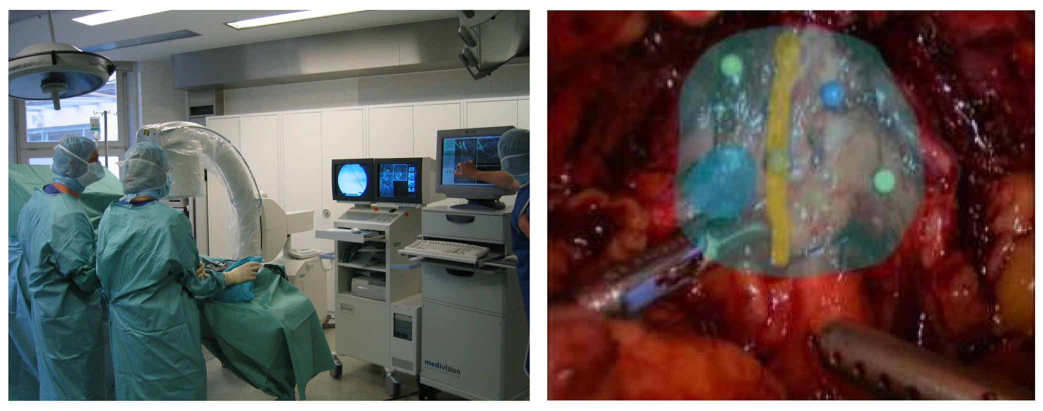
Uncertainty-aware Information Fusion for Real-time Motion Estimation in Intervention Navigation and Interaction

Kocev B., Linsen L., Hahn H. K.

Fraunhofer MEVIS

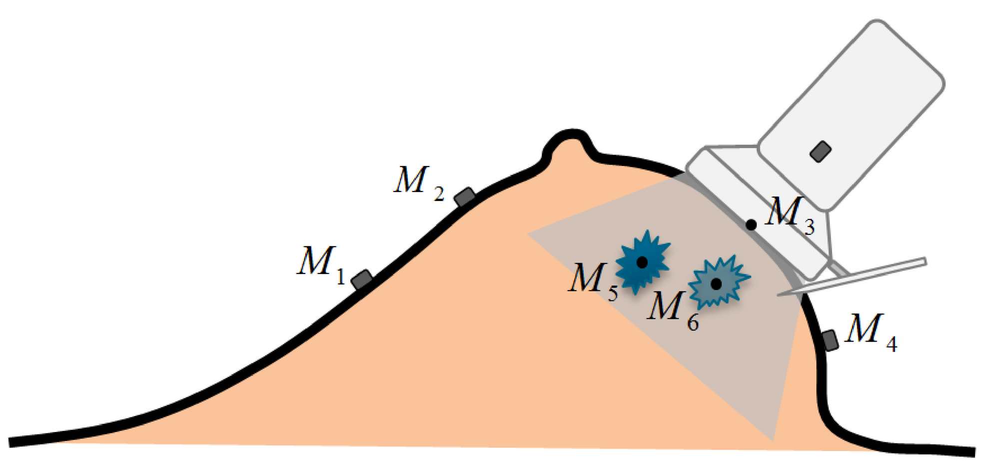
Motivation



(left to right) Intraoperative navigation system of Medivision; Navigated laparoscopic radical prostatectomy by Meinzer et. al.

The intra-operative use of smart information processing and interactive visualization systems is facing obstacles in terms of intervention navigation and interaction therewith. There are *inaccuracies in the registration* of the navigation information on the deformable soft-tissue organ, mainly due to a rigid registration or erroneous real-time soft-tissue motion tracking. Furthermore, there is *an increase in the cognitive load* of the intervention specialist during the transfer of the navigation information to the intervention situs, because the *navigation system is usually placed far away* from the specialist.

Soft-tissue Motion Tracking



To track the deformations of the breast surface, we attached small electromagnetic sensors. For tracking the breast interior soft-tissue deformations, we employed a real-time ultrasound imaging device (localized in the electromagnetic tracking space). The ultrasound device captures the interior of the breast by acquiring 2D images, which reveal distinctive soft-tissue structures. These structures are tracked in real time by a digital image correlation algorithm (based on Isard et al. [4]). The $\mathbf{M_i}$ points above, constitute the set of measurement points.

