapy. The algorithm is fast because it restricts the registration to a small area of the whole dataset. Once the target is found, the application returns the target's coordinates and its displacement from the plan position in order to consequently adjust the treatment parameters. Because the program finds quickly (about 20 seconds) the new tumour's position, it is a suitable interactive tool in the radiotherapy praxis.

Introduction

An important issue for an effective radiotherapy is to localize the target volume when the patient lies on the treatment couch. Few days before a therapy takes place, a planning study is carried out to identify the target volume. Knowing target's location, the radiation beams can be adjusted for treatment planning. Between planning and application of a therapy, patient and tumour may have changed their position relative to the plan coordinates. In order to apply the therapy, the actual position has to be identified and its displacement according to the plan has to be calculated.

The movement of the target volume can be measured by registration of the planning with the therapy studies. Image registration is nowadays a central research matter. There have been several reviews on this topic including [1-3]. Image registration is a method to find a spatial correspondence between two images. This correspondence is such that it maps the coordinates of an image into the coordinates of the other.

Van Herk et al. [4] proposed a method where the user has to manually mark some organ contours in order to get a rigid registration describing prostate motion. The method we present in the next paragraphs uses also rigid transformations. It requires user intervention to mark a region of interest in a plan volume. As output the program localizes this region of interest in a therapy dataset, gives the displacement of the region of interest between the two volumes and also gives the transformation describing this motion.

Material and methods

Before a therapy is executed, a treatment study is carried out. The Radiology Department at the Univesitätsklinikum Würzburg disposes of a Philips Tomoscan in the therapy room, as shown in Figure 1. To control patient's position for therapy a new dataset is taken with this Tomoscan, i.e. the treatment study. This new dataset is compared with the planning study in order to adjust the therapy to the actual patient's and tumour's position.

Figure 1: Radiotherapy room, Radiology Department at the Univesitätsklinikum Würzburg.

Using the xrayortho++ library from the Medical Applications Research Group at TU Munich [5], we developed an application to identify target's motion. The program first performs a global registration between the planning and therapy studies. The result of the global registration is used to get a coarse approximation of region of interest's position. Then a local registration is performed to improve accuracy in the localization of this region. The program flow is described in detail in the following paragraphs.

Global registration

The first step in our application is a global registration. As input the program receives two datasets to be registered, the planning volume and the treatment volume. At initialization time both volumes are globally registered using a rigid body transformation model.

There are several advantages of using a rigid body registration. Rigid body registration has been extensively used in the last decades because of its low computational cost. As it consists of
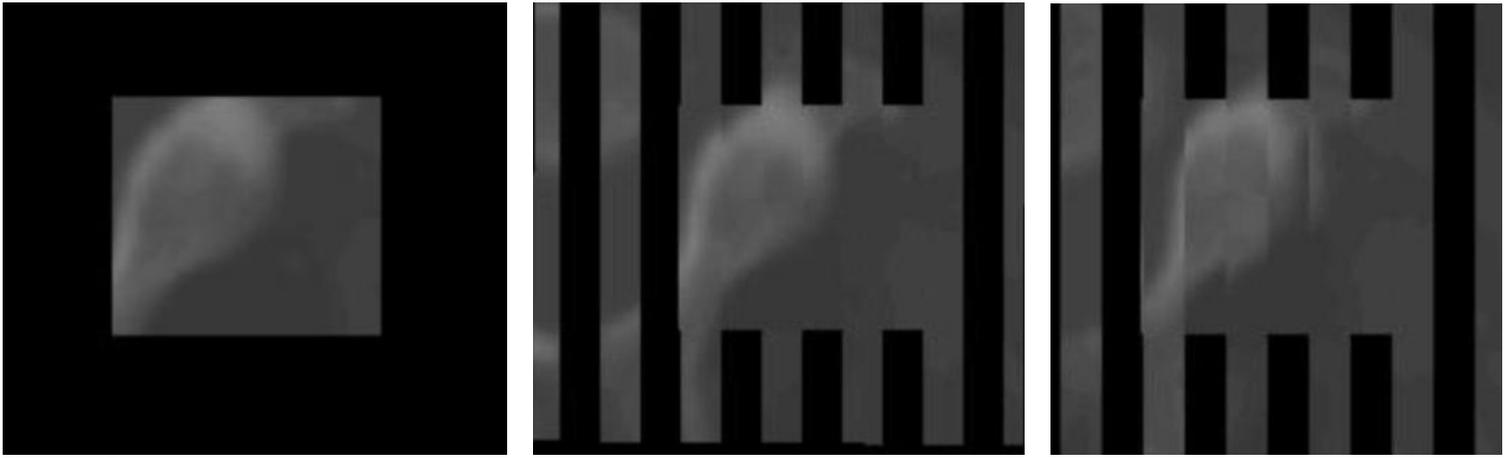
Figure 2: Local refinement vs. global registration. On the left, selected ROI within original planning CT. In the middle, registration result after local refinement. On the right, registration result after global registration only.

