Retrospective analysis of lung tumor position prediction using MR image for x-ray image-guided adaptive radiotherapy

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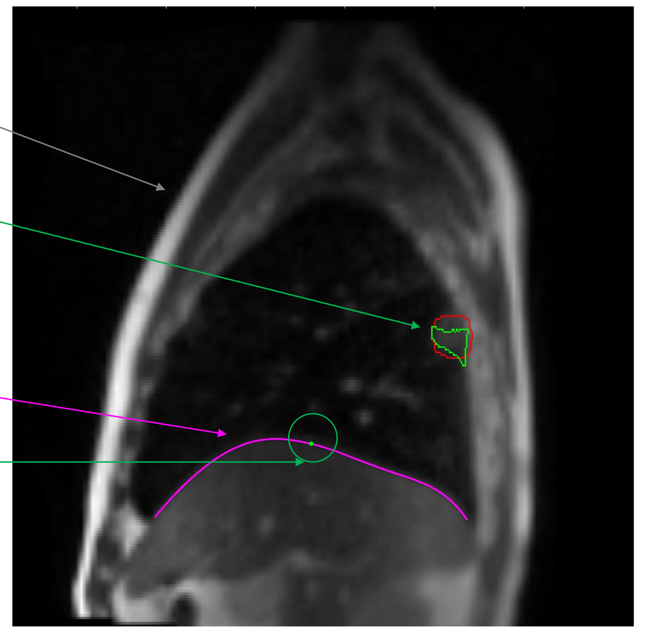
PURPOSE

- To provide improved tumor positional information from on-board x-ray images, we developed a statistical model to predict tumor motion from surrogates visible on x-ray imaging, for example diaphragm, from MR images acquired on an MRgRT system, which provide excellent soft tissue contrast and real-time tumor tracking.

METHOD

- Cine MRI was acquired during treatment for real time tumor tracking in the standard MRgRT clinical workflow. Auto-segmented target contours for tracking and gating were generated by the system on sagittal cine MRI images. In-house software was developed to generate surrogate contours on MR images using a template-based auto-segmentation method.

- Data provided from Viewray MRIdian :
  - **MRI images during treatment time**
  - Target Contour : the tumor contour generated from the system automatically
- User-defined data :
  - Contour for a Surrogate (Diaphragm)
    - Hand-drawing manually or automatically
    - A Point represented the contour



- Two approaches for modeling the correlation between the position of the tumor and surrogate were considered. The first approach utilized traditional regression analysis between the position of the tumor center and the dome of the diaphragm and linear regression was used to develop a simple linear model. A second approach used principle component analysis (PCA) to apply multiple input data sets, such as multiple time points or surrogates, for model generation and all diaphragm dome positions from a single fraction were used for PCA, including those that occurred in later cine MRI frames.

RESULTS

- In total 85,214 cine MRI images from 22 fractions for 3 lung cancer patients were analyzed retrospectively. These models were made fraction by fraction for the intrafractional motion prediction. These models were trained and tested using 70% and 30% of cine MRI images, respectively.

