Computer assisted surgery and computer aided diagnosis based on recognition, understanding and generation of 3D image

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These days there has been remarkable progress in three-dimensional (3D) medical imaging devices, such as multi detector-row CT (computerized tomography) scanners. Since a 3D medical image involves very precise information of the inside of a human body, a medical doctor can diagnose or plan a surgical operation based upon such information. However, the burden on the doctor's load to review such a large amount of images has increased rapidly due to the improvement of image resolution. Therefore, development of a computer assisted surgery (CAS) system and a computer aided diagnosis (CAD) system has been strongly expected.

Three-dimensional image processing including image recognition, understanding and generation is a key technology in the development of CAS and CAD systems. This paper introduces several applications of CAS and CAD systems developed in our laboratory. Actual demonstrations of these systems are exhibited at the Symposion hall.

1. Virtual endoscopy system and bronchoscope navigation system

The virtual endoscopy system (VES) enables clinicians to explore freely with 3D images as if they were inside of a human body. Image generation technologies such as virtual reality and computer graphics are used in the VES. Nowadays, the VES is widely used in the clinical field.

One of the applications of the VES is to guide bronchoscopic operations. The bronchoscope navigation system (BNS) navigates a physician to the desired location or displays anatomical structures beyond the organ's wall currently being observed. This navigation system requires camera motion tracking to obtain the current location of the bronchoscope. A registration technique between real and virtual endoscopic images is used in the tracking process.

2. Simulation system for virtual pneumoperitoneum and specimen

Image deformation also plays an important role as a tool for assisting laparoscopic surgery that is widely performed as it is minimally invasive. The virtual laparoscopic system creates virtual laparoscopic views based on 3D CT images. During laparoscopic surgery, the abdominal wall is lifted by air to creat working space in the abdomen. Since the 3D CT images are taken before the lifting process, volumetric image deformation is used for virtually lifting the abdominal wall. The created virtual laparoscopic views are very useful for assisting laparoscopic surgery. The virtual specimen is the simulation of streching an organ in order to observe the entire organ surface at a glance.

3. CAD system for colonic polyp detection

Colonic cancers are now rapidly increasing in western countries. Since colonic polyp screening using a colonoscope is painful for patients, 3D CT images are considered a primary modality for diagnosing colonic polyps. Automated polyp detection techniques from CT images are demonstrated here. Curvature is used for characterizing the colonic wall shape. Regions that show polyp–like shapes are extracted. Detection results are overlaid on virtual endoscopic images for assisting diagnosis using the VES.

4. CAD system for quantifying COPD

COPD (chronic obstructive pulmonary disease) is the fifth most common cause of death in the world (2.7 million, '02). Since it is an irreversible disease, early detection and early treatment are important. COPD regions are observed as dark gray regions on X-ray films or X-ray CT images. These dark areas are often called LAAs (low attenuation area). We have developed a CAD system for quantifying COPD based on CT images. The system can quantify three dimensional distribution of LAAs. Relations between LAAs and bronchial and blood vessel regions also can be measured.

CAS and CAD systems based on recognition, understanding and generation of 3D image

- Surgery
- Treatment

Real human body (RHB)

Imaging + 3D Reconstruction

Combination of RHB and VHB

Virtual human body (VHB)

- Diagnosis
- Planning
- manipulation

Key technologies

Recognition
- ★segmentation
- ★distance transformation
- ★thinning

Understanding
- ★anatomical knowledge and database

Generation
- ★computer graphics
- ★virtual reality
- ★fast volume rendering

Computer Assisted Surgery (CAS)

Bronchoscope Navigation

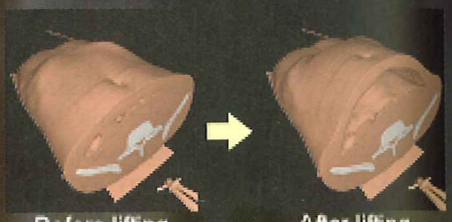
- Navigates a physician to the desired location
- Displays anatomical structures beyond the organ's wall
- ★Camera motion tracking by registration technique between real and virtual bronchoscopic images

Bronchoscope navigation with anatomical information

Augmented display of anatomical structures beyond the bronchial wall

Virtual Peumoperitoneum

- simulates lifting of the abdominal wall (peumoperitoneum)
- is useful for assisting laparoscopic surgery
- ★Volume deformation technique

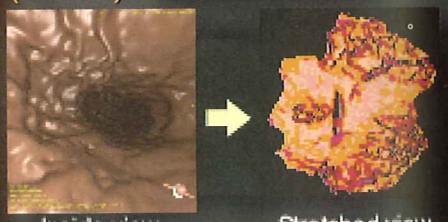


Before lifting — After lifting

Computer Aided Diagnosis (CAD)

Virtual Specimen

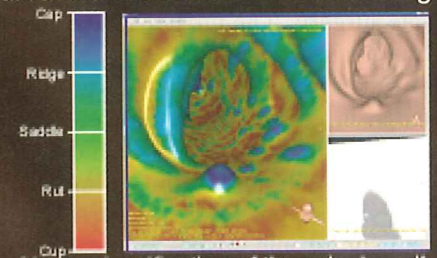
- simulates stretching of an organ
- enables entire observation of the organ surface at a glance



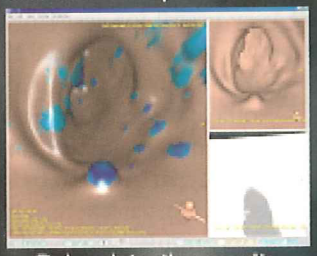
Inside view — Stretched view

Colonic Polyp Detection

- Colorectal cancers are now rapidly increasing in the western countries
- Automated polyp detection is useful for diagnosis of colorectal cancers
- Curvature is used for characterizing the colonic wall shape



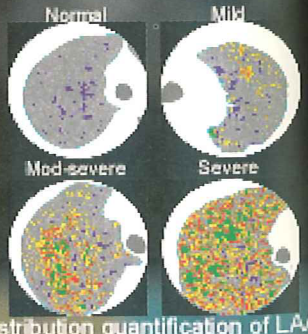
Shape classification of the colonic wall



Polyp detection results

Quantification of COPD

- Chronic obstructive pulmonary disease (COPD) is fifth most common cause of the death in the world ('02)
- COPD regions are observed as dark gray regions (low attenuation area: LAA) on CT image
- Three dimensional distributions of LAAs are quantified



Distribution quantification of LAAs