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Manual control methods for handheld surgical instruments: a review

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Minimally Invasive Surgical (MIS) procedures, which are carried out through small incisions(s), are evolving towards less and less trauma to patients while allowing less and less work space to surgical instruments. In the case of key-hole surgery (such as laparoscopic surgery), the workspace of surgical instruments is limited within a work-cone around the incisions. In the case of path-way surgery---new MIS procedures that are carried out through natural openings in human body by following anatomical pathways (such as NOTES, Natural Orifice Transluminal Endoscopic Surgery), the workspace is restricted by the anatomical structure. Thus, the less invasive the surgery becomes, the more difficult the surgical target access is.

New instruments are under development: steerable instruments (instruments with one steering segment at the tip) can access surgical targets that are outside of the work-cone, and manoeuvrable instruments (instruments with multiple steering segments) can shape an arbitrary curve that fits the pathway. Despite the availability of automated control approaches, handheld surgical instruments are preferred by surgeons due to the similarity to conventional instruments and the direct manual control of the performance. Developing intuitive and effective control methods for handheld manoeuvrable instruments are thus an important topic for engineers.

This study reviews the state-of-art in manual control methods for handheld surgical instruments, and groups the manual control methods in three levels: a) number of steering segments, b) number of Degrees Of Freedom, c) coupling between control motion of the handle and steering motion of the tip. The review finds that for controlling steerable instruments, one controller is commonly utilized and the hand controlling motion is transferred to the tip steering motion either directly or indirectly. In the case of manoeuvrable instruments, both separated control (with parallel or serial controllers) and integrated control (one controller) methods have been applied, while a gradual shift is noticed from separated control to integrated control.

Our study suggests that: in controlling manoeuvrable instruments during pathway surgery, it is more intuitive to make motions with limited maneuverability (integrated control with one controller) than to make a three-dimensional curve with maximum manouverability (separated control with multiple controllers). The suggestion is contributing to the control method development for multiple branches instruments in the future.