Research of finger bone position and posture estimation method utilizing magnetic motion capture:

Development of skeletal finger model for estimating finger motion

(磁気式モーションキャプチャを用いた指骨の位置姿勢推定手法の研究：
手指動作推定のための手指スケルトンモデルの構築)

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Rong TANG

Akita University

Abstract

Motion capture is an important technology for surgical operation training, such as ergonomic assessment of hand motions in laparoscopic surgery. Researches relating to wrist angle and finger joint angles with glove-based motion capture device are available. However, hand motion and finger joint positions during laparoscopic surgery has not been discussed in previous researches because finger position measuring method for laparoscopic training has yet to exist within our knowledge. There are also some researches on dexterous movements using hand motion capture methods that applies methods such as optical motion capture. However, these researches are not related to laparoscopic training. To measure the hand motion of surgical operation when using scissor-like tools, such as laparoscopic instruments, the self-occlusion problem with optical motion capture cannot be avoided, as optical markers may be occluded by either the hands or surgical instruments. To address the occlusion problem, a magnetic motion capture device that is capable of finger motion measurement as magnetic field is able to pass through human body is useful solution. Another problem that needs to be addressed is the physical collision between the aforementioned instruments and magnetic receivers. When using scissor-like laparoscopic instruments, the handgrip may collide with magnetic receivers. In order to reduce these physical collisions, the number of receivers that placed on finger have to be reduced. As the result, skeletal finger model is necessary to estimate position finger segments that do not have receivers placed on them.

In this paper, we proposed a method to develop skeletal finger model for the estimation of finger motion when using scissor-like tools. We developed a calibration method for receiver posture, an estimation method for joint rotation center and rotation axis, and a joint center positions estimation method utilizing two receivers attached on fingertip and hand dorsum. In addition, we have measured and evaluated the motion of index finger which includes bone length (segmental length) and finger bone position by attaching receivers on the fingertip and hand dorsum during grasping. Furthermore, we compared the fingertip position generated by the proposed skeletal finger model to a finger model with rotation axes orthogonal to the finger bone.

For evaluating the skeletal finger model, we compared the fingertip positions generated by the proposed skeletal finger model to that of a finger model with rotation axes orthogonal to the finger bone. As the result, the mean (standard deviation) distance between the fingertips of all subjects and all target positions was

2.6 mm (0.9 mm). Compared to a finger model with rotation axes orthogonal to the finger bone, the mean error and standard deviation of the finger model generated by the proposed skeletal finger model was reduced by 45% and 47%, respectively. It is confirmed that the skeletal finger method generated by our method had better accuracy and reproduced a more realistic finger motion.

Further, we evaluated the mean segment lengths during a specified grasping motion were calculated by determining the position of joint centers. As the result, the standard deviations of all estimated segment lengths were under 0.2 mm. The positions of the joint centers obtained through our method with that obtained by attaching a full set of four receivers between the dorsal hand and index fingertip were compared. The Pearson correlation coefficients between the joint center positions estimated by our method and that of full set of receivers were calculated. The results showed a strong correlation between the joint center positions estimated by our method