Development of a Robot Assisted Intubation System and Parameter Optimization

Chuntao Leng, Qixin Cao, Guodong Sheng, Yang Cao, Tiewen Pan
Engineering Training Center, Shanghai Jiao Tong University, Shanghai, China; Fujie Laboratory, Waseda University, Tokyo, Japan; Division of Thoracic Surgery, Shanghai Changzhen Hospital, Shanghai, China
ctleng@sjtu.edu.cn,qxcao@sjtu.edu.cn,sgdking@sjtu.edu.cn,a15caoyang@gmail.com,13601616543@163.com

Abstract: A robot-assisted intubation system based on remote teleoperation is developed. The architecture and the system configuration are introduced. It is composed of Master manipulator in hospital and slave manipulator in first aid site. When the ambulance equipped with this medical device arrived at the disaster site, doctors with specialized skills can stay in hospital and control the robot to carry out the intubation by remote teleoperation method. The proposed system solves the lack of doctor with specialized skills in the rescue work. To improve the effectiveness of the system and guarantee the safety of patients and medical staff at the same time, we analyze the articulation of the robotics arm, and optimized the parameters.

1. Introduction

It is the highest priority and the most important procedure to establish patient's respiratory airway in emergency case. The most important method to establish respiratory airway is to implement tracheal intubation. But it is not uncommon to encounter difficulties and complications, which make this procedure challenging. The reported complication rates of emergency intubation by doctors in early studies were alarmingly high [1]. Therefore, this work must be performed by a doctor with specialized skills. In order to complete the work with better result, there have been some related researches [2].

For earthquake disaster scene, experienced medical staff cannot reach every patient who need for endotracheal intubation. It is necessary to develop some medical device to help overcome the current problem. And many robot assisted systems are proposed in this area [3]. T. M. Hemmerling developed a robotic intubation system (Kepler intubation system, KIS) for oral tracheal intubation [4].

In this paper, we develop a robot-assisted intubation system with remote teleoperation method. When the ambulance equipped with this medical device arrived at the disaster site, doctors with specialized skills can stay in hospital and control the robot to carry out the intubation by remote teleoperation method.

In Section 2, the system configuration and architecture is described. The parameter optimization is presented in Section 3. Some conclusions and perspectives for further research are given in Section 4.

2. System Configuration and Architecture

The architecture of the system is shown in Fig.1. According to the image returned from the scene, the doctor operates the master manipulator. Then the robot equipped with intubation equipment works by executing the order of the master manipulator. The information transmission between hospital and first aid site is achieved by wireless network, and the high speed network is necessary for real-time control requirements.

In our system (Fig. 2), the master device is an Omega.7 [5] that is capable of providing 4 degree-of-freedom force-feedback. The slave device is a 6 degree-of-freedom Universal Robot [6].

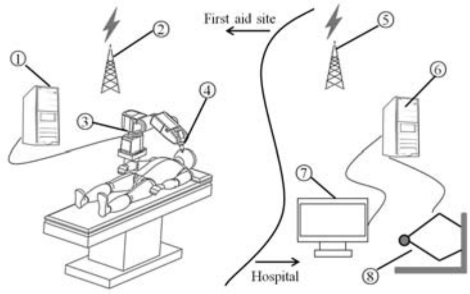

Fig.1 System architecture

① Controller in first aid site, ② information transmission equipment in first aid site, ③ Robot, ④ Intubation equipment, ⑤ information transmission equipment in hospital, ⑥ Controller in hospital, ⑦ Display, ⑧ Master manipulator.

Fig2. Robot-assisted intubation system

3. Parameter Optimization

In this system, we simplify the laryngoscope to a linear tool which has the same start and end points as the laryngoscope. The parameters of the end-effector and the link between the laryngoscope and robotics arm is shown in Fig.3.

Suppose the length of d6 and d7 is 150mm. Take a point whose coordinates are [0, 250, 0] for example. Computing the inverse kinematics on the tool position of each point through MATLAB, if the inverse kinematics exist, which means it's reachable for the robotic arm, we indicate the point by blue '*'; on the contrary, if not exist, use red '.' representing the point. The simulation results are as follows (Fig.4). The ratio of the number of '*' and the number of all points is the articulation of this point. As shown, the articulation of [0, 250, 0] is 0.859649.

