

# Improving accuracy of markerless tracking of lung tumours in fluoroscopic video by incorporating diaphragm motion

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**Abstract.** Purpose: Conformal radiation of moving tumours is a challenging task in radiotherapy. Tumour motion induced by respiration can be visualized in fluoroscopic images recorded during patients breathing. Markerless methods making use of registration techniques can be used to estimate tumour motion. However, registration methods might fail when the tumour is hidden by ribs. Using motion of anatomical surrogates, like the diaphragm, is promising to model tumour motion. Methods: A sequence of 116 fluoroscopic images was analyzed and the tumour positions were manually defined by three experts. A block matching (BM) technique is used to calculate the displacement vector relatively to a selected reference image of the first breathing cycle. An enhanced method was developed: Positions, when the tumour is not located behind a rib, are taken as valid estimations of the tumour position. Furthermore, these valid estimations are used to establish a linear model of tumour position and diaphragm motion. For invalid estimations the calculated tumour positions are not taken into consideration, and instead the model is used to determine tumour motion. Results: Enhancing BM with a model of tumour motion from diaphragm motion improves the tracking accuracy when the tumour moves behind a rib. The error (mean  $\pm$  SD) in longitudinal dimension was  $2.0 \pm 1.5$  mm using only BM and  $1.0 \pm 1.1$  mm when the enhanced approach was used. Conclusion: The enhanced tracking technique is capable to improve tracking accuracy compared to BM in the case that the tumour is occluded by ribs.

## 1. Introduction

Precise lung tumor irradiation requires not only paying attention to interfractional position variations of the target but also gaining information about the target trajectory throughout the treatment. The 2D motion induced by respiration can be visualized with fluoroscopic images recorded during patients breathing. Since implanting fiducial markers is not widely accepted, we prefer a marker-less method making use of registration techniques to extract the tumor motion.

Directly tracking for tumor was assessed by a number of research articles coping with fluoroscopic images or 2D-plane MR images [1, 2].

The projective character of fluoroscopic images becomes apparent in the varying image intensities throughout a breathing cycle. Moreover a local structure, which is distinguishable in one image, may disappear in another image.



To overcome these intensity changes, we have developed an approach using multiple reference images to track for tumor motion in fluoroscopic video with present illumination changes [3]. The multiple template approach was first mentioned in terms of tumor tracking in fluoroscopic images by Cui *et al* [4].

Here, we present an alternative method to cope with these issues. It enhances the direct tracking method based on block matching by making use of the image information available in the rest of the image, e.g. when the tumor lies behind the rib. In this work, we track the tumor and an internal surrogate motion simultaneously. Whenever the tumor is hidden by another structure, we fall back to the surrogate tracking. This way the limitations of a direct tracking techniques can be compensated.

## 2. Methods

### 2.1. Fluoroscopic image data

A sequence of 116 fluoroscopic images of a single patient recorded during 10 breathing cycles from identical view angles was analyzed to determine the induced tumor motion. Distances of 1540 mm from the radiation source to flatpanel and 1000 mm from the radiation source to the isocenter were used. The pixel size was 0.8 mm x 0.8 mm on the panel with a matrix size of 512 x 512 pixels.

To generate ground truth data, the tumor positions were manually defined by one radiation oncologist and two computer scientists with experience in reading fluoroscopic images. The range of motion was 14-19 mm in superior-inferior (SI) direction. In this direction the averaged interobserver standard deviation was found to be around 0.8 mm. The motion in left-right (LR) direction was found to be only 0.8-1.6 mm. Since the averaged inter-observer standard deviation of the ground truth in LR direction was in the same range, results for the LR direction were discarded in this study.

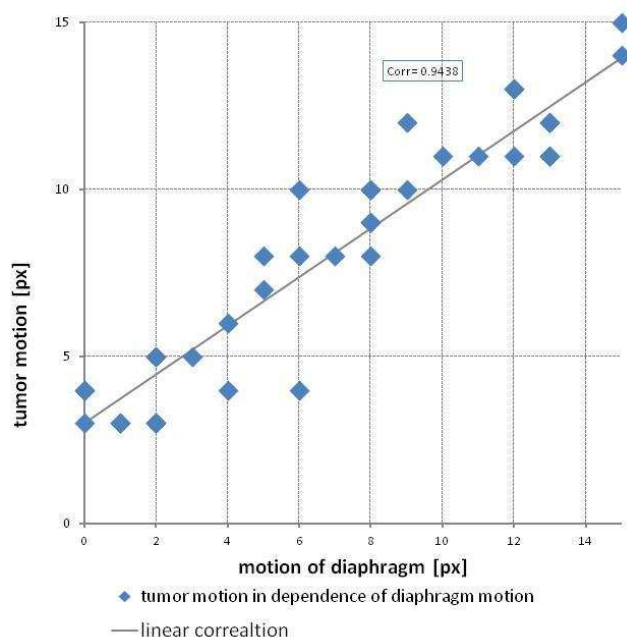
### 2.2. Direct tracking technique with block matching

The reference image for the direct tracking approach was selected out of the images recorded during the first exhalation. In this study, the selected reference image represents the position at maximum inhalation. To estimate the tumor motion, a block matching technique is used to calculate the motion vector relatively to the selected reference image. The tumor motion is assumed to be rigid. The region of interest (ROI) is limited to a rectangle that encompasses the whole tumor contour.

