Robotic Bronchoscopy with Structure/Image-based Path Planning and Navigation: Results from Animal Experiments

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Summary

There still exist uncured injuries, e.g., pulmonary fibrosis, inside the lungs of most of people infected by COVID-19. A robotic bronchoscopy with omni-directional bending section within 4mm outer diameter and a 1mm-diameter working channel for MSC (Mesenchymal Stem Cells) spraying and direct medication to the target areas [1,2]. This robotic bronchoscopy can be manipulated automatically or manually by a surgeon based on the proposed structure/image-based path planning and navigation control algorithm. In this paper, animal experiments in vivo on an adult pig are conducted for verification. Results support the effectiveness of the developed robotic bronchoscopy.

Introduction

The motivation is to design a robotic bronchoscopy capable of moving along the bronchial tree inside the lungs for following treatments. And path planning and navigation is then developed for automatic manipulation.

The bending section is made by precise laser engraving where specific pattern is on the surface of the stainless-steel tube (with diameter < 4mm) and several sub-sections with 90° interlaced are made for omni-directional bending (Figure 1). At the tip of the bending section a CMOS camera is mounted. The kinematics calculation and control scheme is described in [2] and the overall system is as (Figure 2) shows. In this paper, we focus on the animal experiments in vivo on an adult pig.

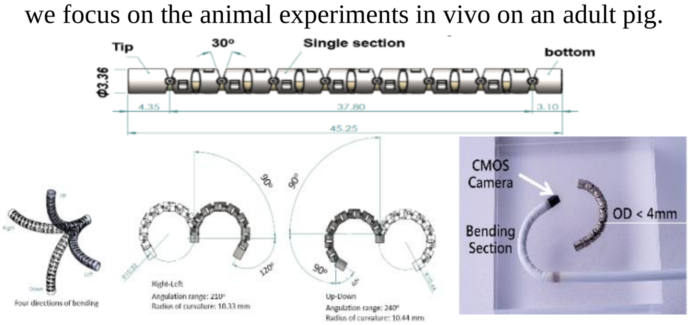

Figure 1: Omni-directional bending section of this robotic bronchoscopy.

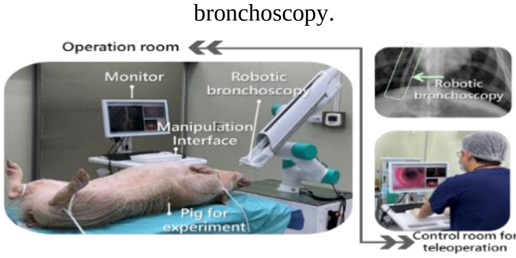

Figure 2: Overall system of this robotic bronchoscopy.

Methods

The user interface for manipulating the robotic bronchoscopy is implemented (Figure 3). Path planning and navigation is performed based on the 3D Bronchial Tree derived from CT images and its invariant feature via object/feature recognition by visual information captured by the CMOS camera in real-time, in situ, and in vivo manner.

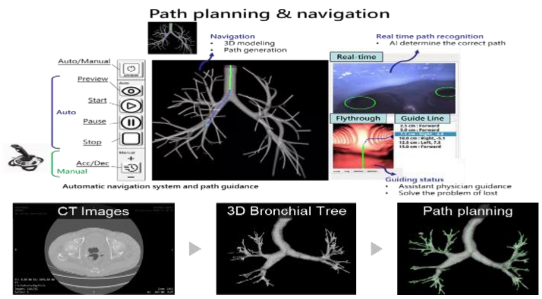

Figure 3: Path planning and navigation – robotic bronchoscopy.

Results and Discussion

(Figure 4) shows the results from animal experiments in vivo on an adult pig where successful path planning and navigation is achieved. The robotic bronchoscopy is navigated automatically by recognizing the bronchial tree structure where the path planning is applied in advance.

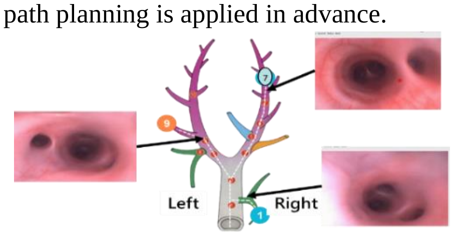

Figure 4: Real images captured along the movements of the robotic bronchoscopy at different positions 1, 7, & 9.

Conclusions

Results from animal experiments on an adult pig demonstrate the effectiveness of the developed robotic bronchoscopy and the path planning/navigation mechanism. Currently, a force controlled-contact navigation is under developing for dexterous interventions.

Acknowledgments

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References

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[2] Kuan, C-P et al. (2023). *Path Planning and Navigation of Miniature Serpentine Robot for Bronchoscopy Application. Micromachines*, 14, 969, doi:10.3390/mi14050969