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Contents

- vii *Conference Committee*
- ix *Registration of patch optical and MRI or CT imagery for real-time 3D organ tracking, [7533-41] (Abstract Only)*
D. Wang, A. H. Tewfik, Univ. of Minnesota (United States)

IMAGE ANALYSIS

- 7533 02 **A regions of confidence based approach to enhance segmentation with shape priors** [7533-20]
V. V. Appia, B. Ganapathy, Georgia Institute of Technology (United States); A. Abufadel, Khoury Group (United States); A. Yezzi, Georgia Institute of Technology (United States); T. Faber, Emory Univ. (United States)
- 7533 03 **Human pose tracking from monocular video by traversing an image motion mapped body pose manifold** [7533-02]
S. Basu, Univ. of Virginia (United States); J. Poulin, Hanscom Air Force Base (United States); S. T. Acton, Univ. of Virginia (United States)
- 7533 04 **Semi-automatic object geometry estimation for image personalization** [7533-03]
H. Ding, Purdue Univ. (United States); R. Bala, Z. Fan, R. Eschbach, Xerox Corp. (United States); C. A. Bouman, J. P. Allebach, Purdue Univ. (United States)
- 7533 05 **A method for recognizing the shape of a Gaussian mixture from a sparse sample set** [7533-04]
H. J. Santos-Villalobos, M. Boutin, Purdue Univ. (United States)
- 7533 06 **Extraction of arbitrarily-shaped objects using stochastic multiple birth-and-death dynamics and active contours** [7533-05]
M. S. Kulikova, I. H. Jermyn, X. Descombes, EPI Ariana, CR INRIA Sophia Antipolis Méditerranée (France); E. Zhizhina, Institute of Information Transmission Problems (Russian Federation); J. Zerubia, EPI Ariana, CR INRIA Sophia Antipolis Méditerranée (France)

REMOTE SENSING I

- 7533 07 **Symmetrized local co-registration optimization for anomalous change detection** [7533-06]
B. Wohlberg, J. Theiler, Los Alamos National Lab. (United States)
- 7533 08 **High resolution SAR-image classification by Markov random fields and finite mixtures** [7533-07]
G. Moser, Univ. of Genova (Italy); V. Krylov, Lomonosov Moscow State Univ. (Russian Federation) and EPI Ariana, CR INRIA Sophia Antipolis Méditerranée (France); S. B. Serpico, Univ. of Genova (Italy); J. Zerubia, EPI Ariana, CR INRIA Sophia Antipolis Méditerranée (France)

- 7533 09 **Randomized group testing for acoustic source localization** [7533-08]
W. Mantzel, J. Romberg, K. Sabra, Georgia Institute of Technology (United States)

REMOTE SENSING II

- 7533 0B **Blind deconvolution of depth-of-field limited full-field lidar data by determination of focal parameters** [7533-10]
J. P. Godbaz, M. J. Cree, A. A. Dorrington, Univ. of Waikato (New Zealand)

BIOMEDICAL IMAGING I

- 7533 0D **Compressive inverse scattering using ultrashort pulses** [7533-13]
K. H. Jin, K. Lee, J. Ahn, J. C. Ye, Korea Advanced Institute of Science and Technology (Korea, Republic of)
- 7533 0E **Implementation and evaluation of a penalized alternating minimization algorithm for computational DIC microscopy** [7533-14]
C. Preza, The Univ. of Memphis (United States); J. A. O'Sullivan, Washington Univ. in St. Louis (United States)
- 7533 0F **Virtual surgical modification for planning tetralogy of Fallot repair** [7533-15]
J. Plasencia, H. Babiker, Arizona State Univ. (United States); R. Richardson, E. Rhee, B. Willis, J. Nigro, D. Cleveland, St. Joseph's Hospital and Medical Ctr. (United States); D. H. Frakes, Arizona State Univ. (United States)
- 7533 0G **Numerical observer for cardiac motion assessment** [7533-37]
J. G. Brankov, T. Marin, Illinois Institute of Technology (United States); P. H. Pretorius, Univ. of Massachusetts Medical School (United States); Y. Yang, M. N. Wernick, Illinois Institute of Technology (United States)

