Texture-Model-based Real-Time Tracking with Planar Image Data

PARACELSUS MEDIZINISCHE PRIVATUNIVERSITÄT

MSMI – Methods of Statistical Modeling in medical Imaging

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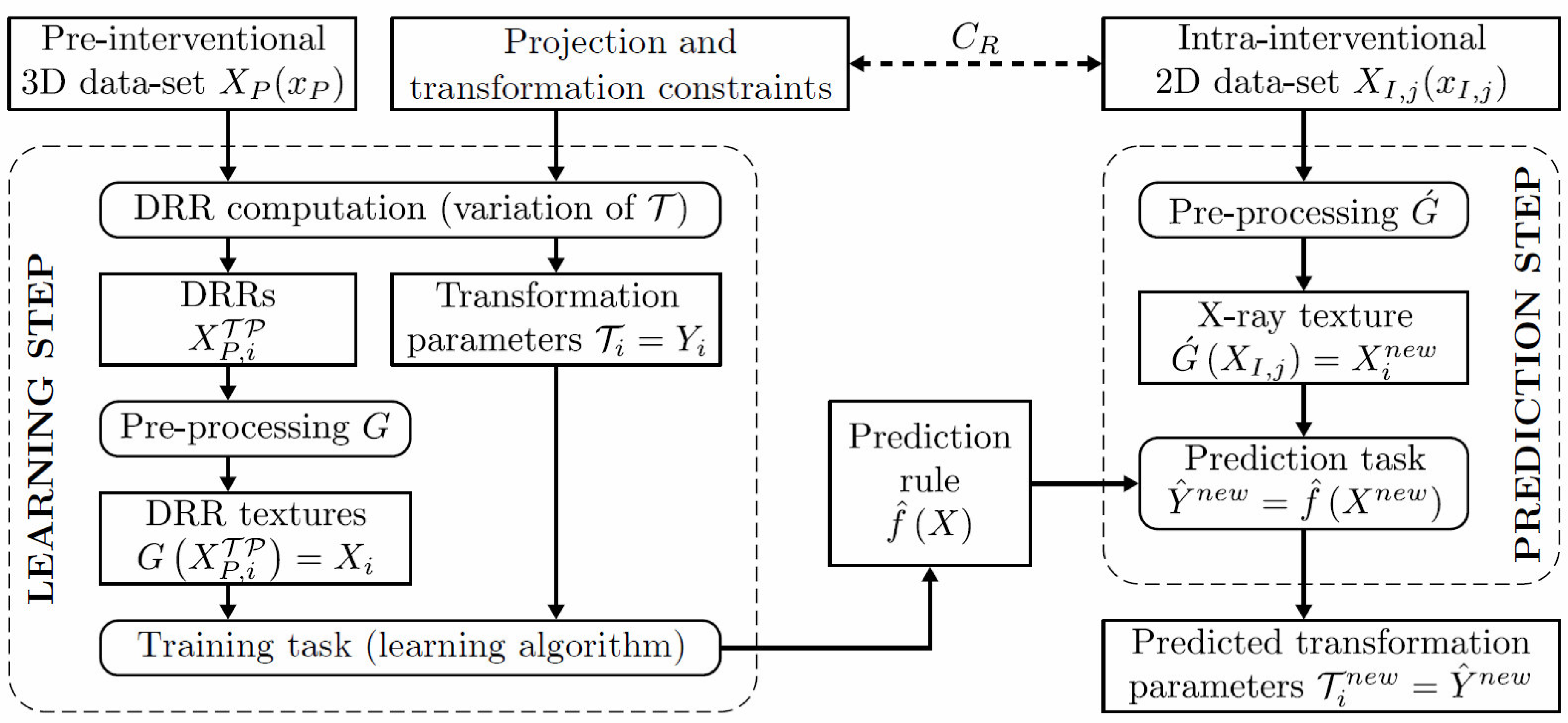
Motivation

In almost all image-guided medical interventions the **spatial alignment of pre- and intra-interventional image data** plays a central role. For example in image-guided radiotherapy (IGRT) the planned patient setup must be verified right before and during beam delivery in order to guarantee an efficient treatment and to avoid adverse effects.

