Performance Assessment of Kinematics and Control Interfaces for Laparoscope Positioners

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Which laparoscope positioner is the most efficient? Simple question but still no accurate answer, nearly twenty years after the introduction of AESOP, the first robot that could hold and move the endoscope and camera used in minimally invasive laparoscopic surgery. Metrics and methodologies to measure the performance of industrial robots are defined by international standards (e.g. ISO 8373, ISO 9283). Unfortunately, no such regulation is established yet for surgical robots.

In medicine, a common way to estimate the performance of a new device is to carry out a small clinical study. Most commercially available laparoscope positioners (e.g. AESOP, EndoAssist and its successor FreeHand, LapMan, and ViKY) were introduced by means of such studies. Most authors report that these devices can actually replace the assistant, with several advantages over manual holding: more stable image, fewer contacts between lens and organs that require a cleaning, less fatigue for the surgeon, less strain for the assistant, etc. These studies in real conditions are sufficient for a proof of concept. However, they are not very reproducible, since operation duration—the most common comparison performance metric—is affected by many external factors.

A couple of studies compared the motion performance of AESOP and EndoAssist in a more standardized way, using a benchtop experiment that is more controllable than a series of real surgical procedures. The main limitation of these studies lies in the fact that robots were analyzed as whole devices. It is therefore difficult to find out why a robot performs better than the other in terms of motion duration to reach a target. It could be thanks to a more intuitive and fast-reacting interface, or just because the preprogrammed laparoscope angular velocity is set at a higher level.

Yet, it is desirable to identify the influence of specific characteristics of laparoscope positioners on their performance. In particular, one can anticipate that two factors play a major role: (1) the control interface, which could be provided with more directions than the commonly available 'Up/Down', 'Left/Right' and 'In/Out', and (2) the robot kinematics that defines how the intra-abdominal image is shifted in response to the surgeon’s orders. To measure the influence of only these two factors on motion performance, accuracy, and intuitiveness, we pushed the standardization further. We used the EVOLAP robot developed at UCL [1], upgraded with a laparoscope rotation device and programmed to mimic the kinematic behavior of existing devices. An omni-directional joystick was also used, whose output signals could be post-processed to restrict motion in specific directions. This permits to exclude all uncontrollable sources of variability between different devices (e.g. maximum laparoscope velocity, acceleration and deceleration duration, reaction time of the interface). The experimental setup is depicted on Fig. 1.

Twelve surgeons were recruited for this experimental study. Each surgeon performed a camera displacement task with 9 combinations of kinematics and number of controllable directions in random order. Time required to perform the task was recorded to assess the motion performance. After the trials, the surgeons filled out a survey about the subjective performance (i.e. velocity, precision, intuitiveness, and general efficiency) of each kinematics and each interface. Results show that kinematics has a large influence on motion duration and on intuitiveness. It also appears that performance and perceived efficiency are increased significantly with an interface that provides more controllable directions than usually available.

REFERENCES