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VIS-a-VE: Visual Augmentation for Virtual Environments in Surgical Training

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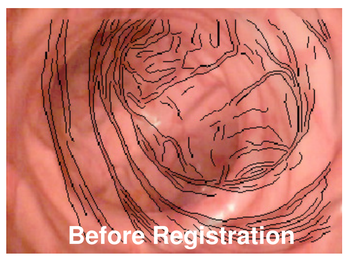
http://www.doc.ic.ac.uk/~ajchung/VISaVE/

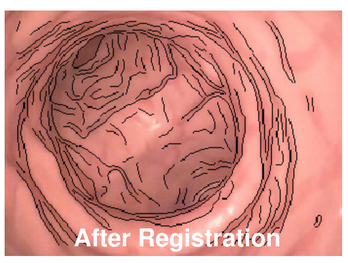
Introduction

Computer simulation applied to surgical training can improve surgical skills, reduce patient risk, increase reliability of diagnosis and chances successful treatment. Training on simulators is generally lower in cost and more efficient than traditional methods that involve supervised learning on actual patients. Incorporating genuine patient data in the simulation can significantly improve the efficacy of training and skills assessment. Using simulators enriched by a library of datasets with sufficient patient variability, trainees can experience a wide range of realistic cases with correct visual information, including rare pathologies.

An important contribution towards training and objective assessment of surgical skills, is the provision of matched real-life structure and surface properties for bronchoscope and endoscope simulations. The matching of CT and video data is accomplished by using a newly developed 2D/3D registration method that exploits a shape from shading similarity measure. Additionally, a method has been devised to allow shading parameter estimation by modelling the bidirectional reflectance distribution function (BRDF) of the visible surfaces. The derived BRDF is then used to predict the expected shading intensity such that a texture map independent of lighting conditions can be extracted. Thus new views can be generated that were not captured in the original bronchoscopy video, thus allowing free navigation of the acquired 3D model with enhanced photo-realism.

2D/3D Registration





In 2D/3D image registration the aim is to localize the real endoscopic image in the 3D coordinate system of the virtual world. Ideally, after registration, if the real view is superimposed on the virtual view it matches perfectly.

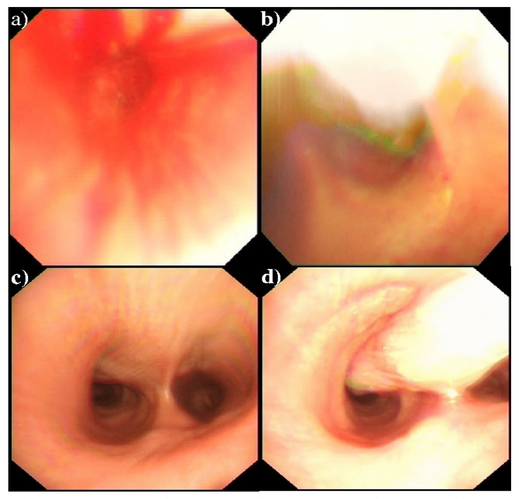
Registration typically employs intensity or feature based techniques. Both categories have limited efficiency under the special endoscopic illumination conditions.

pq-space based 2D/3D registration[1] involves of surface normals for each pixel of the video images by using a linear local shape-from-shading algorithm derived from the unique camera/lighting constraints of the endoscopes. A similarity measure based on angular deviations of the *pq*-vectors used to provide a robust 2D/3D registration framework.

For patient specific bronchoscope tracking and modelling , respiration and patient motion can introduce significant distortion to the bronchial tree.

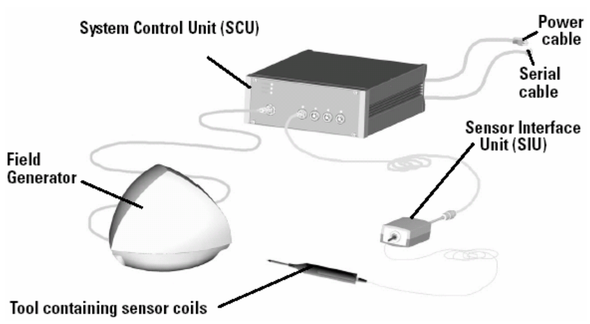
Artefacts:

a) Excessive bleeding due to pathology
b) Appearance of bubbles when patient coughs
c) Large tissue deformation between successive image frames.



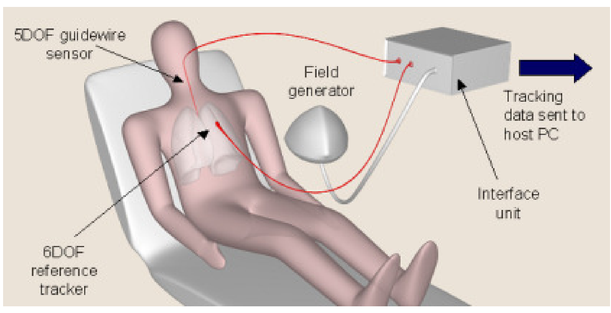
Common endoscopy-image artefacts affects image-based 2D/3D registration techniques

EM Tracking



To simplify the 2D/3D registration process and accommodate general tissue deformation during examination, the use of catheter tip EM tracker provides a practical way forward.