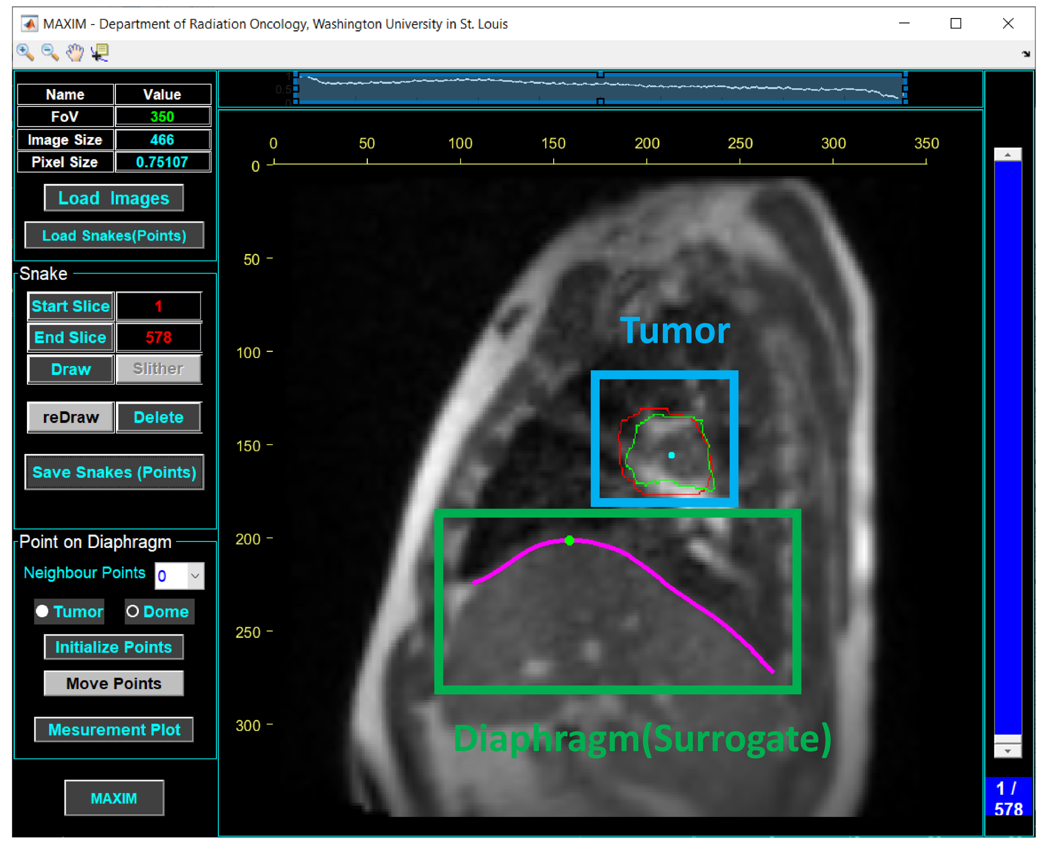


Figure 1. In-house software to draw the contour and extract the data in workflow

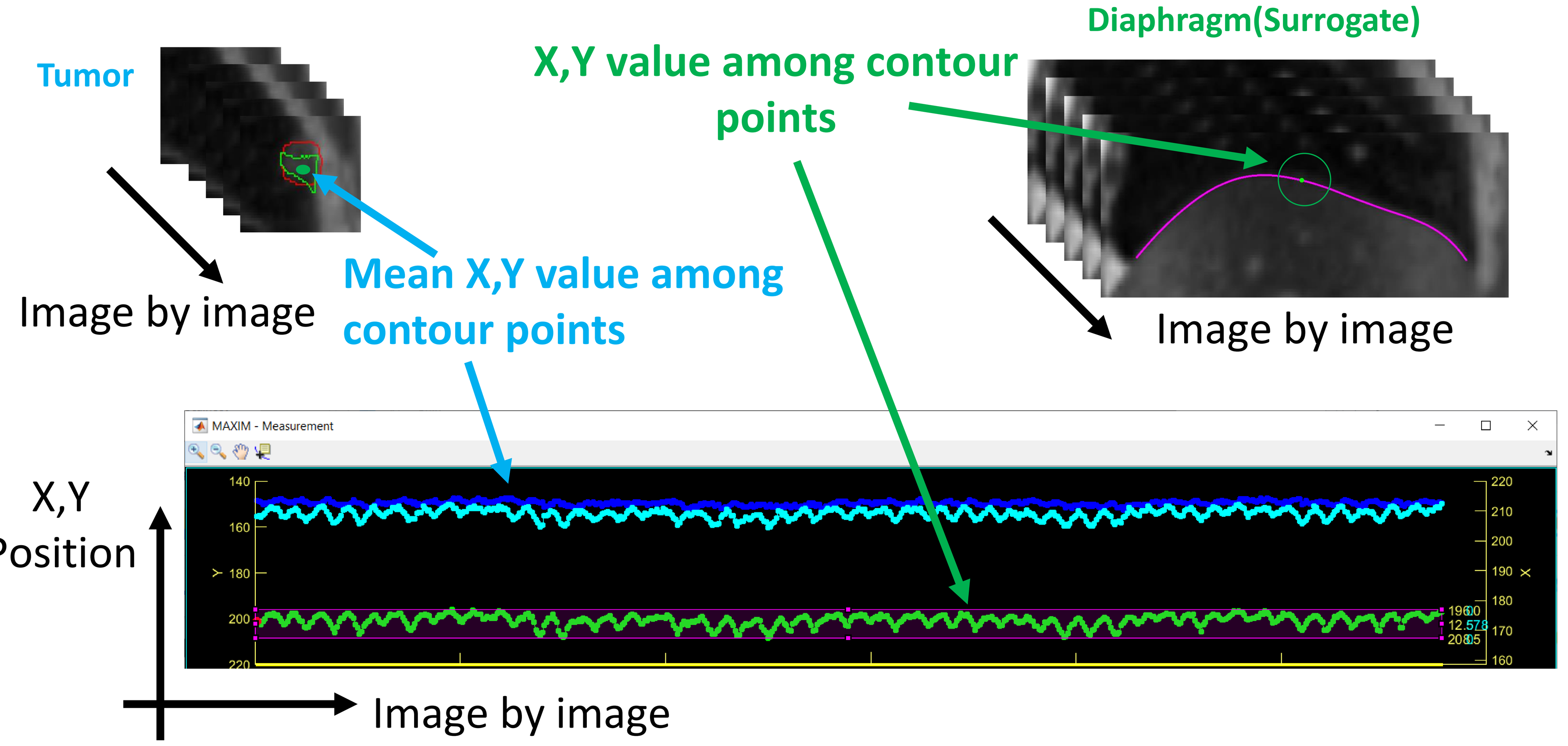


Table 1. Preliminary results about prediction models. The error was calculated fraction by fraction independently. The table show the maximum and mimimum average error among fractionss in same patient.