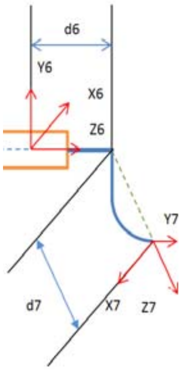

Fig.3 the parameters of the end-effector

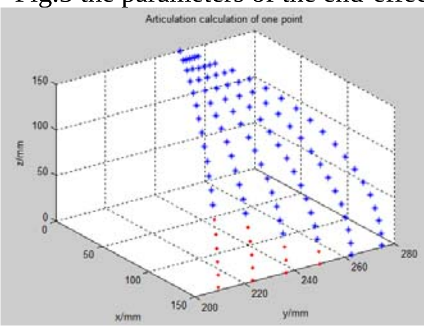

Fig.4 articulation calculation of one point

Compute the articulation of all points in the workspace. First in a specific plane (z = 0), we can see from Fig.5, the distribution of points where the articulation is greater than 0.9 is an annular, which is decided by the base joint of Universal Robot. Therefore, the distribution in the entire space is also an annular. And its longitudinal section is shown in Fig.6. And the area marked in Fig.6 is the best region for intubation.

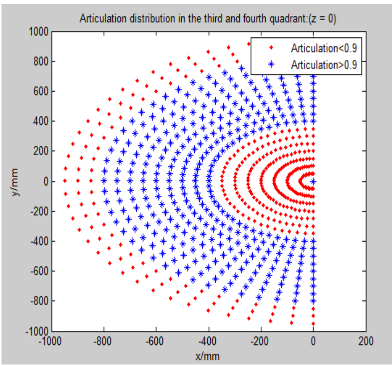

Fig.5 the cross-section of articulation distribution

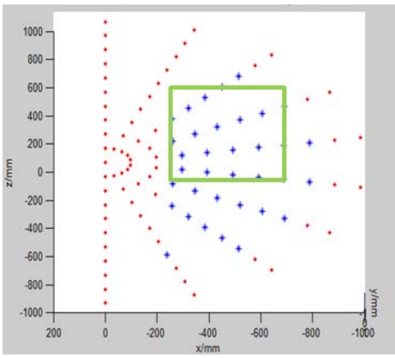

Fig.6 Longitudinal section of articulation distribution, '*' stands for the region where meet the requirements

The principle of the above calculation is the space required during intubation can be completely covered by the space where its articulation is greater than 0.9. As is shown in Fig.5 and Fig.6, it is in line with the principle under the assumptions (d6 = 150mm, d7 = 150mm). if not, we can use the control variable method to optimize the length of d6 and d7 to meet the design requirements. For an adult, the length of d7 is approximately 150mm. The result for d6 is shown in Fig.7, from which we can see the optimum range of d6 is 150-200mm.

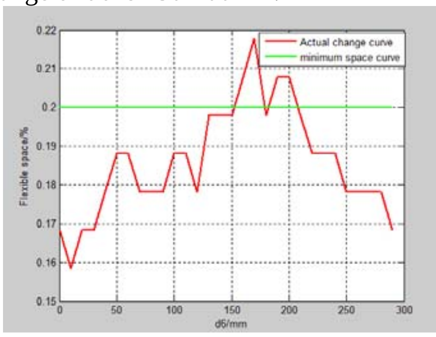

Fig.7 the relationship between d6 and the flexible space (d7=150mm)

5. Conclusion

We established a robot assisted intubation system. The system configuration and architecture are introduced. To improve the effectiveness of the system and guarantee the safety of patients and medical staff at the same time, we analyzed the workspace for intubation and optimized the parameters of this system so that it can fully meet the requirements of teleoperation intubation. Our results show that the workspace for intubation can be totally covered by the flexible workspace when the length for parameter d6 is 150-200mm.

In the future, we will focus on the control strategy to improve the success rate of intubation. Also, we will design the end-effector according to the optimization results and carry out more experiments.

References

[1] Choi YF, Wong TW, etc., A study of orotracheal intubation in emergency departments in five district hospitals in Hong Kong, HKJEM 2003, 10:138–45

[2] Shih-Chung Chen, Sung-Yuan Yang, etc., A Portable Auto-Detective Instrument for Endotracheal Intubation, IEEE Conference on Electron Devices and Solid-State Circuits, Page(s): 1103 – 1106, 2007

[3] Chen Daguo, Shen Jie, Yan Yonghua, An overview of robot assisted catheter insertion system, Chinese Journal of Medical Instrumentation, 2010, 34(1):35–8

[4] T. M. Hemmerling, R. Taddei, M. Wehbe, etc., First robotic tracheal intubations in humans using the Kepler intubation system, British Journal of Anaesthesia, 2012, 108 (6): 1011–1016

[5] http://www.forcedimension.com/omega7-overview

[6] http://www.universal-robots.com/