

Application of Multiple Linear regression for Indirect Tracking of Functional Target for Respiratory Compensation in Radiotherapy

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Approaches

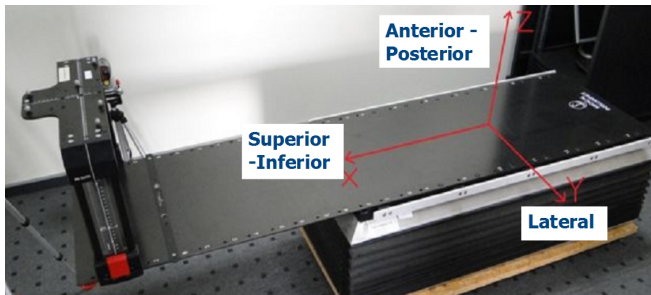
- ▶ Do nothing
- ▶ Gating
- ▶ Controlled-breath
- ▶ Probability-based planning (planning tumor volume)
- ▶ Displacing multi-leaf collimator (MLC)
- ▶ Changing configuration of MLC
- ▶ **Using patient support structure to compensate movement**

- ▶ 8 sets of 2D signals
- ▶ 3 surrogate markers per record
- ▶ 6-10 points-of-interest
- ▶ Duration: from 300 to 500 frames (150 - 400 sec.)
- ▶ Overall 87 signal-pairs

- ▶ We thank
 - ▶ Jonas Venius and his colleagues for help in collecting signals
 - ▶ Gabrielius Čaplinskas for extracting them from DICOMs

Motion directions

- ▶ 5 series: anterior-posterior and lateral directions.
- ▶ 3 series: anterior-posterior and superior-inferior directions.



- ▶ Signals transformation:

$$\tilde{x}_{ij} = x_{ij} - \min(x_{i1}, x_{i2}, \dots, x_{in})$$

$$\tilde{y}_{ij} = y_{ij} - \min(y_{i1}, y_{i2}, \dots, y_{in})$$

- ▶ Multiple linear regression:

$$y_i = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n$$

Loss function

- ▶ Mean absolute error:

$$MAE = \frac{\sum_{i=1}^n \sqrt{(\hat{x}_i^t - x_i^t)^2 + (\hat{y}_i^t - y_i^t)^2}}{n}.$$

- ▶ Root mean square error:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (\hat{x}_i^t - x_i^t)^2 + (\hat{y}_i^t - y_i^t)^2}{n}}.$$

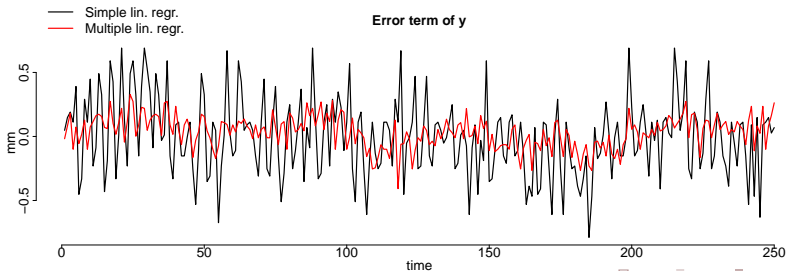
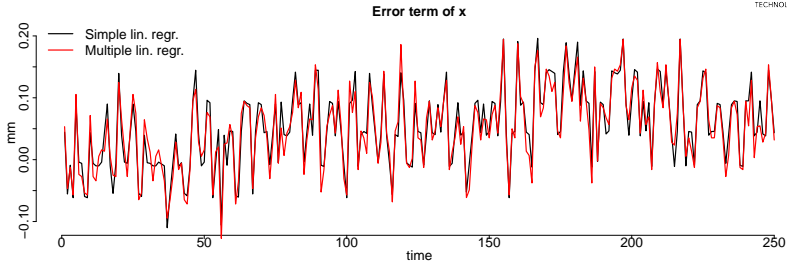
$t_i = (x_i^t, y_i^t)$ - true position of the tumor at time i