### 2.3. Diaphragm motion and linear correlation model

The diaphragm is sharp in contrast to the neighboring lung tissue and therefore is more visible in the fluoroscopic images than the tumor. Hence, the calculation of diaphragm motion supplies accurate results regardless of the respiratory phase. If there is a positive correlation between the movements of the tumor and diaphragm, the diaphragm can be used as an internal anatomic surrogate for the tumor. A linear correlation model between the tumor and the diaphragm motion is built to access the partial occlusion of the tumor with ribs (see Fig. 1).

First, a template matching for the tumor and the diaphragm is performed. A collision detection for the contour of the tumor and the static contours of the ribs, created manually from the first image of the sequence, determines whether the tumor is located behind a rib. If this is not the case, the tumor position is taken directly from the template matching. Additionally, the positions of the diaphragm and tumor are added to the data set for the linear correlation model. Otherwise, the calculated diaphragm movement is used to determine the tumor's position based on the established correlation model.



**Figure 1.** The estimated tumor positions based on direct tracking by use of a block matching technique- for the images without overlapping of tumor and ribs - show a positive correlation to the corresponding diaphragm movements.

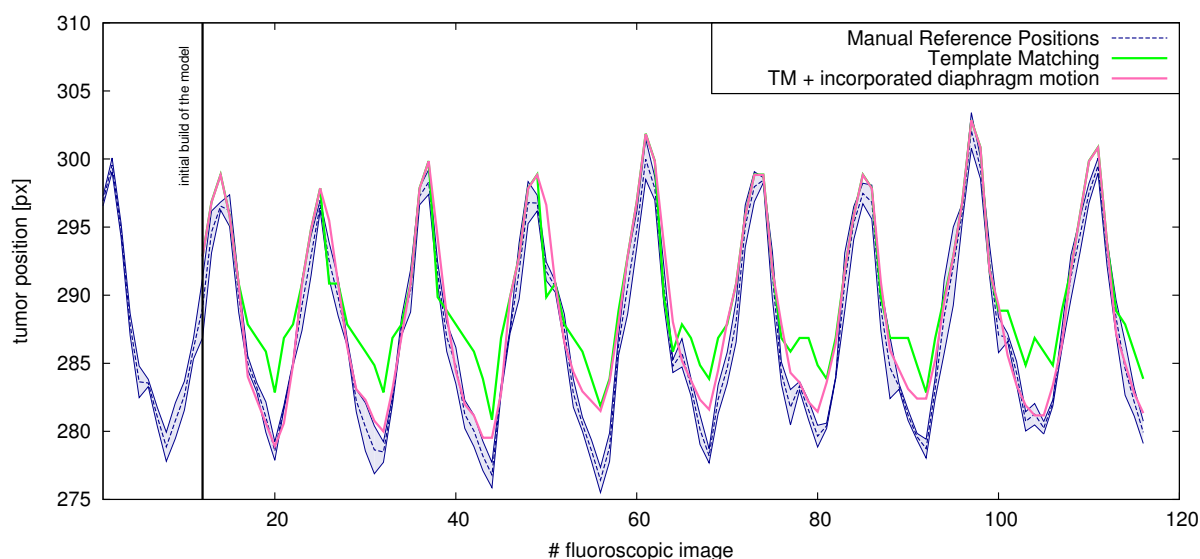
### 3. Results

The error (mean  $\pm$  SD) in longitudinal dimension was  $2.0 \pm 1.5$  mm ( $2.5 \pm 1.9$  pixels) using only BM and  $1.0 \pm 1.1$  ( $1.3 \pm 1.4$  pixels) when the enhanced approach was used. Regarding the interobserver variability of about 1 pixel in the ground truth data, the enhanced approach shows no significant difference in its error rate (see Fig. 2). The inter-observer variability is shown as a band surrounding the dotted blue line.

### 4. Conclusion

In difficult conditions, such as superposition of rib and tumor, advanced tracking techniques can contribute to a significant reduction of the tracking error. The described extension of the template matching technique permits coping with partial occlusions of the tumor by a rib. The incorporation of the modeling component improves the tracking result compared to direct estimation of the tumor's position by template matching.

The decision whether the tumor is located behind a rib is conducted by comparing the calculated position of the ribs and the estimated tumor position. As a preferred alternative, a threshold based on the correlation coefficient after matching could have been used to make the decision. The threshold method was successfully used by Cervino *et al* to determine, if contrasting structures in 2D MR sequences were moving away from the selected layer [2]. For the present data, a positive correlation between occlusion and change in the maximum correlation coefficient has been established. This knowledge will be incorporated into future work.



**Figure 2.** Realtime tracking algorithm based on cross correlation (green). Enhanced approach (direct tracking plus incorporated diaphragm motion) to cope with the situation when the tumor is hidden by a rib (pink). For comparison, the manually determined reference positions are plotted (dotted-blue).

## References

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