ICRA 2009 Workshop on
Advanced Sensing and Sensor Integration in Medical Robotics
May 13,2009 - Kobe, Japan

Real-time 3D Modeling from Endoscope Image Sequences

Óscar García, Javier Civera, Antonio Güeme, Victor Muñoz, and J.M.M. Montiel

Abstract

During the last years, the convergence between SLAM —developed with in the robotics community— and computer vision have produce a first generation of algorithms that can, in real time, estimate both the 3D scene structure, modeled a a set of points, and the camera trajectory, using the sole monocular camera image sequence as data input. There is vast experimental validation to safely assume good performance when processing general robotic scenes both indoor and outdoor.

Our contribution is to use our leading edge visual EKF monocular SLAM algorithms to underpin a real time 3D simultaneous camera location and map building for monocular endoscope image sequences. The nature of endoscope image sequences makes these algorithms particularly suitable. 3D perception can be extracted by processing monocular sequences, a unique image cannot produce 3D information, but a sequence gathered by a non rotating camera can effectively estimate 3D information. The camera motion geometry, a rotation around the fulcrum, produce naturally a translational motion in the endoscope tip quite accurate for 3D perception.

Basic visual SLAM algorithms produce a simple scene map composed of an small, up to 100 for real time performance, 3D points. This sparse map representation gathers very accurate geometrical scene information, but is poor for 3D model understanding. For medical applications is not only important to produce exact location estimates for a set points but it is also important to produce a textured 3D model easy to be interpreted by surgeons. Because of that, the system presented in the paper produces 3D photorealistc models composed of textured planar triangular facets.

The resulting 3D textured models are quite relevant for endoscope surgery because they can overcome the two main weakness of the endoscope images. On one hand, the depth can be recovered, and the 3D model can be used to estimate, along with the corresponding covariance, metric magnitudes such as distances; the 3D model includes the camera location with respect to the observed scene, so the geometrical backbone for adding augmented reality annotations to the endoscope live output is also available.

The other important endoscope image limitation is the narrow field of view. The textured 3D model allows to synthesize panoramic view of the cavity that expands the limited field of view of the current actual narrow angle view.

In the paper we describe all system components.

- The inverse depth EKF monocular SLAM coding for the uncertain geometrical information.
- The image processing applied to successfully detect persistent features in the medical endoscope sequences.
- The sequential triangulation algorithm to approximate the 3D model surface.
- The equations to derive relative distance estimates for four point map sets.
- The camera calibration model.
- Experiments processing at 25 Hz real abdominal cavity sequences where a textured model is extracted, the relative distance between four points is computed (along with is uncertainty), and annotations are added to the live endoscope image in an augmented reality system.

The link provides a video showing the overall system performance.

We believe that this algorithms provide a solid basis to support real time 3D estimation when endoscope imagery is used as input.

Óscar García is with Dpto. Informática e Ingeniería de Sistemas Universidad de Zaragoza, Spain.
Javier Civera is with Dpto. Informática e Ingeniería de Sistemas Universidad de Zaragoza, Spain.
Antonio Güeme is with Hospital Clínico Universitario “Lozano Blesa” de Zaragoza, Spain
Victor Muñoz is with Dpto. Informática e Ingeniería de Sistemas Universidad de Zaragoza, Spain.
J.M.M. Montie is with Dpto. Informática e Ingeniería de Sistemas Universidad de Zaragoza, Spain.

References to your own related work

- Javier Civera, Andrew J. Davison and J.M.M. Montiel ”Inverse Depth Parametrization for Monocular SLAM” . IEEE Transactions on Robotics Vol 24(5) pp 932-945. October 2008.
- Javier Civera, Andrew J. Davison, Juan A. Magallon and J.M.M. Montiel ”Drift-Free Real-Time Sequential Mosaicing” . Accepted for publication in International Journal of Computer Vision.

Relevant web links

- Video01 (http://robots.unizar.es/data/videos/icra09/video01.avi): this video shows how our application works.
- Video02 (http://robots.unizar.es/data/videos/icra09/video02.avi): shows the final cavity reconstruction.