INVERSE PROBLEMS

- 7533 0H **Passive imaging with cross correlations in a discrete random medium** [7533-16]
M. Moscoso, Univ. Carlos III de Madrid (Spain); G. Papanicolaou, R.-H. Sun, Stanford Univ. (United States)
- 7533 0J **Construction and exploitation of a 3D model from 2D image features** [7533-18]
K. Ni, MIT Lincoln Lab. (United States); Z. Sun, MIT Lincoln Lab. (United States) and Boston Univ. (United States); N. Bliss, MIT Lincoln Lab. (United States); N. Snavely, Cornell Univ. (United States)

CONSUMER IMAGING

- 7533 0K **An optimal algorithm for reconstructing images from binary measurements** [7533-01]
F. Yang, Y. M. Lu, Ecole Polytechnique Fédérale de Lausanne (Switzerland); L. Sbaiz, Google (Switzerland); M. Vetterli, Ecole Polytechnique Fédérale de Lausanne (Switzerland) and Univ. of California, Berkeley (United States)

- 7533 0L **Digital neutral density filter for moving picture cameras** [7533-21]
M. Schöberl, Univ. of Erlangen-Nuremberg (Germany); A. Oberdörster, S. Föbel, H. Bloss, Fraunhofer IIS (Germany); A. Kaup, Univ. of Erlangen-Nuremberg (Germany)
- 7533 0N **Adaptive removal of show-through artifacts by histogram analysis** [7533-23]
J.-K. Hong, K.-M. Kang, S.-H. Kim, SAMSUNG Electronics Co., Ltd. (Korea, Republic of)
- 7533 0O **Automatic portion estimation and visual refinement in mobile dietary assessment** [7533-24]
I. Woo, K. Otsmo, S. Kim, D. S. Ebert, E. J. Delp, C. J. Boushey, Purdue Univ. (United States)

DENOISING AND FILTERING

- 7533 0P **Motion blur removal in nonlinear sensors** [7533-25]
T. Faktor, T. Michaeli, Y. C. Eldar, Technion-Israel Institute of Technology (Israel)
- 7533 0R **SPIRAL out of convexity: sparsity-regularized algorithms for photon-limited imaging** [7533-27]
Z. T. Harmany, Duke Univ. (United States); R. F. Marcia, Univ. of California, Merced (United States); R. M. Willett, Duke Univ. (United States)
- 7533 0S **Novel integro-differential equations in image processing and its applications** [7533-28]
P. Athavale, Univ. of California, Los Angeles (United States); E. Tadmor, Univ. of Maryland, College Park (United States)

INTERACTIVE PAPER SESSION

- 7533 0W **Band reduction for hyperspectral imagery processing** [7533-29]
S. A. Robila, Montclair State Univ. (United States)
- 7533 0X **Identifying a walking human by a tensor decomposition based approach and tracking the human across discontinuous fields of views of multiple cameras** [7533-30]
T. Hori, J. Ohya, Waseda Univ. (Japan); J. Kurumisawa, Chiba Univ. of Commerce (Japan)
- 7533 0Y **Restitution of multiple overlaid components on extremely long series of solar corona images** [7533-31]
A. Llebaria, J. Loirat, P. Lamy, LAM-OAMP, CNRS, Univ. de Provence (France)
- 7533 0Z **Several approaches to solve the rotation illusion with wheel effect** [7533-32]
C. Zhang, R. Parent, The Ohio State Univ. (United States)
- 7533 10 **Restoring the spatial resolution of refocus images on 4D light field** [7533-33]
J. Lim, B. Park, J. Kang, S. Lee, SAMSUNG Advanced Institute of Technology (Korea, Republic of)
- 7533 11 **OASIS: a simulator to prepare and interpret remote imaging of solar system bodies** [7533-34]
L. Jorda, Lab. d'Astrophysique de Marseille, CNRS, Univ. de Provence (France); S. Spjuth, H. U. Keller, Max-Planck-Institut für Sonnensystemforschung (Germany); P. Lamy, A. Llebaria, Lab. d'Astrophysique de Marseille, CNRS, Univ. de Provence (France)

Author Index

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Registration of Patch Optical and MRI or CT Imagery for Real-time 3D Organ Tracking