References

[1] Kocev B., Ojdanic D., and Peitgen H.O.: An approach for projector-based surgeon-computer interaction using tracked instruments. In: Proc. of GI Workshop: Emerging Technologies for Medical Diagnosis and Therapy, 2011.

[2] Kocev B., Ritter F., and Linsen L.: Projector-based Surgeon-computer Interaction on Deformable Surfaces. International Journal of Computer Assisted Radiology and Surgery, pages 1-12, 2013.

[3] Burrus N.: Rgbdemo 0.7.0. http://labs.manctl.com/rgbdemo/

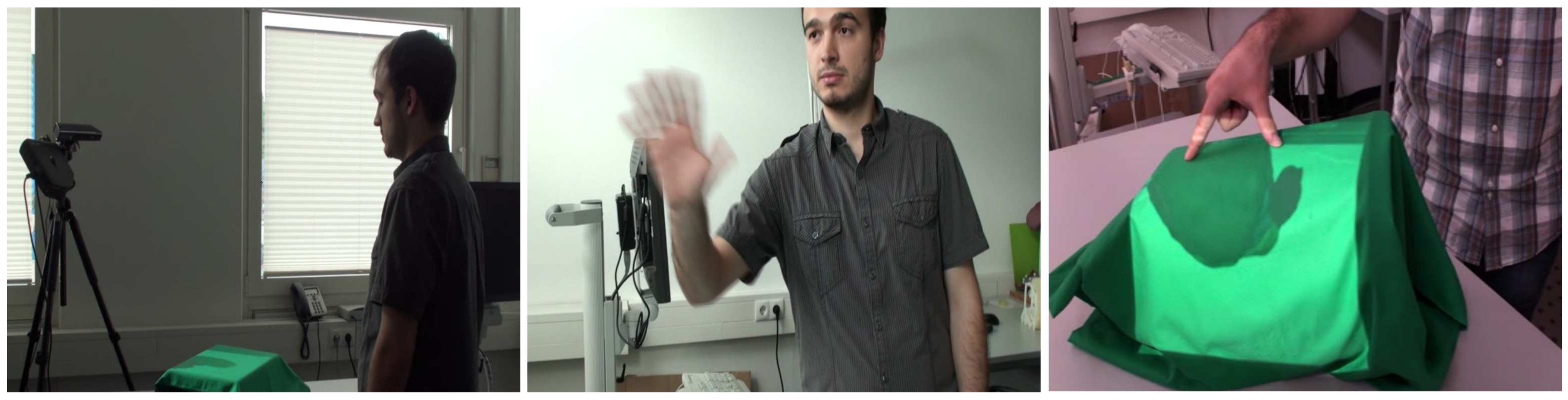
[4] Isard M., Blake A.: Condensation-conditional density propagation for visual tracking. International journal of computer vision 29, 1 (1998), 5-28. 3

[5] Georgii J.: Real-time simulation and visualization of deformable objects. GRIN Verlag, 2008. 4