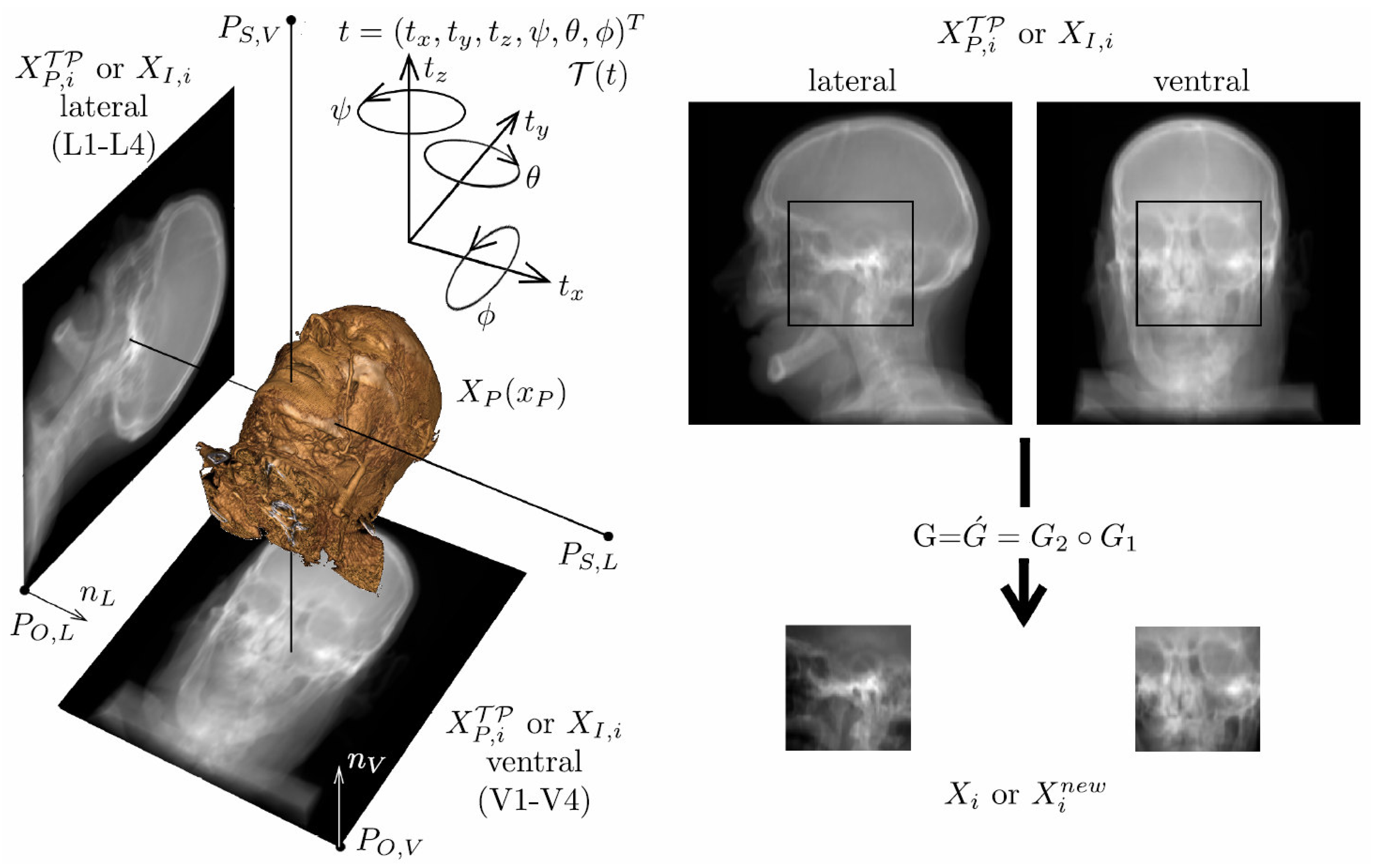
Methods: Texture Model Registration (TMR)

We propose a novel framework for image registration of 3D pre-interventional data (e.g. CT) with online 2D intra-interventional images (e.g. X-rays). In contrast to traditional approaches, **Texture Model Registration (TMR)** is based on supervised machine learning and yields a quasi-analytical solution thereby eliminating the necessity of iterative numerical optimization.

WORKFLOW



- The registration task is split into an offline **learning step** and an online **prediction step**.
- **LEARNING STEP**
  - Random transformations T_i (translations, rotations) are sampled and utilized for generating digitally reconstructed radiographs (DRRs) $X^{TP}_{P,i}$
  - Subsequently characteristic textures X_i are extracted from the DRRs using feature-, intensity- or gradient-based pre-processing operations G
  - Machine learning techniques such as principal component regression (PCR) construct a prediction rule f which is able to predict T_i from X_i
- **PREDICTION STEP**
  - Transformations T_i^{new} of unseen images $X_{I,j}$ are predicted by simply applying pre-processing operations G' and passing X_i^{new} to prediction rule f



Experimental Results

Using PCR for machine learning and simple pre-processing operations which consisted of cropping (G_2) and intensity rescaling (G_1) a first so-called **TMR-PCR** pipeline was established. The implementation was tested on a clinical 3D CT head and neck data set and 8000 synthetic X-rays from lateral and ventral views taking initial mean target registration errors (mTREs) of up to 30 mm into account.

ID	Prediction Par. Measures (MSE)						Registration Measures			
	t_x mm^2	t_y mm^2	t_z mm^2	ψ $^{\circ 2}$	θ $^{\circ 2}$	ϕ $^{\circ 2}$	$\overline{mTRE}$ mm	$mTRE_{0.9}$ mm	$mTRE_{0.95}$ mm	$mTRE_{max}$ mm
L1	0.498	0.003	0.001	-	-	-	0.377	0.797	1.113	11.882
L2	-	0.168	0.116	1.106	-	-	0.709	1.384	1.867	4.570
L3	-	0.217	0.141	0.668	4.383	5.185	2.052	3.571	4.339	9.208
L4	-	0.001	0.001	-	-	-	0.019	0.033	0.050	0.555
V1	0.002	0.003	1.260	-	-	-	0.657	1.540	2.193	8.548
V2	0.058	4.358	-	5.814	-	-	1.976	3.805	5.015	16.185
V3	0.443	2.583	-	1.453	2.309	1.651	1.995	3.370	4.232	16.432
V4	0.000	0.001	-	-	-	-	0.017	0.031	0.046	0.350

Conclusion

Preliminary results show that the performance of our first tangible TMR-PCR implementation is comparable to the registration accuracy of traditional approaches. Furthermore we demonstrated that our approach is able to register images with 49 Hz on average (real-time). However, in order to enhance the accuracy and to cope with increasing nonlinearities caused by rotational transformations alternative machine learning techniques (e.g. kernel PCA) and pre-processing strategies must be investigated.

Further Reading

Steininger, P., Neuner, M., Fritscher, K., Sedlmayer, F., Deutschmann, H.: A Novel Class Of Machine-Learning-driven Real-Time 2D/3D Tracking Methods: Texture Model Registration (TMR). Medical Image Computing and Computer-Assisted Intervention, Lecture Notes on Computer Vision, Springer Berlin Heidelberg (2010). [submitted]

We thank the **Paracelsus Medical University** for their support in the course of **PMU-FFF grant R-09/03/004-STE**.

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