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A Unity-based Da Vinci Robot Simulator for Surgical Training

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◆Back ground:

1. The da Vinci surgical system (Intuitive Surgical, CA, USA) has obtained great success in RAMIS.
2. The system is high-cost. Inexperienced surgeons have limited preparation to employ these new techniques.

◆Our proposal:

1. Low-cost simulation-based surgical training.
2. Develop a virtual simulation platform composed of full da Vinci surgical system components for surgical training.
3. A virtual fixture based training task to evaluate the training system.

◆Methods

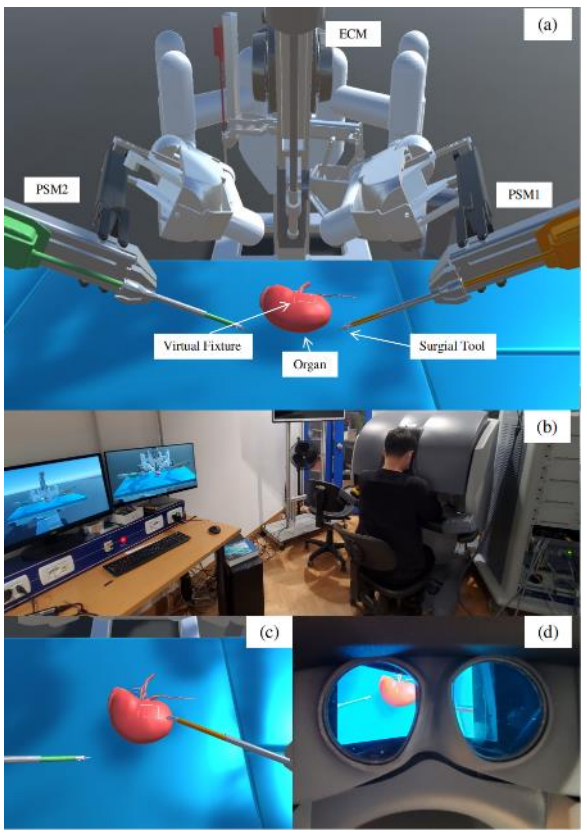

Fig.1 System overview

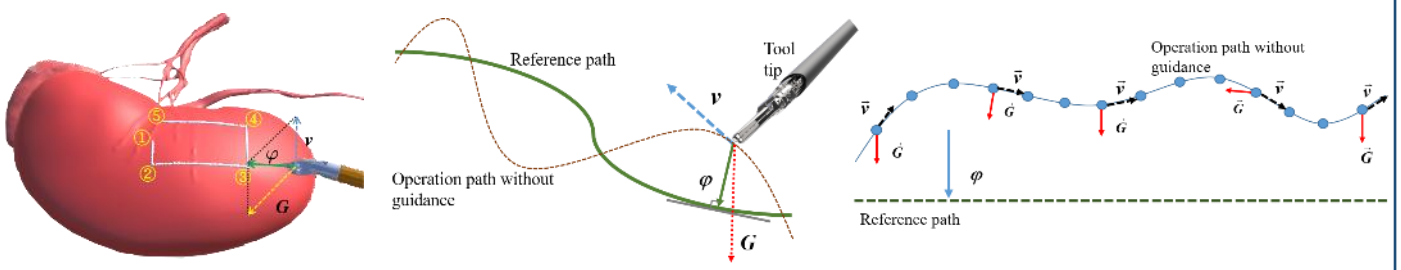

Fig.2 Virtual fixture based surgical task

This paper proposes the development of a virtual simulation platform composed of full da Vinci surgical system components for surgical training, as shown in Fig.1. The simulator is a tele-surgical system. The Master Tool Manipulators (MTMs) are used as the haptic input device. The dynamic simulations of three Patient Side Manipulators (PSMs), Setup Joints (SUJs) and the Endoscopic Camera Manipulator (ECM) are provided in this simulator. Furthermore, the haptic function is integrated into the simulator. In order to validate the potentiality for surgical training of the simulator, we developed a scenario of the virtual fixture. Virtual fixtures are control strategies used in robotic surgery that restrict or adjust the motion of the surgical tool with respect to predefined paths, trajectories, as shown in Fig 2. We studied the effect of haptic assistance in path following by ten non-medical subjects. The experimental task is implemented in the simulator as shown in Fig. 2. The task requires both hand-eye coordination and manual dexterity of users. Since the assistance force is computed based on both tool's velocity and deviation, the user will not be affected by force when staying static. This can relieve mental stress of users during the task. Each user was told to move the surgical tool through MTMs along a curved reference path from point 1 to point 5 for ten times and attempts to avoid possible deviation from the path. The curved path is designed to span along the three Cartesian dimensions. Users need to do 90◦ rotation for three times at point 2, point 3 and point 4. We calculate the deviation error and completion time. The results are shown below.

◆Results

The results suggest that the virtual fixture have reduced deviation in cases with three different force intensity compared with cases without assistance force. As shown in Fig 3, the deviation decreases with the force increasing. However, When the force is too large, the virtual fixture does not demonstrate improvements compared with the middle force. It also can be observed in Fig. 4. The task with a large assistance force is more time-consuming than the case with a middle assistance force. Furthermore, the variability of the deviation error has been seen reduced in three cases with assistance force among the subjects compared to the case without assistance force.

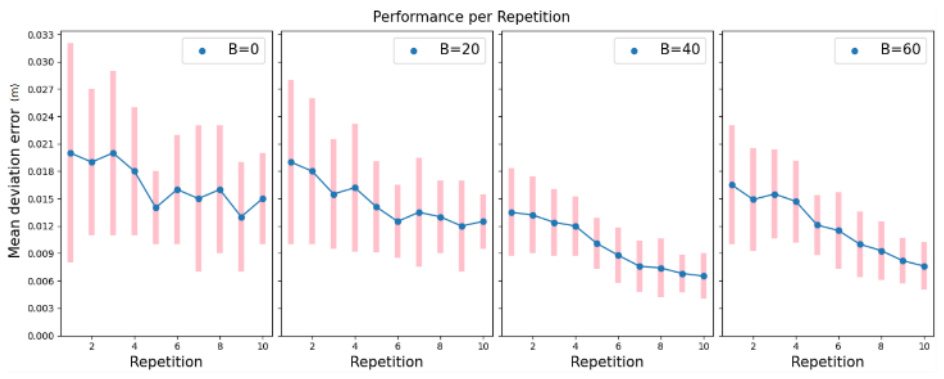

Fig.3 The mean deviation error from reference path of four cases with different assistant force intensity. Blue dots represent the mean deviation error of all subjects in each repetition. The bars shows the 20th to 80th percent of data in each repetition.

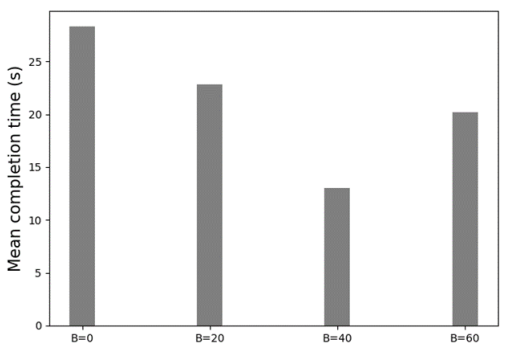

Fig. 4 The mean completion time for four cases. The assistance force increases with the parameter B increasing