ICTR-PHE 2016

PROTON THERAPY CENTER

Proton radiotherapy at PTC Czech in Prague

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Repainting/triggering benefit

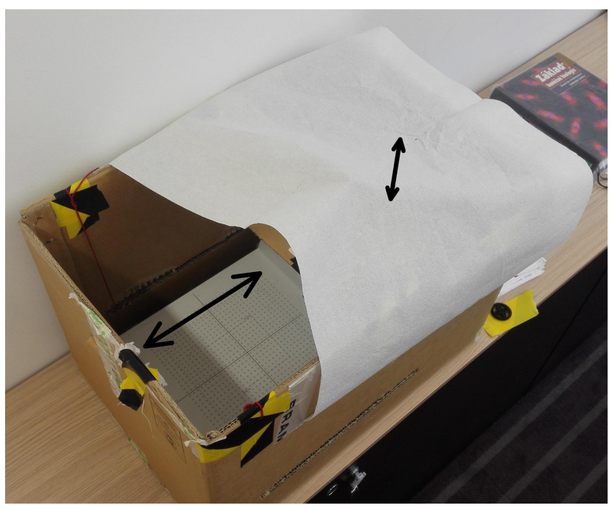


Figure 1: Experimental setup

Materials and Methods:
In this experiment an actual clinical treatment plan was used. A cartonbox phantom was constructed for simulation of internal and external body movement during breathing cycle. In this phantom a 2D detector with array of ionization chambers was wired in so it can move freely in one horizontal direction and simulate internal movement of the target. At the top of the phantom a rod was placed covered with a canvas to simulate superficial movement of human body. Both the detector and the rod were driven by Lego stepper motors programmed to mimic breathing cycle.
Above the array detector a tray was placed for insertion of RW3 plates in order to measure in various depths of the plan. For monitoring of superficial movement a system of stereoscopic cameras was used.

Repainting and beam triggering are techniques used for mitigate interplay effect observed during irradiation of moving target with scanned beam. In this experiment their combination was examined in order to determine ballance between preservation of dose delivery quality and increase of treatment time.

Beam triggering – the irradiation is on hold until the target returns within given spatial limits

Repainting – dose amount for each spot is delivered in multiple loops to prolong its delivery time and increase the probability of hitting intended part of the target. The paterns of loops are usually layer by layer scan or volumetric scan.

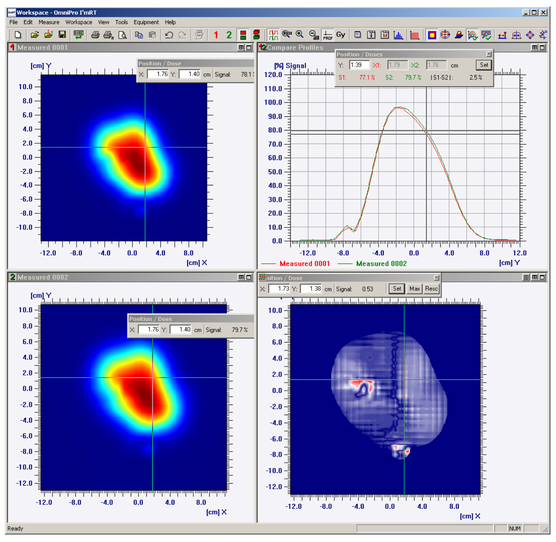


Figure 2 : Gamma Analysis evaluation

This system is able to evaluate change of surface position and geometry with frequency $14s^{-1}$ and is linked to treatment delivery console as an optional trigger.
From the original plan a copies containing various levels of repainting were prepared. Depth of the measurement was chosen in respect for selected plan to detect worst case scenario in dose distribution distortion.
As a reference a measurement with static detector was taken. Subsequent measurements were taken with moving detector and several combination tested techniques. For evaluation gamma analysis was used. Criteria of evaluation were 2% Dose difference and 2mm DTA or 1% and 1mm respectively.

