# FOURIER BASED PATIENT POSITITIONING FOR RADIOTHERAPY TREATMENT

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## ABSTRACT

Accurate patient positioning during each fraction of a radiotherapy treatment is crucial to ensure accurate treatment of the tumor while preserving surrounding healthy tissues. The precision of the treatment can be increased with portal imaging devices which provide real time digital images during treatment. Detecting discrepancies in the patient setup can be derived from a comparison of images obtained during the planning phase (reference images) and images taken during each fraction of the treatment (portal images). As the megavoltage images used in treatment have low contrast and resolution, limited contrast adaptive histogram equalization is used to enhance image quality. A Fourier-Mellin transform is used to recover the translation and rotation parameters of the portal images in comparison to a reference image. In previous works, this approach was tested by registering a reference image against a scaled and rotated version of itself. In this paper, we applied the method to two experimental data sets containing phantom images taken on a radiotheraputic simulator and linear accelerator (LINAC). The average error rates obtained for different rotation angles were 0.76 and 2.8 degrees on simulator and LINAC images, respectively. Translational errors were 1.07 and 1.57 pixels in the x and y direction for simulator images and 1.77 and 1.55 pixels on the x, and y axis for LINAC images.

## 1. INTRODUCTION

The accuracy and safety of cancer treatment continues to be an important concern. One of most common cancer treatment methods is radiotherapy, which includes External Beam Radiotherapy (EBRT), Brachytherapy and Unsealed Source therapy. The goal in radiotherapy is to deliver a prescribed radiation dose as accurately as possible to a tumor while preserving healthy surrounding tissues [1]. In the EBRT, external source of radiation is directed at the tumor from an external source produced by a linear accelerator or cobalt units [2]. The process consists of two major parts; a planning phase and treatment phase. In the planning phase, the shape and location of the tumor is determined using a treatment simulator and the optimal way of delivering the prescribed dose to the tumor using the high energy beams is calculated. In order to get the desirable result, the position of the patient for each fraction of radiotherapy treatment needs to be known and controlled. Incorrect setup or patient movement during treatment may result in a geometric localization error causing inadequate radiation treatment of the tumor or unnecessary exposure of healthy tissue to radiation [3]. In this paper, we discuss a method for automatic patient positioning during radiotherapy treatment. The paper is organized as follows. In the next section, a brief overview of different methods for reducing patient positioning uncertainty is reviewed. In addition, the preprocessing step and our method for recovering patient misalignment are discussed. Results are discussed in Section 3. The last section is dedicated to conclusions and future works.

## 2. METHODS

Patient immobilization during radiotherapy treatment is important to achieve good result. Devices such as plastic mesh, foam cradles and breast arm boards are used to immobilize the patient. Despite the immobilization, the patient position should be verified. Position verification is done by using tattoos, and other optical markers together with orthogonal laser beams to verify the external position of the patient while the position of the anatomy is visualized using Electronic Portal Imaging Devices (EPID) offering real time digital readout. Discrepancies in the patient setup can be detected from the comparison of the images obtained during the planning phase and portal images obtained on treatment. In other words, the patient positioning problem can be considered as an image registration problem between reference and portal images.

Traditionally, a radiation oncologist visually evaluated the reference and portal images to determine if a treatment setup adjustment was required. Although this approach is generally accepted in clinical practice, it is sensitive to observer expertise and it is time consuming and subject to human error. Therefore, fully or semi-automatic discrepancy detection between portal and reference images is required. Image registration for radiotherapy treatment has its own particular challenges:

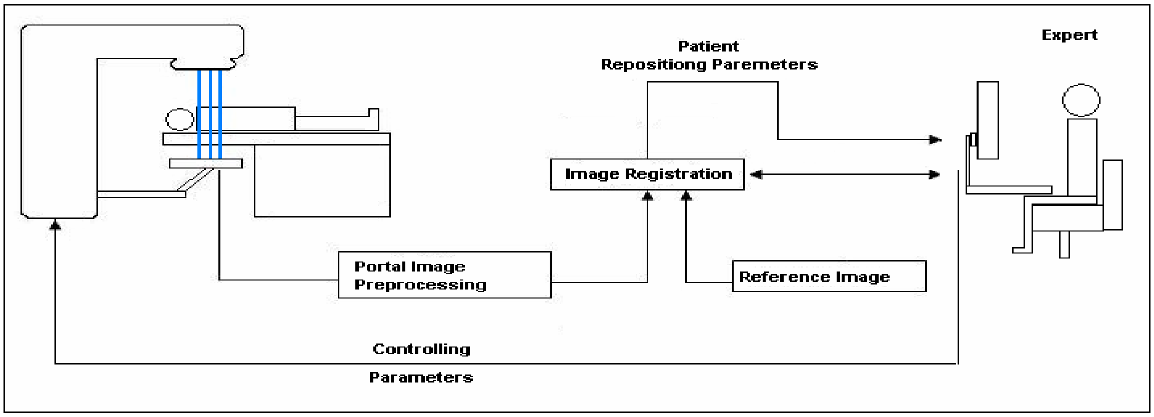



Figure 1: Overall structure of the radiotherapy treatment process equipped with fully or semi-automatic image registration.

- Poor quality portal images caused by high energy therapeutic beams
- Partial data caused by the use of multi-leaf collimator which is used to define the treatment field size.
- Internal organ movement which results in some organs like the prostate moving independently of bony structures.
- Different modalities are used for the reference and portal images
- Large or small distortions; including large free form deformation specially seen in bladder, prostate, rectum, lung, etc.

Image registration methods especially for this type of application are classified into landmark based and intensity based techniques [8]. In landmark based methods, the transformation is determined based on natural or artificial landmarks; including points, external fiducial, open curve or lines. The accuracy of these methods depends on robustness and accuracy of feature extraction phase. Examples of land mark based approaches can be found in [9] [10] [11].

Intensity based methods find the optimal match between intensity distribution of reference and portal images. For optimal performance of these methods, the images should have similar contrast distributions. Since the reference and portal images could have different modalities, it is possible to use a megavoltage portal image taken at the beginning of treatment as a reference or to change digitally reconstructed radiographs to match the distribution of the megavoltage images [8]. Intensity based correlation methods have been applied to portal images for treatment setup [12]. Mutual information is also used to determine the translation and rotation parameters. [13]. A “minimax entropy” method [14], one based on Local Normalized Correlation (LNC) as well as techniques using similarity measures and Levenberg-Marquardt optimization methods have also been used for this purpose [15].

The overall structure of the radiotherapy treatment process equipped with fully or semi-automatic image registration is depicted in Figure 1. A Portal image is taken with therapeutic beams and is preprocessed. An image registration algorithm is then applied to the enhanced portal image and reference image. A two directional arrow between the image registration part and the expert shows that semi automatic registration may be possible. The patient realignment parameters are estimated by image registration method. An expert, which could be a human expert or even an expert system, would send controlling parameters to linear accelerator system.

The method we used for image registration is based on a Fourier-Mellin transform and will be discussed in Section 2.2. Zokai and Wolberg [18] mentioned that “the literature is replete with synthetic examples for the Fourier–Mellin registration method”. In practice, a reference image is registered against a scaled and rotated version of itself. Chen et al. proposed this method to be used in radiotherapy treatment and planning, and for demonstrating performance of the algorithm. Results were reported on only two slices of MRI image [21]. However, in this paper, we want to apply the technique to a dataset containing typical low quality megavoltage images. In the following sections, a brief overview of method will be mentioned, followed by results and conclusions.

### 2.1. IMAGE ENHACEMENT

Portal images are typically low in quality, because these images are taken by high energy therapeutic beams. Contrast Limited Adaptive Histogram Equalization (CLAHE) is a well known approach to improving the image quality for this application [16].

CLAHE operates on sub-regions of image. An intensity distribution for each tile is enhanced based on a pre-defined distribution. Bilinear interpolation is used to remove artificially induced boundaries for neighboring tiles [17]. To minimize the effects of implicit tiling of finite images and also removing unwanted margins, a circular window with blurred edges was applied on the image [19]. Figure 2 shows the result of applying CLAHE and blurred circular mask.