$\hat{t}_i = (\hat{x}_i^t, \hat{y}_i^t)$ - prediction at time i

Results

Model	Simple linear regression						Multiple linear regression					
	MAE, mm	RMSE, mm	p-value		R^2_{adj}		MAE, mm	RMSE, mm	p-value		R^2_{adj}	
			x	y	x	y			x	y	x	y
P3~P0	0.28	0.32	0.4	0.01	0.81	0.88	0.15	0.17	0.49	0.18	0.86	0.98
P3~P1	0.72	0.79	0	0.06	0.69	0.71	0.22	0.26	0	0	0.7	0.91
P3~P2	0.73	0.8	0.32	0.05	0.78	0.52	0.39	0.47	0.28	0	0.79	0.76
P4~P0	0.39	0.43	0.28	0.02	0.37	0.57	0.24	0.27	0.98	0	0.58	0.89
P4~P1	0.53	0.57	0.22	0.02	0.32	0.52	0.33	0.37	0.24	0	0.33	0.72
P4~P2	0.51	0.55	0.66	0.02	0.49	0.63	0.29	0.34	0.7	0	0.49	0.77
P6~P0	0.26	0.31	0	0.01	0.94	0.87	0.13	0.15	0	0	0.94	0.98
P6~P1	0.76	0.84	0	0.05	0.91	0.75	0.21	0.25	0	0	0.91	0.9
P6~P2	0.77	0.86	0	0.04	0.77	0.51	0.41	0.51	0.01	0	0.77	0.74
P7~P0	0.26	0.29	0.75	0.25	0.7	0.88	0.17	0.2	0.96	0	0.72	0.95
P7~P1	0.67	0.74	0.81	0.06	0.66	0.77	0.24	0.27	0.77	0	0.66	0.85
P7~P2	0.68	0.75	0.96	0.05	0.47	0.61	0.4	0.47	0.93	0	0.47	0.7

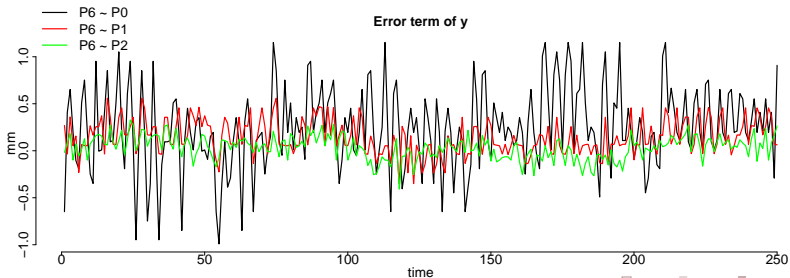
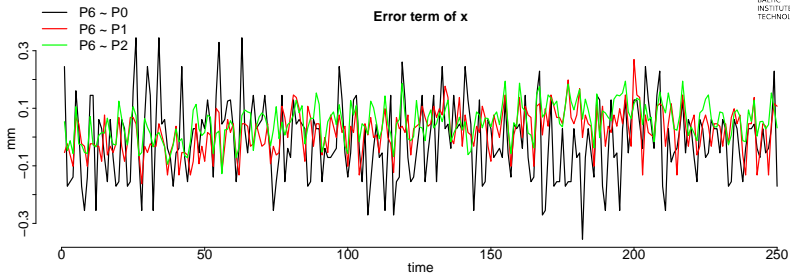
Simple vs Multiple linear regression (relation $P6 \sim P0$)



Position of external marker (relations $P6 \sim P0, P1, P2$)

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Results (overall models)

	Simple linear regression		Multiple linear regression	
	MAE, mm	RMSE, mm	MAE, mm	RMSE, mm
Average	1.069	1.245	0.81	0.958
Min	0.26	0.29	0.13	0.15
Max	3.44	4.01	3.35	4.05

Results and Conclusions

- ▶ Multiple linear regression model:
 - ▶ increases testing accuracy
 - ▶ improves the values of R_{adj}^2
 - ▶ regression residuals are autocorrelated
- ▶ Better results are obtained using markers with a greater range of movement and
 - ▶ middle abdomen if lateral direction is ignored
 - ▶ otherwise upper abdomen

Future Plans

- ▶ Experiments with more complex regression cases
- ▶ Perform experiments
 - ▶ using only one coordinate with the largest amplitude
 - ▶ using coordinates of different external markers
- ▶ **Analyze respiratory motion prediction and design cases of an overall radiation therapy system with respiratory motion compensation**
 - ▶ We already have some results in predicting respiratory motion
 - ▶ More results in relating external markers and targets

THANKS