Results:
From the cases summarized in Table 1 is obvious that a significant improvement in interplay effect suppression is achieved with use beam triggering only. The use of repainting only demonstrates gradual improvement of interplay effect reduction with increasing number of repaints as expected. This comes with reasonable time increase. Unfortunately this technique is limited to targets with mild excursion up to 1cm. Application of both techniques brings only little effect in comparison to triggering only case at the cost of substantial treatment time prolongation.

No of repaints	Trigering Yes/No	$Y_{2\ mm,\ 2\%}$ Y<1 [%]	Y<1,5 [%]	average	max	$Y_{1mm,\ 1\%}$ Y<1 [%]	Y<1,5 [%]	average	max	$t_{irradiation\ [s]}$
1	0	58.75	86.07	0.91	2	25.77	41.06	0.47	2	103
1	1	98.82	99.98	0.38	1.64	71.91	96.65	0.76	2	204
2	0	67.5	85.91	0.84	2	29.8	51.06	1.37	2	122
2	1	99.04	100	0.3	1.52	85.87	96.64	0.6	2	235
3	0	83.74	94.32	0.61	2	50.2	69.09	0.62	2	139
3	1	97.9	99.54	0.33	2	82.46	93.71	0.64	2	241
5	0	99.55	99.92	0.22	1.8	84.24	96.98	0.59	2	174
5	1	99.82	100	0.3	1.47	91.51	98.01	0.44	2	343
7	0	94.47	98.96	0.3	2	73.74	89.97	0.74	2	212
7	1	94.48	99.18	0.44	2	68.36	86.28	0.86	2	350

Table 1 : Results for combination of triggering and repainting technique

Diaphragm reliability

For patients with lesion in mediastinal region respiratory gating system is applied. Use of this system reduces patient setup and treatment delivery uncertainty. Focus of this study was to evaluate reproducibility of diaphragm position in breath hold state during treatment fraction.
If proved as reliable it might present a landmark for setup of lung lesions treatment.