Case	N images	N fraction	OLS Max	OLS Min	PCA Max	PCA Min
#1	17347	7	2.49	1.11	1.51+-0.89	0.87+-0.42
#2	9738	5	2.36	1.87	1.54+-0.71	0.95+-0.47
#3	24230	10	1.73	1.1	1.35+-0.72	0.91+-0.53

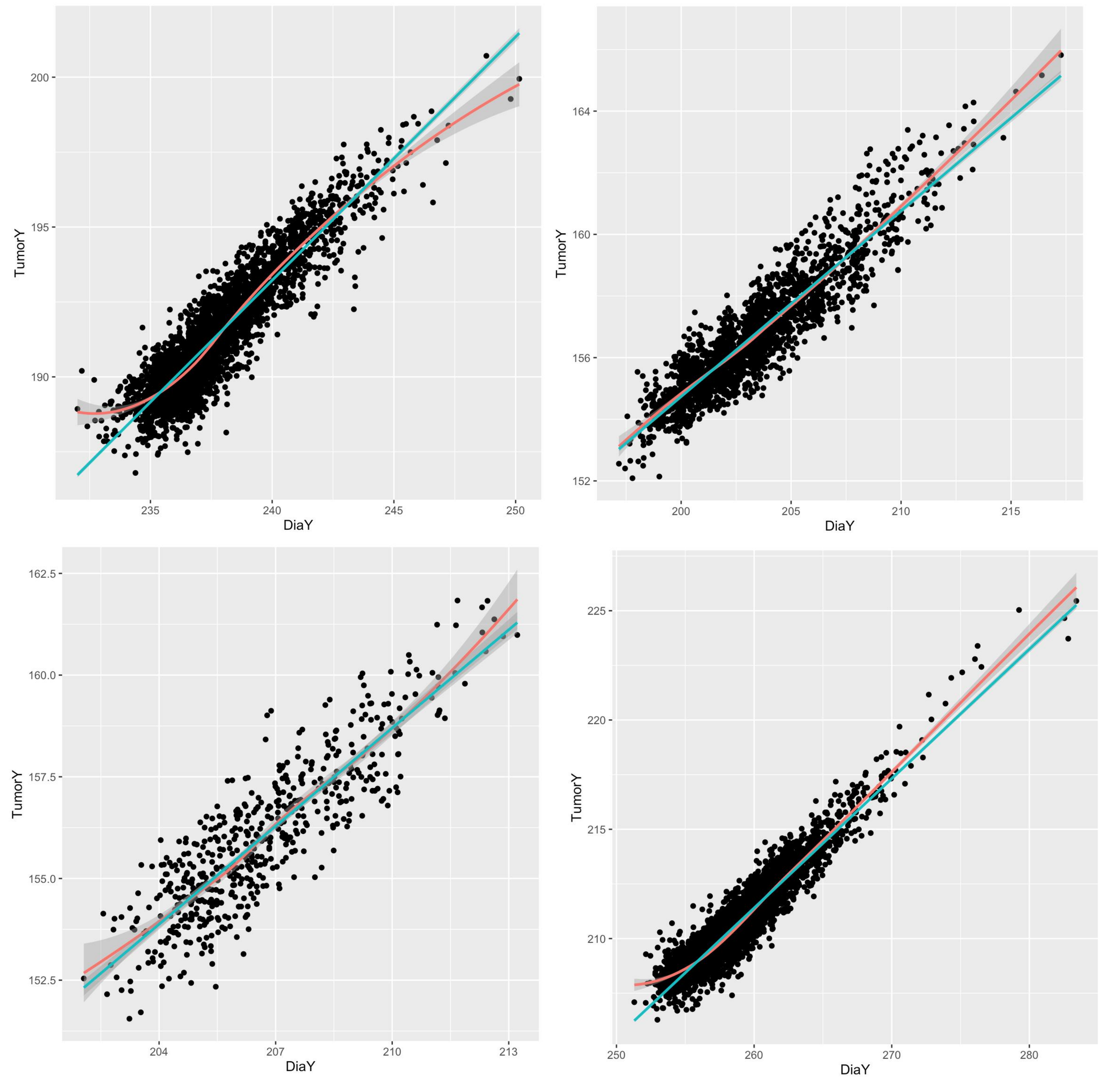


Figure 2. OLS model fitted on 4 fractions in case #1. The green line was OLS. The red line was non-linear model but was not addressed in this report.

The first approach, the traditional linear regression model utilizing ordinary least squares (OLS), predicted the y-position of the tumor center from the y-position of the diaphragm with a mean square error (MSE) of 1.73 mm in best case. The second model from PCA predicted the tumor center with the maximum average error of 1.35 mm with standard deviation 0.72 within each fraction. In our study, analysis focused on the motion of tumor and diaphragm in the superior-inferior direction due to negligible variation, within a subpixel of the image, in the anterior-posterior position of the tumor and diaphragm on sagittal images.

CONCLUSIONS

- We developed a model to predict tumor motion from an anatomical surrogate, visible on MR imaging, using sagittal cine MRI. In the preliminary result, the tumor motion can be predicted using a simple linear model within a couple of mm subpixel difference and accuracy can be further improved with a more complex modeling method. This study is still on-going to develop a more accurate model with an increased number of patients and the inclusion of additional imaging modalities, for example on-board x-ray imaging.

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