Acknowledgements

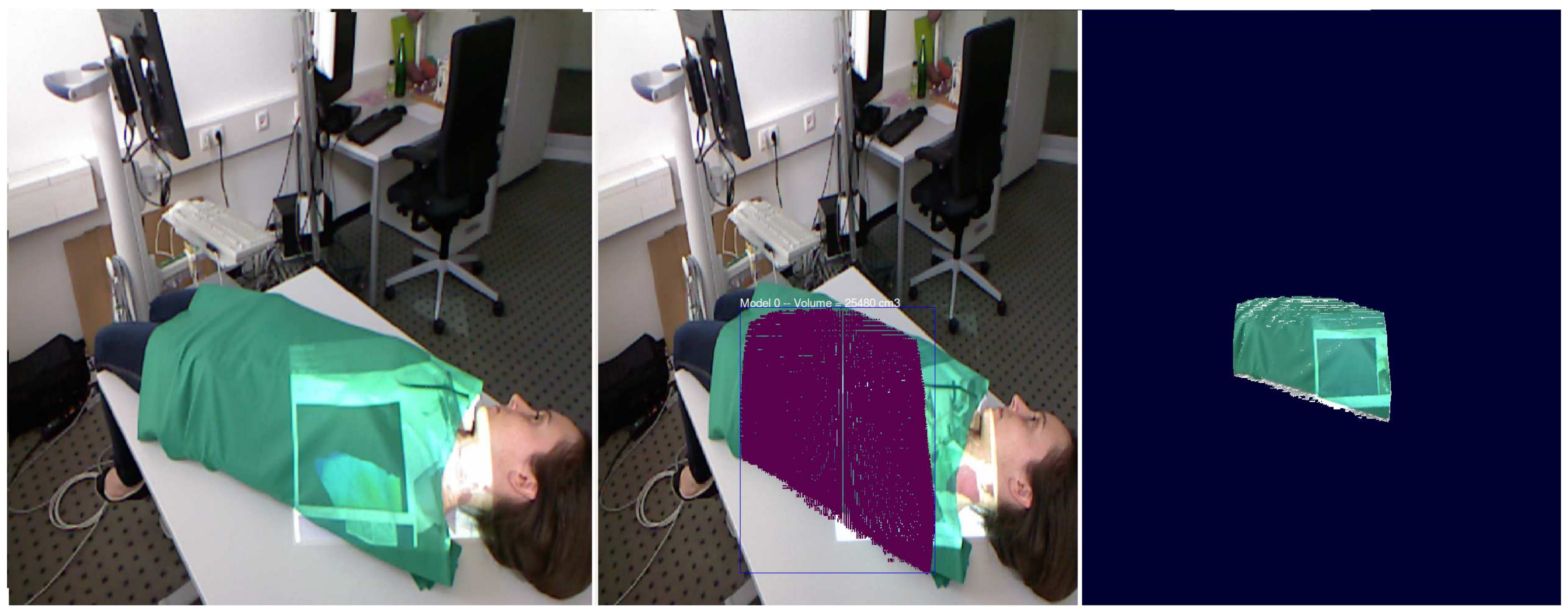
We thank Dr. Joachim Georgii for his guidance on the deformation modeling aspects. We also thank the Fraunhofer society, under the project MARIUS (Magnetic Resonance Imaging Using Ultrasound), for providing financial support on some aspects of the presented work.