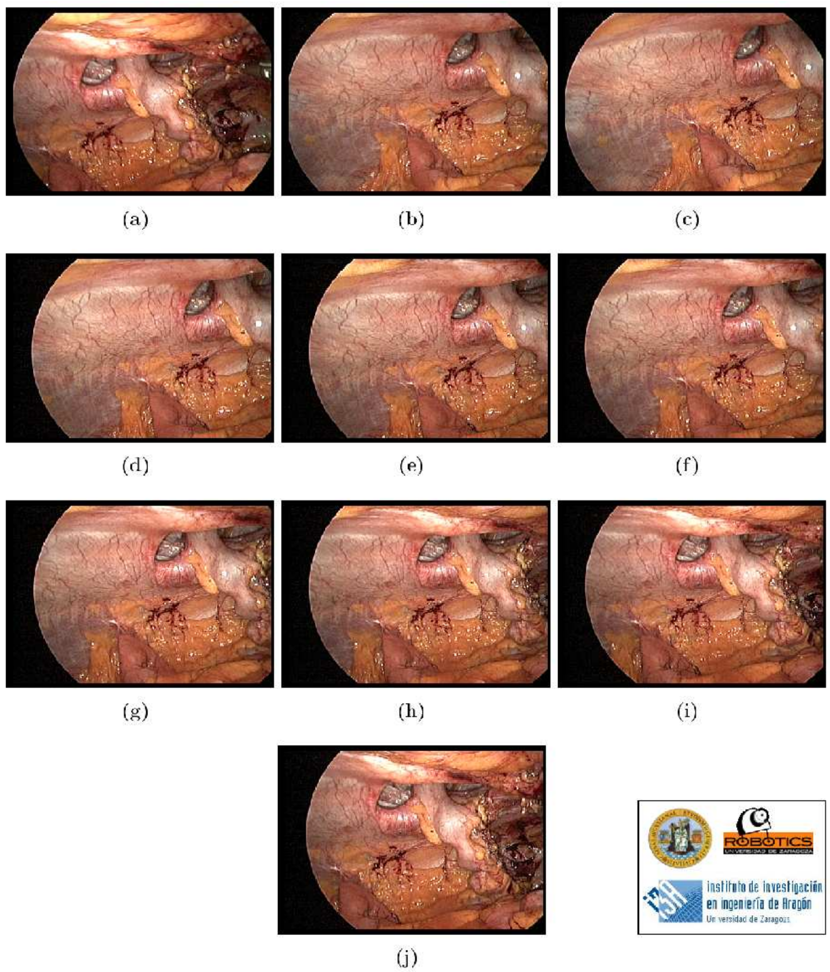

Fig. 1. Figure 1 shows several images from the abdominal cavity sequence.

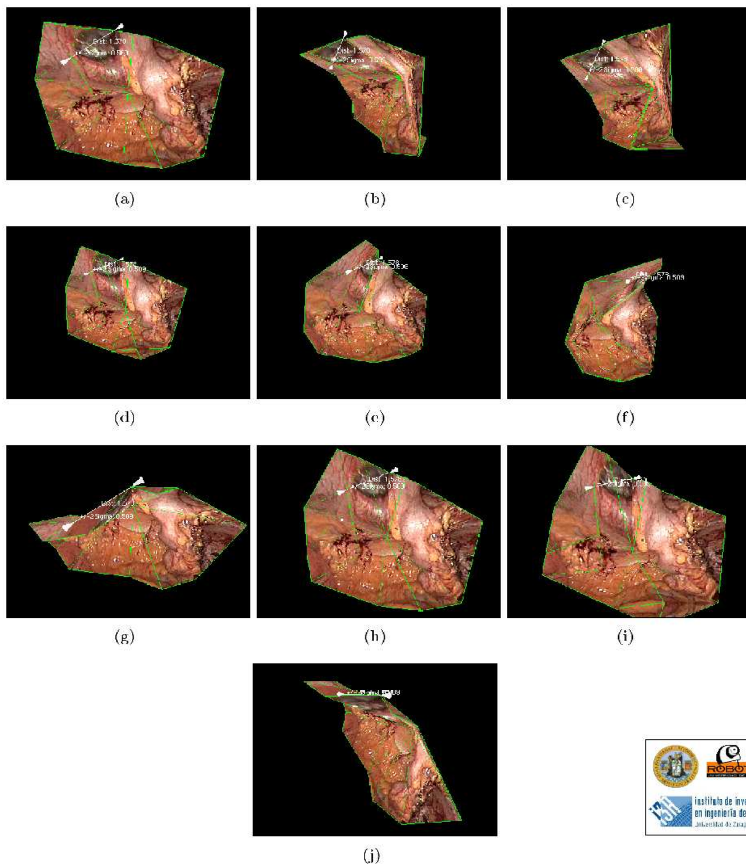

Fig. 2. Figure 2 shows several views of the estimated 3D model along with the relative distance measurement.