Link Length Optimisation of a Medical Robot in Minimally Invasive Surgery

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Introduction

The usage of robots in minimally invasive surgery (MIS) becomes more and more frequent. So far, only a few robots are available to perform MIS, and guidelines for optimal design of such robots are rare. This work defines requirements for medical robots to accomplish MIS. Furthermore, it presents an approach to optimise the link lengths of a robot to meet these requirements.

Methods

The first step consists in analysing the following standard MIS interventions in terms of workspace and required positioning accuracy of the instrument tip: totally endoscopic bypass graft, mitral/aortic valve repair/replacement, tricuspid valve repair, cholecystectomy, appendectomy, hernia repair and laparoscopy. Three workspaces are derived from these interventions, where certain constraints addressing the accuracy and the manipulability of the instrument tip have to be observed to meet the surgeons' needs: Manipulability plays an important role in the considered master-slave setup to ensure that the commanded motions remain isotropic on the slave side. Accuracy is introduced to comply with the high precision demands required in e.g. bypass graft procedures. As optimisation criterion, the minimisation of the overall link length is considered, thus ensuring a compact design of the robot. This is of great interest in an extremely unpredictable and overcrowded environment such as the operating room. Moreover, in emergency situations the robot has to be removed manually, therefore easy manageability (light weight construction) is important. Since errors in registration between preoperative imaging and intraoperative patient models are still in the order of several centimeters, it is necessary that found solutions are insensitive with respect to small variations concerning work space (e.g. due to insufflation) and port placement (due to inaccurate registration of the patient). The arising demand for robustness of the found solutions is included into the presented optimisation scheme. The particular kinematic structure of medical robots assisting in MIS which results from a loss of two degrees of freedom at the entry point into the human body is taken into consideration. Optimisation itself is carried out using genetic algorithms.

Results and Conclusion

A medical robot design is determined, assuring the feasibility of the considered MIS interventions. The robustness of found solutions can be demonstrated in the scope of a subsequent analysis. The implemented optimisation procedure is flexible and will be expanded to studies such as preoperative planning of port placement and robot positioning in the future.

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