Review of surgical robot development in China

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In the past decade, the global medical device industry has experienced substantial growth, the medical robotic systems market also has experienced exponential growth owing to the increased patient acceptance of robot-assisted minimally invasive procedures to treat various diseases. Based on geography, North America is the largest market for surgical robots while the Asian market is believed to grow at the highest CAGR over the next five years because of the increased government funding for health care and increased spending capacity of people. Therefore, when it comes to the development of surgical robots in China, although it has experienced a shorter history compared with the U.S. and Europe, it fosters rapidly due to the reasons mentioned above.

In China, the first robot successfully applied to the clinic is a system integrating by a PUMA 260 industrial robot on May 6th, 1997 (Chen et al., 1998). It was a robot system for stereotactic neurosurgery implemented by the Robotics Institute of Beihang University from 1997 to 2011 with five generations in total and over 2000 operations were performer in the Navy General Hospital. This robot, named NeuroMaster, is consisted of four major components including the robot arm with its controller, the 3D vision system, the surgical planning software and a remote control system. The robot has five degree-of-freedom (DOF) with the first axis allowing translational movement vertically and other four rotational movements (Tian, et al., 2004). The kinematic diagram is shown in Fig. 1.

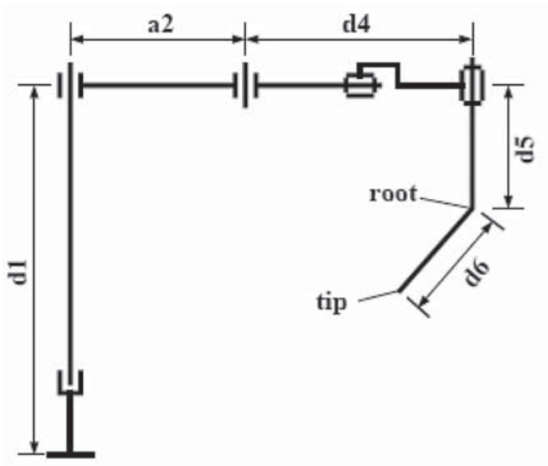


Fig. 1. Kinematic structure of the robot

The surgical procedure includes mainly three steps, namely surgical planning, registration and insertion (Tian, et al., 2004). Surgical planning is achieved by using CT or MRI data to specify the target location and orientation, registration is calibrated via a binocular stereovision system marked by four markers and in insertion, the robot automatically moves to the location while the surgeon inserts the surgical instrument along a straight line.

Apart from the neurosurgery assisted robot, robots are also applied in the orthopaedic trauma surgery. In 2012, researcher Kuang et al., announced a novel passive/active hybrid robot for orthopaedic surgery. It is a 7-DOF robot with a C-arm-like remote-center-of-motion (RCM) structure joint. A switchable, back-drivable joint actuator is used to achieve the passive/active hybrid operation, once the button SB1 is pressed, the actuator switches to the power-off state and the surgeon could control the robot link manually. However, only three experiments including two clinical trials were conducted to exam the feasibility of this robot. The results showed that with an image-guided navigation system, the robot, HybriDot could work with high positional accuracy, rigidity and reliability in the surgery.

Nevertheless, it is also acknowledged that currently China still rely more on imported orthopaedic surgery robot systems other than domestic designed and manufactured robots while many software or computer-assisted navigation systems are generated by academic institutes in China, especially in the orthopaedic robot systems. Zhang and his team (2009) proposed a novel application of the navigational templates in orthopaedic surgery. It served to transfer the preoperative plan accurately to the operating theatre. Wang et al. (2011) also demonstrated a computer-assisted navigation system for insertion of cannulated

