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主　論　文　の　要　旨

論文題目　Study on bronchoscope tracking for bronchoscopy navigation
（気管支鏡検査ナビゲーションのための気管支鏡追跡に関する研究）

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論 文 内 容 の 要 旨

This thesis describes the author's work on the study of image-based bronchoscope tracking for bronchoscopy navigation. In the United States and worldwide, the populations' death from lung cancer and bronchial cancer is the most among people that die from other common cancers. Early diagnosis can effectively improve the survival rate of patients because the respiratory system is an essential organ of the human body.　There are many diagnosis methods, such as the use of computed tomography (CT) images to diagnose the lesions; or the use of a flexible endoscope for pathological examination of the bronchial lumen (transBronchial Biopsy). However, during a transBronchialbiopsy, since the field of view (FoV) of the camera is narrow and the obtained real bronchoscopic (RB) images have high similarity in appearance.　Bronchoscopist is easy to get lost in the tree-like bronchus.　Therefore, a navigation system is used to locate the bronchoscope camera in three-dimensional (3D) bronchus and provide the necessary3D information to the bronchoscopist during bronchoscopy.

A bronchoscopy navigation system works like a 'car navigation system'.　The bronchoscopy navigation system shows the camera position of the bronchoscope in real-time in CT image coordinate to navigate physicians during an examination. The kernel part of the navigation is bronchoscope tracking, which is used to estimate the camera pose of the bronchoscope. Existing navigation systems either use video-CT-based tracking or an additional electromagnetic (EM) sensor-based bronchoscope tracking. However, for the type of video-CT-based tracking, the tracking result suffers from the difference between preoperative CT images and intraoperative images; and the EM sensor-based tracking is easily affected by metallic surgical tools and patient movements. To accurately estimate the camera pose, we use methods in computer vision to precisely estimate the camera pose for each coming RB frame.　We use a technique called simultaneous localization and mapping (SLAM) to recover the camera pose of a bronchoscope. SLAM uses image sequence as input. The 2D keypoints detected in the RB images are used to estimate the camera pose and reconstruct the 3D surroundings. This technique calculates the camera pose by minimizing the reprojection error of the 3D points on the image plane. The original method is mainly designed for ordinary indoor/outdoor scenes; however, the bronchus scene contains more complex scenes, such as organ deformation caused by patient breathing. Therefore, we improve the original SLAM before applying it for bronchoscope tracking. The 3D position of the point is considered as a condition to find 3D points, which are used to find accurate points for tracking. For validation, two phantoms are used to create bronchoscopic videos. The deformation from the breath is simulated by adding periodic force to the phantom. Experimental results showed that the proposed method is more accurate and more stable than the original method. The proposed method tracks more continuous frames as well. This method is described in detail in Chapter 2.

The complex bronchus scene leads to additional difficulties in the image-guided navigation tasks. Therefore, understanding the operation field is critical during examination or surgery. To this end, a segmentation method is proposed to extract the bronchial orifice region, which is an important characteristic of the bronchus scene on RB video frames, to assist the physicians. Previous works use image appearance and gradation of the RB image for the segmentation task, which behaves poorly in scenes of existing bubbles or changes in illumination. We use the distance between the camera and bronchial anatomical structure, which is represented as a depth image, to segment the bronchial orifice region instead of a color image to overcome the previous works' shortcomings. According to the previous literature, depth image-based image-guided procedures per-form better than color image-based procedures. The depth image is estimated using an image-to-image translation network named cycle generative adversarial network (CycleGAN). CycleGAN is trained to find the relationship between the RB image domain and the depth image domain. We segment the bronchial orifice region individually for each image. We use the vertical and horizontal projection profile curves from the depth image to decide the threshold value used for the binarization. The nonzero region in the binarized image is considered as the bronchial orifice region. This algorithm is de-scribed in detail in Chapter 3.

The existing navigation systems estimate the camera pose precisely for each frame, however, the conventional bronchoscope tracking methods will gradually accumulate tracking errors, which will lead the tracking procedure to fail easily. Therefore, a coarse camera localization method is proposed to roughly localize the camera in the bronchi branch using the changes in the anatomical structure of the bronchi. The bronchial orifice is an important anatomical structure in the bronchus, and it changes with the level of the bronchus. Therefore, the understanding of the changes in the bronchial orifice will benefit a lot for the navigation system. The changes in the bronchial orifice are used to estimate the current bronchial level. The orifice region is obtained by using depth images. The camera movement direction is obtained from the feature point-based camera pose estimation. The branching level is estimated by considering the changes of the bronchial orifice and the camera moving direction. Experimental results showed that the proposed method could estimate the branching level with high accuracy. This method is described in detail in Chapter 4.

At last, the advantages and disadvantages of precise and coarse bronchoscope tracking are compared. From the comparisons, a conclusion that the characteristics based tracking will benefit the bronchoscope tracking is obtained. This is described in Chapter5.