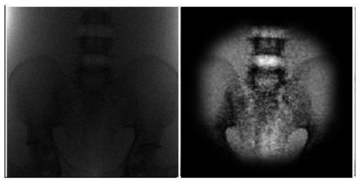


Figure 2: Left: Portal image taken with linear accelerator, Right: CLAHE and blurred circular mask are applied

### 2.2. FOURIER-MELLIN TRANSFORM

The Fourier-Mellin Transform (FMT) uses the Fourier transform and log-polar mapping properties. The log-polar transform is a non uniform and nonlinear sampling of the reference domain [18]. The log-polar coordinate system (*log r*,$\theta$) is based on radial basis (*r*) from the centre ($x_c$,$y_c$) and $\theta$ the angle. Any point in the reference domain is mapped to a point (r,$\theta$) as follows:

$$r = \log_{base}\left(\sqrt{(x-x_c)^2+(y-y_c)^2}\right) \quad (1)$$

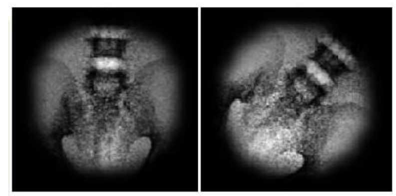
$$\theta = \tan^{-1}\left(\frac{y-y_c}{x-x_c}\right) \quad (2)$$

The magnitude of the Fourier transform is invariant to translation and is called the Fourier-Mellin domain [19]. If the Fourier-Mellin domain is mapped to a log polar coordinate system, the rotation and scale appears as translational shift along $\theta$ and *log r,* respectively. For determining shifts in different directions a phase correlation method is used [20]. This algorithm is a frequency method that finds a translational movement between images.

### 3. RESULTS

Our method is implemented using MATLAB. The test dataset contains 52 simulator and 52 megavoltage pelvis phantom images taken by Varian system at CancerCare Manitoba (CCMB). Each test image is taken at different position of the gantry; so we know the exact transformation parameters between the reference and test images used for determining errors.

As the first step, as discussed in Section 3, CLAHE and blurred circular mask were applied as preprocessing step.
The average error rates obtained for different rotation angles were 0.76 and 2.8 degrees on simulator and LINAC images, respectively. Translational errors were 1.07 and 1.57 pixels in the x and y direction for simulator images and 1.77 and 1.55 pixels on the x, and y axis for LINAC images. Some of the results are illustrated in Figures 4 and 5.

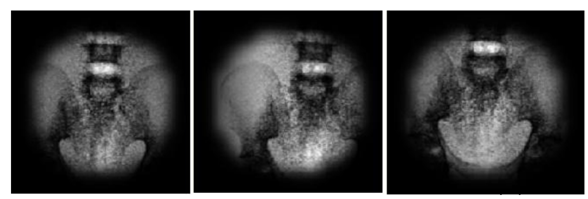


Reference Image Portal Image

**Recovered Parameters:**

Angle: -39.37 , Scale: 1, X translation: 1, Y translation: 1

Figure 4: Left: Errors on different angles, Right: Output of the system, the actual angle was -40 degrees



Reference Image Portal 1 Portal 2

**Recovered Parameters:** (6)

| Portal 1 | Portal 2 |
|---|---|
| Angle=0 | Angle=0 |
| Scale=1 | Scale=1 |
| X translation=29 | X translation=1 |
| Y translation=1 | Y translation=27 |

Figure 5- Left: Errors on different X-Y translations, Right: Output of the system for two sample, portal 1 has actual x translation of 28, and portal 2 has actual y translation of 24

### 4. CONCLUSION

This paper describes an image registration method designed to reduce patient positioning uncertainty during radiotherapy treatment. Although the registration method based on Fourier-Mellin properties and phase correlation has been presented previously, the results were mostly reported on one image and its scaled and rotated version. In this paper, we applied a method on simulator and mega voltage images and the results were reported.

For future work, determining out of plane rotation and developing local registration methods are planned.

## ACKNOWLEDGMENT

Financial supports from CanceCare Manitoba (CCMB) and Mathematics of Information Technology and Complex Systems (MITACS) is gratefully acknowledged.

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