Dan Wang, Ahmed H. Tewfik

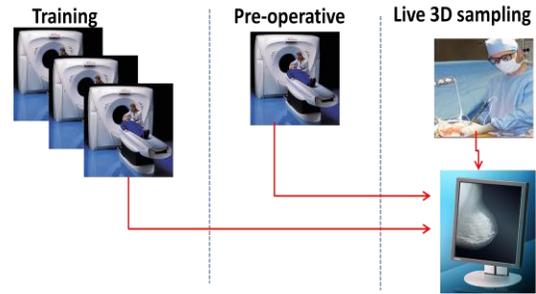
Electrical and Computer Engineering, University of Minnesota

Objective

3D organ tracking is critical for image guided surgery since deformations due to tissue movement significantly deteriorate the precision of the preoperative images. This paper presents a new approach to track the 3D deformation of an organ in real-time by registering limited view optical images and MRI or CT scans.

Approach

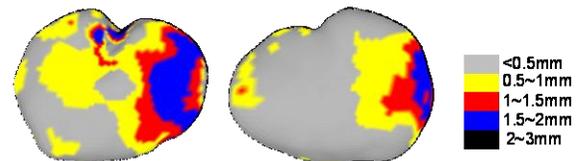
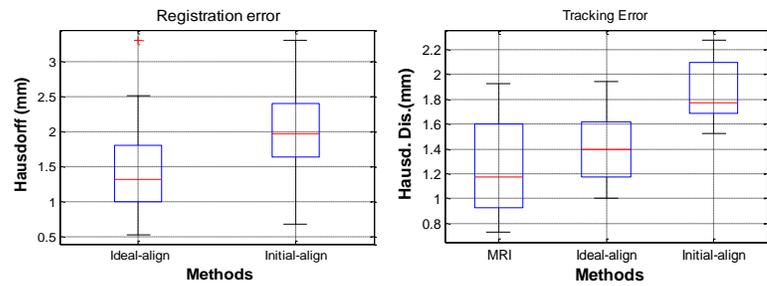
As shown on the right, the live surface samples acquired with a laparoscopic or endoscopic camera featuring 3D imaging is registered and then used to update the 3D organ images on a computer screen. The design principle of the real-time 3D visualization approach relies on our recent discovery that it is possible to identify sparse and structured representations of the entire surface using limited data acquired from a restricted view, because organs deform in limited ways due to their



mechanical properties. The registration during training involves: (i) eliminating the linear transformation between 3D deformations in training set; (ii) finding the pixel-wise correspondence across the different deformations. A method that aligns the spherical harmonic coefficient pairs to match the ridges of the first order ellipsoid is applied in this design. Registration during tracking also involves two steps, including (i) elimination of linear transformation, and (ii) fine tuning. The latter aims to find the optimal patch for tracking by selecting the location yielding minimum reconstruction error at the know positions.

Preliminary Results

Registration error is first evaluated as shown in the left box-plots using three freshly excised porcine kidneys. The error between the ground truth MRI and the 3D optical images (i.e., "initial-align") is 2.1 ± 0.64 mm when the 3D data is aligned to the initial MRI set with the proposed approach. We note that this error level is comparable to the best intra space registration errors reported in the literature. In contrast, the ideal-case registration error between the ground truth MRI and the 3D optical images (i.e., "ideal-align") is 1.4 ± 0.67 mm. For the tracking error, in the "MRI" reconstruction, samples are retrieved from MRI scans as the ideal scenario for comparison. Samples from optical images using "ideal-align" and "initial-align" registration are evaluated respectively as shown in the right box-plot. Errors for three cases are: 1.30 ± 0.45 mm, 1.44 ± 0.40 mm, and 1.88 ± 0.36 mm. Therefore the maximum reconstruction error is below 3 mm. The image of color-coded error field shows that the hidden side (left) has less error than the exposed side (right).



Conclusion

We report an approach of using a single MRI scan for real time 3D visualization of organ deformations from limited view of optical imagery. The preliminary experiment utilized 3D MRI scans with a 1.3 mm resolution and real time limited view single side optical imagery with 0.38 mm resolution. The results show that this new 3D tracking procedure achieves a spatial resolution better than 3 mm on the hidden side of the organ and better than 1.7 mm on the partially observed side of the organ.

