

# Investigation of Relation Between Internal-External Markers for Respiratory Motion Compensation in Radiotherapy

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# Previous work

- ▶ Simple linear regression
- ▶ Linear regression with AR(1) errors
- ▶ Multiple linear regression

# Approaches:

A Use external marker with the largest amplitude:

$$\begin{aligned}x^t &= \hat{\beta}_0^x + \hat{\beta}_1^x z^m \\y^t &= \hat{\beta}_0^y + \hat{\beta}_1^y z^m \\z &= \operatorname{argmax}(sd(x^m), sd(y^m))\end{aligned}\tag{1}$$

B Use all external markers:

$$\begin{aligned}x^t &= \hat{\beta}_0^x + \hat{\beta}_1^x x^{m1} + \hat{\beta}_2^x x^{m2} + \hat{\beta}_3^x x^{m3} \\y^t &= \hat{\beta}_0^y + \hat{\beta}_1^y y^{m1} + \hat{\beta}_2^y y^{m2} + \hat{\beta}_3^y y^{m3}\end{aligned}$$

# 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  $i$

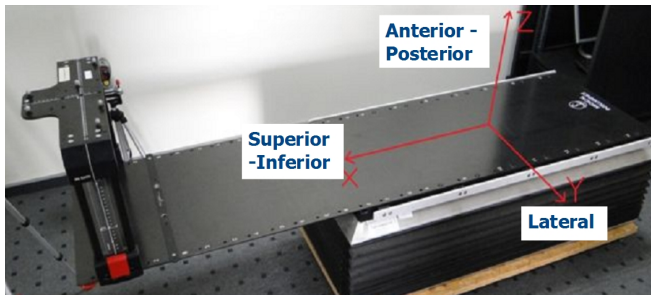
$\hat{t}_i = (\hat{x}_i^t, \hat{y}_i^t)$  - prediction at time  $i$

# Signals

- ▶ 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

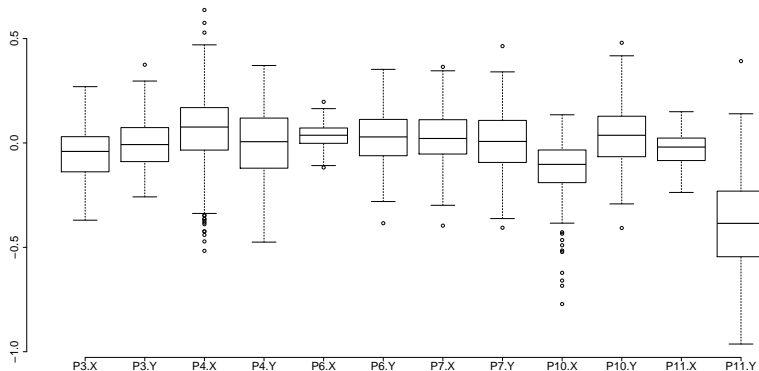
- ▶ 5 series: anterior-posterior and lateral directions.
- ▶ 3 series: anterior-posterior and superior-inferior directions.



# Results (overall models)

	Scheme A		Scheme B		Simple lin. regr.		Multiple lin. regr.	
	MAE, mm	RMSE, mm	MAE, mm	RMSE, mm	MAE, mm	RMSE, mm	MAE, mm	RMSE, mm
Avg.	0.83	0.99	0.65	0.77	1.07	1.25	0.81	0.96
Min	0.14	0.15	0.13	0.15	0.26	0.29	0.13	0.15
Max	3.07	3.5	2.38	2.82	3.44	4.01	3.35	4.05

# Results (scheme B)





# Results and Conclusions

- ▶ Proposed approaches improve the accuracy of forecasting
- ▶ Scheme B is the most suitable in this context
- ▶ Accuracy of the future predictions increases relative to the amount of information we provide about the external markers
- ▶ Better results are obtained using external markers:
  - ▶ with a greater range of movement
  - ▶ placed in abdomen area

## **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
  - ▶ Time series models
  - ▶ Artificial neural network

# THANKS