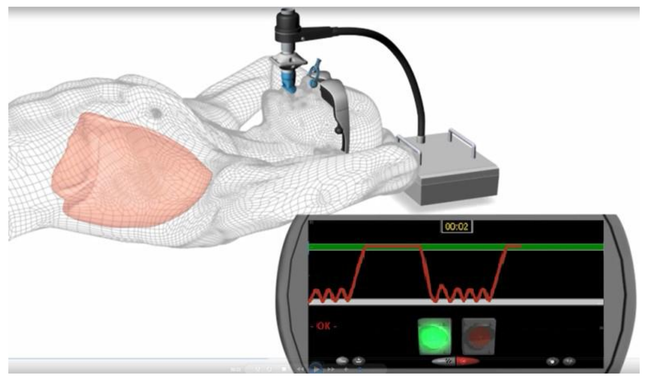


Figure 3 : X- ray imaging setup conditions

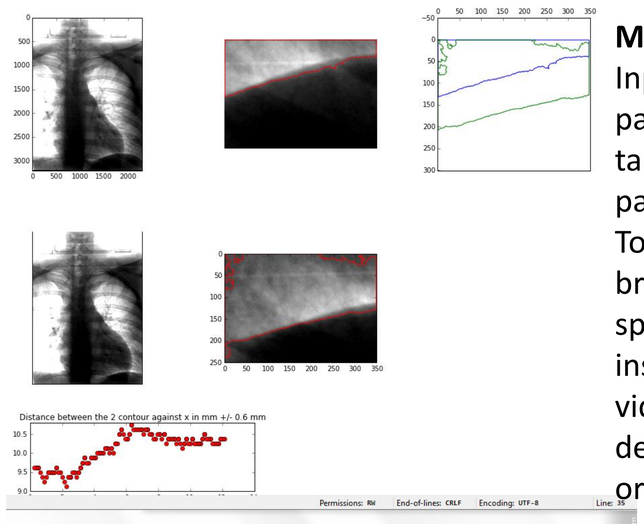
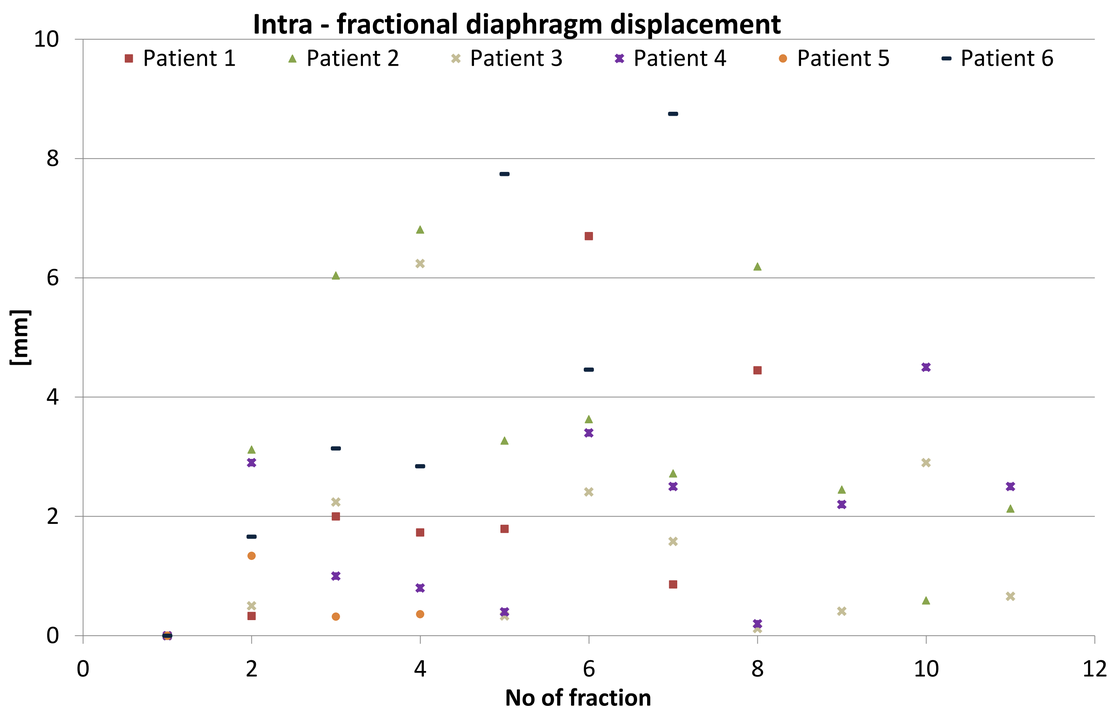


Figure 4: Script evaluation of diaphragm displacement

Materials and Methods:
Input for this study were X-images of patients in AP projection. Images are taken before and after the treatment of patient.
To take the image patient must be in breath hold state. This is achieved with spirometer which gives information about inspired volume to the patient through video googles. Once patient reaches the desired level of inspiration X-ray imaging or beam delivery is enabled.

A script in python was written to detect and calculate displacement of diaphragm before and after treatment. Functionalities from scientific python and ITKsnap were used. Otsu's method along with opening, closing and erosion were used to determine position of diaphragm. In case of image taken prior to the treatment the same correction vector was applied as it was for the patient. For each set of compared images a manual selection of ROI and thresholds for edge detector was performed in order to receive acceptable agreement between detected edge and diaphragm contour visible on image. Second aspect of parameters selection was effort to suppress excessive noise detection that would bias the result of displacement calculation. Difference for each pair of points from detected edges. The result value is average of horizontal component from previous step. Error of this method is 1mm.

Results:
For evaluation 6 patients were selected. Number of fraction recorded for each patient differ due unexpected events during treatment course of each patient. The images were evaluated off-line. These results served as an auxiliary evaluation of treatment quality. So far the set of data is too limited to draw distinct conclusions and needs to be further extended. On the other hand even in such limited set encouraging pattern can be observed if we assume a 5mm threshold as clinically acceptable criteria.



Graph 1 : Results for intra – fractional diaphragm displacement