rotations and translations, the problem of finding the best transformation has only six degrees of freedom and it can be quickly solved with a modern PC. Another advantage is the fact that it can be performed completely automatically. Similarity measures between two images drive the spatial correspondence search. Measures as mutual information or correlation coefficients [1] rely just on image information. Therefore, to get a geometric transformation between two images, there is no need of additional information, like user-defined landmarks or segmentation. Despite these advantages, there are some other aspects to take into account, especially for medical applications.

A global rigid transformation can not always provide an accurate solution for tumour localization. Because the transformation is applied to the entire volume, the distance between any two points in the floating volume is assumed to be the same after being mapped in the reference volume. Although this is true for rigid structures like bones, it is not always the case in body parts, like thorax or pelvis, where local displacements may take place because of internal organ movements. These local displacements may also affect tumour's position. Therefore, the global registration needs to be refined.

Local registration

To improve the tumour's position accuracy we apply a local registration. The result of the global registration, i.e. a rigid transformation to align the planning with the treatment volume, is saved in a file to be used later by the local registration. The planning study may have marked the target volume as a region of interest (ROI). In this case the application has to read it. If not, using a graphical user interface (GUI) the user can directly mark a ROI on the planning volume. Having the ROI, the local registration is achieved in three steps. Firstly, the centre of ROI is mapped to the treatment volume using the global transformation. Secondly, this point is used as the centre of a search region with twice the width, twice the height and twice the depth of the ROI. And thirdly, these two subvolumes, i.e. the ROI in the planning image and the search region in the treatment

image, are then locally registered also with a rigid transformation. With this last transformation we calculate tumour's position.

Knowing tumour's position in the volume, the program provides its coordinates to the user. The patient lying on the treatment couch may have skin markers, which are easy to recognize in the treatment volume. These markers establish a coordinate system, which is used as reference for the treatment. Thus, the program can also calculate tumour's position and displacement from the origin of this skin markers coordinate system.

A local rigid registration provides a refinement of target's position. Because both datasets are from the same patient and usually made with a difference of few days, big changes in target's shape and position are not really expected. Thus is reasonable to look for the tumour within the search region. In this way, local registration will detect small local movements.

Results and discussion

We realized 180 tests of our application with eleven pairs of CT-CT volumes. These volumes correspond to thorax, neck, head and pelvis. By visual inspection, in most of the cases the local registration seems to deliver an improved result of the global registration alone.