Projector-based soft-tissue navigation and interaction



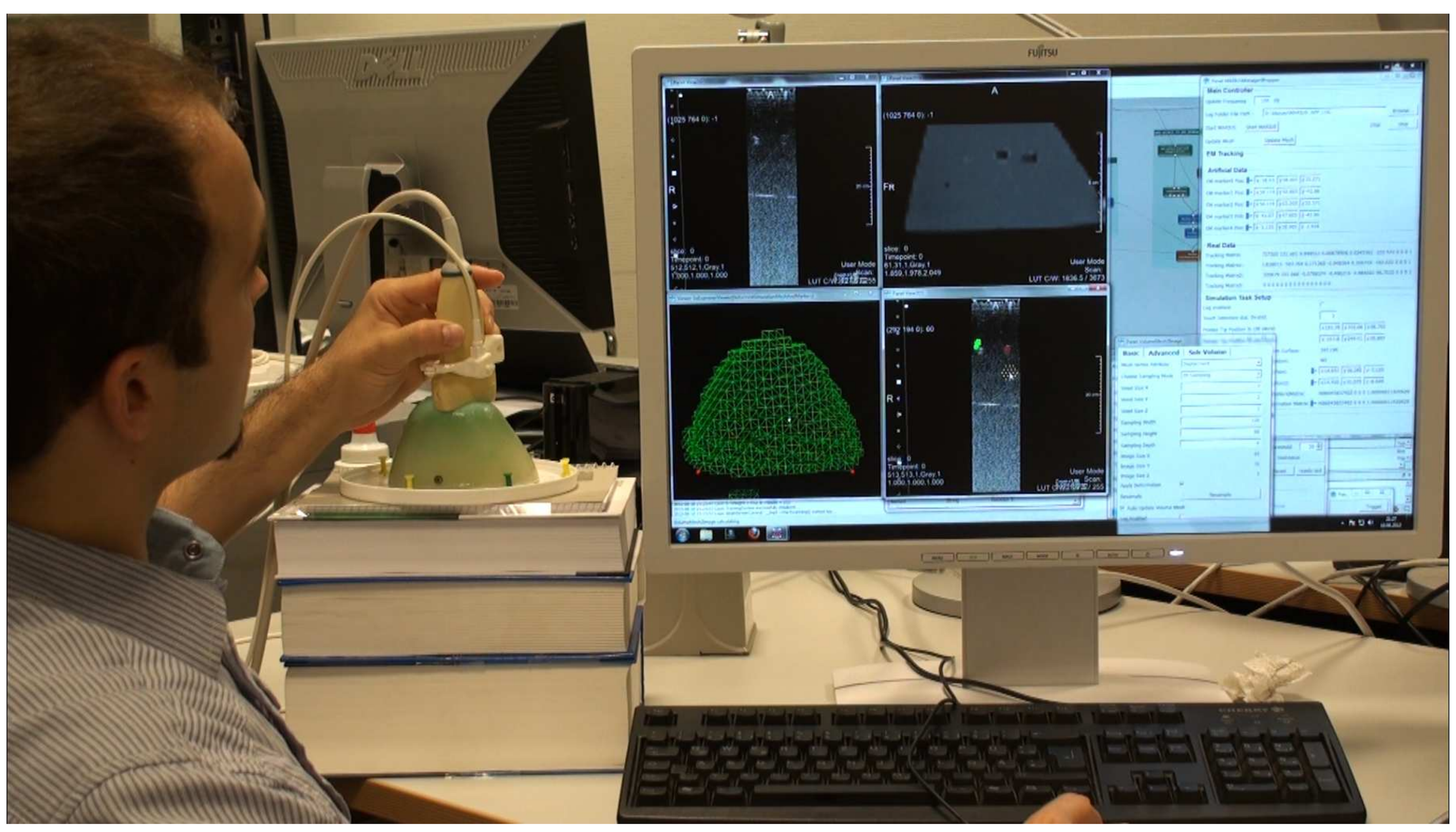
Projector-based soft-tissue navigation and surgeon-computer natural interaction mechanisms [1, 2] are very promising in circumventing the obstacles in the transfer of the virtual navigation information and in the interaction therewith. *However, the overall acceptance of the navigation systems as beneficial for the intra-operative medical interventions is still confronting big challenges, mainly due to the uncertainties in the registration of the navigation information on the deformable soft-tissue organ.*

Kinect-based Deformable Surface Tracking



A Microsoft Kinect camera is used to capture the deformations of the surface over time. The retrieved 3D point cloud is processed using the Point Cloud Library to create a 3D virtual model of the interaction zone. This figure shows the computation of the interaction zone for a set-up, where the virtual information is projected onto the cloth covering a person (simulating the set-up in an operating room). The surface can have any shape, and it can deform over time. (This image was created using the viewers in RGBDemo [3]).

Information Fusion for Real-time Motion Estimation



We are devising an intelligent and uncertainty-aware information fusion engine for real-time motion estimation of a given soft-tissue instance. The tracked instance is represented in a discrete fashion, while its motion state at a discrete time k is directly defined by the positions of the points which constitute its discrete representation. The engine fuses, at the state points, three uncertain information sources: motion dynamics, motion measurements, and shape information. The motion dynamics modeling is embedded in a finite element-based model [5], which is used to simulate in real time the prediction of the motion which the tracked instance undergoes from time *k-1* to *k*. Furthermore, the finite element-based model is actually extracted from a segmented volumetric scan of the tracked instance, which in return embeds the shape information source into the finite element-based motion prediction. The motion measurements information source is composed of real-time surface and volumetric tracking data. The virtual navigation information (e.g., a prior diagnostic MRI) is always updated in real time according to the output of our fusion engine, such that it reflects the estimated current shape of the tracked instance.