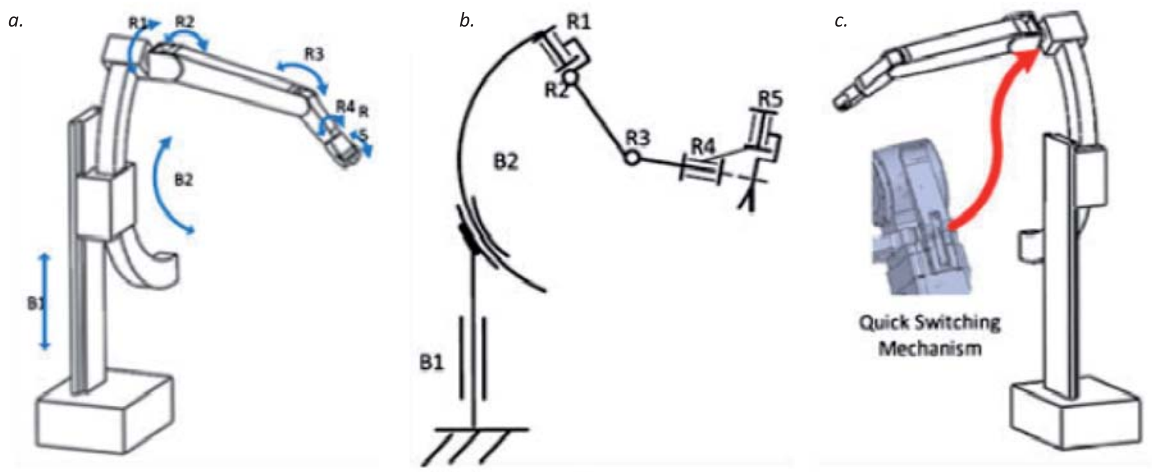


Fig. 2. Robotic design: a. 7-DOF HybriDot; b. kinematic diagram; c. quick-switching mechanism

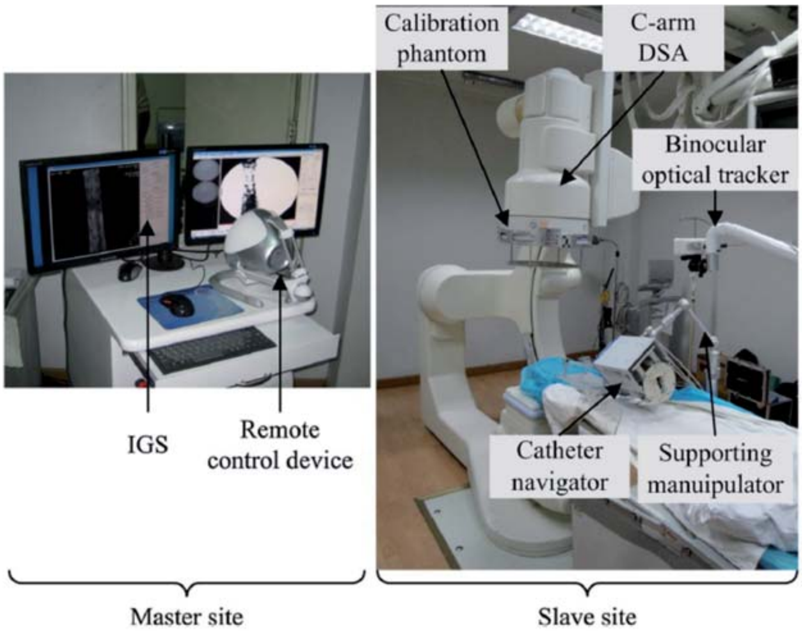
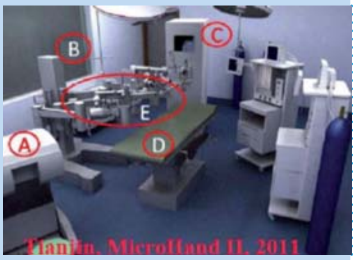


Fig. 3. Structure of RVIR

screws in femoral neck fractures with a bi-planar robot. The result indicated that the computer-assisted system provided significantly improved accuracy compared with the freehand technique. Similar robotic system is also applied to the spinal surgery, Jin et al., (2014) suggested that two essential aspects related to safety issue of Robotic Spinal Surgery System (RSSS) could be further developed: the cooperative control mode for positioning and the fine adjustment mode for precisely adjusting orientation.

Besides, for blood vessel intervention surgery, surgical robots also play an essential role in such process by helping doctor conduct the minimal invasive surgery remotely in a safe place with reduced X-ray radiation. Meng et al. (2013) proposed a master-slave structured robotic system to help surgeon perform with accurate teleoperation. The remote control device is a three- degree of freedom (DOF) Falcon haptic device from Novint Technologies. It provides a human computer interface to support doctor to manipulate the catheter and feel the force feedback. The slave comprises a rotational C-arm-based DSA machine, a binocular optical tracker, the medical robot and an operating bed. The medical robot consists of two parts, a supporting manipulator and a catheter navigator. There is a passive hydraulic mechanism to allow locking manipulator at any position while there is a micro force sensor at the end of the catheter to give feedback to the doctor and prevent potential damage of blood vessel.

Other surgical robots without journal support

Surgical Robot	Time/institution	Function
	Robot assisted orthopaedic surgery system (ROSS) Developed by Harbin Institute of Technology in 2004	Long bone reposition Lock distal holes of intramedullary nail
	Orthopaedic robot Developed by Beijing Science and Technology University in 2010	Used for head and face orthotics
	Spine assisted Designed by Shenyang and Shenzhen institute of Chinese Academy of Science (CAS)	Assisted laminectomy surgery (milling) and transpedicular screw insert guiding
	MocroHand Studied by Tianjin University, HIT, and Jinshan Company	Laparoscopic Surgery assistance
	Microsurgery robot: “RAMS” Designed by Nankai University in 2005	Ophthalmic surgery; Organism operation

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