A quantitative comparison of both methods was also achieved. To have a quantitative performance measure, we examined the differences between the region of interest in the plan volume and the two resulting images from the therapy volume. In this way, we compared how well a resulting image covered the original region of interest. In our tests, we found that in 75% of the cases, the local registration covers better the region of interest (62%) or at least as good as the global registration (13%). The other 25% corresponds to body parts with higher flexibility, like spine. In these cases both local and global registration performed poor, because such movements can not be captured by a rigid body model.
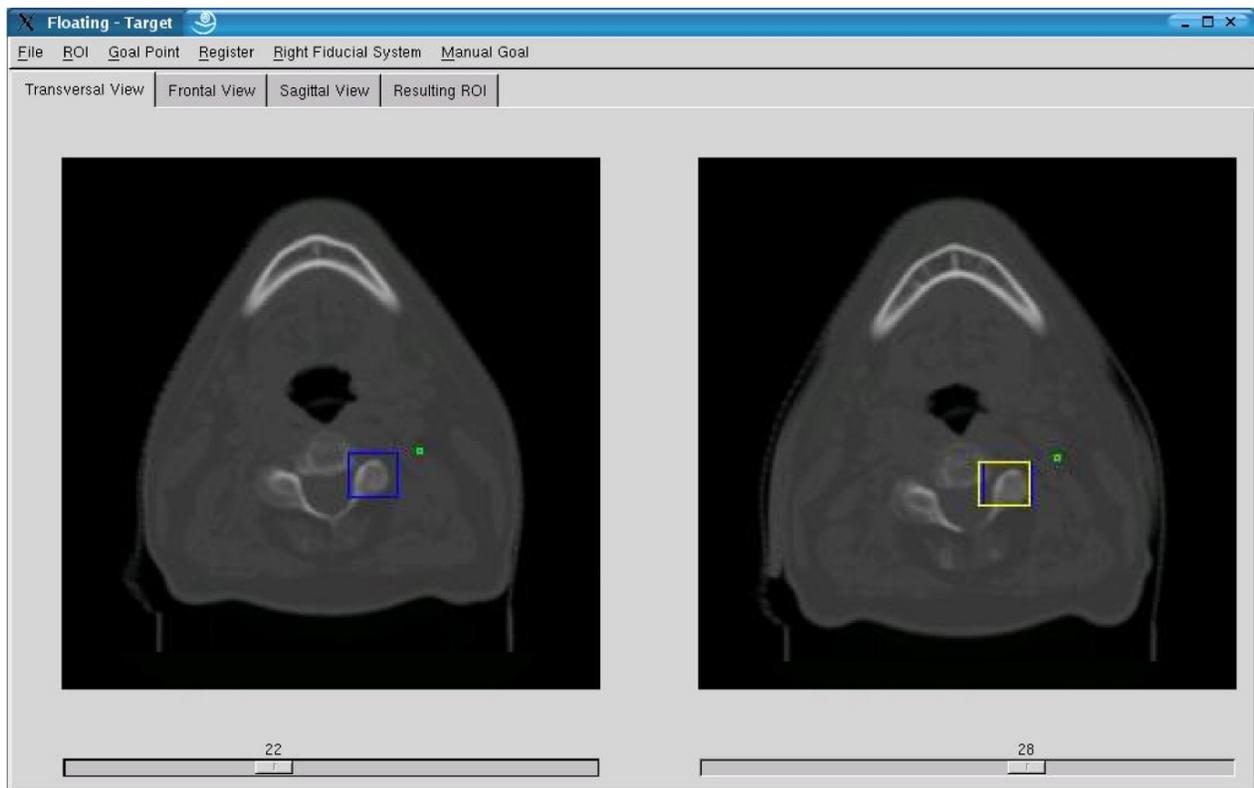
Figure 3 Graphic user interface of our application. The image on the left is a slice of the planning CT, in blue is the ROI marked. On the right is the corresponding slice of the treatment CT, in blue is marked the resulting ROI of the local registration and in yellow the resulting ROI of the global registration. The isocentre (green dot) is fixed to the ROI. The coordinates of the isocentre are calculated for the treatment coordinate system.

For such body parts where local deformations may take place, non-rigid registration may deliver better results [6, 7], but at a more expensive time complexity.

The program is a valuable tool in the radiotherapy praxis. The initialization of the application takes up to three minutes, because the global registration is performed, but once the GUI comes up, the user can select with the mouse a region of interest in the planning volume or the program reads it from a file. With this information the program finds automatically the region of interest in the treatment volume, it gets tumour's current coordinates and provides the transformation used for the registration. If the result is not satisfactory, the user can mark with the mouse the target in the treatment volume and the program calculates its coordinates. In our tests, the local registration needed 20 to 60 seconds (depending on ROI's size) on a PC Pentium 4 with 512MB RAM running at 2.4 GHz.

Conclusion

We have presented an application for tumour localization. This application calculates tumour's coordinates when the patient lies on the treatment couch. After an automatic initialization the user provides a ROI in the plan data. The new coordinates of ROI in the therapy volume are calculated. Because this is done in few seconds, this program is appropriate for user interaction.

For some body parts, big changes in shape and position are not expected, because both datasets are made within few days of difference. Although nonrigid models could provide

more accurate coordinates in more flexible body parts, like neck, they are also more time consuming. In such situations, the user has the option of manually mark the target, and the program calculates its coordinates. Therefore the application using a local rigid registration method provides an acceptable compromise between time and accuracy.

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