In a catheter tip tracking enabled bronchoscopy examination, a 6 DoF tracker is required to monitor the global position and orientation of the patient. This allows the cancellation of global motion, thus facilitating the localisation of the bronchoscope in relation to the CT scan volume. One of the issues involved in tracking the pose of bronchoscope camera is its motion due to respiratory motion. The trajectory acquired needs to be separated into different phases of the respiratory cycle such that the corresponding bronchoscope views can be co-registered with 3D tomographic data. Since during bronchoscope examination, both patient and respiratory motion affect the reading of the catheter tip, they need to be decoupled before further processing steps can be applied.

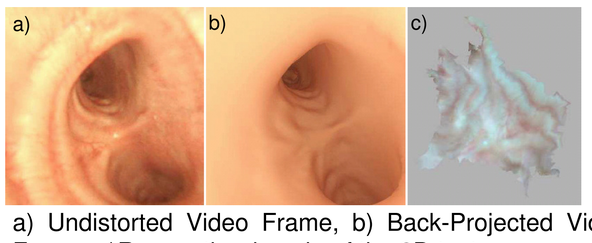


Decoupling of Respiratory Motion

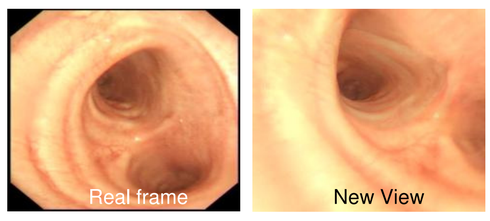
Due to the different frequency characteristics of the respiratory and global motion, it is possible to simultaneously acquire and decouple these motions by using a single sensor positioned on the chest wall[2].

BRDF Modelling

One of the major challenges of combining 2D video with 3D morphological data for patient specific simulation is the extraction of intrinsic surface texture and reflectance properties that are not dependent on specific viewing and illumination conditions. This allows the generation of new views with different camera and lighting configurations. For surgical simulation, this permits the incorporation of tissue instrument interaction, and thus greatly enhances the overall realism of the simulation environment.

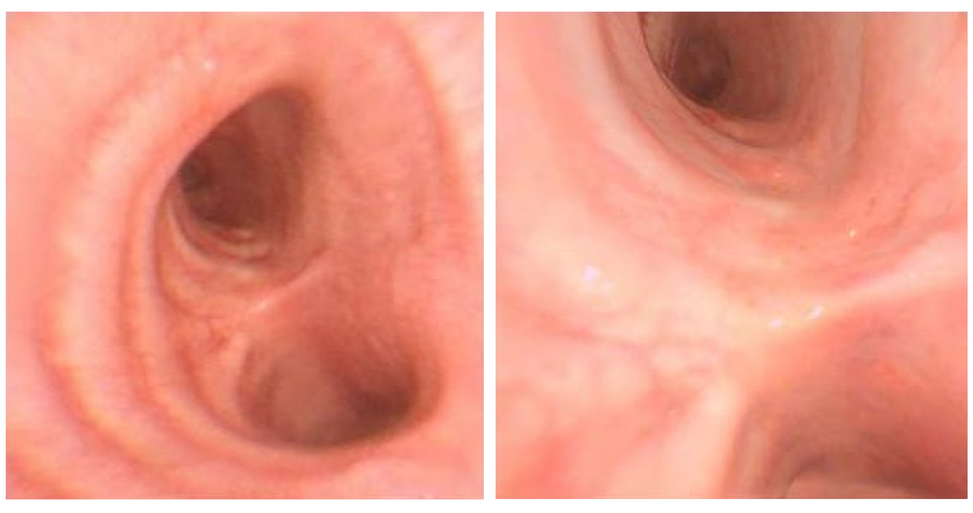


a) Undistorted Video Frame, b) Back-Projected Video Frame, c)Remap the domain of the 2D texture map



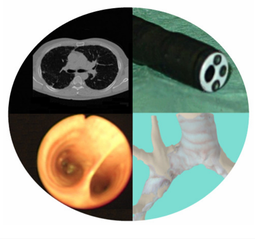
Shading parameters are covered by modelling the BRDF of the visible surfaces by exploiting the restricted lighting configurations imposed by the bronchoscope[3].

A global texture map which is independent of shading variations and global illumination was created by merging all the texture maps together.



Which one is synthetic and which one is real?

Conclusions



We have presented a novel architecture that combines a robust 2D/3D registration technique with BRDF modelling to recover intrinsic surface properties of the bronchial tree. The current method relies on high accuracy of the initial 2D/3D registration, but in reality this is difficult to guarantee particularly in the presence of airway deformation. Improving robustness and accuracy of 2D/3D registration in the presence of pre-operative and intra-operative deformation is the topic of future research.

[1] Deligianni, F., Chung, A. J., Yang, G. Z., *Computer Aided Surgery*, 2005, in press.
[2] Deligianni, F., Chung, A. J., Yang, G. Z., *MIUA*, 2004, 13-16.
[3] Chung, A. J., Deligianni, F., Shah, P., Wells, A., Yang, G. Z., *MICCAI*, 2004, 2, 486-493.