First steps toward autonomous robot surgeries

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The day may be getting a little closer when robots will perform surgery on patients in dangerous situations or in remote locations, such as on the battlefield or in space, with minimal human guidance.

Engineers at Duke University believe that the results of feasibility studies conducted in their laboratory represent the first concrete steps toward achieving this space age vision of the future. Also, on a more immediate level, the technology developed by the engineers could make certain contemporary medical procedures safer for patients, they said.

For their experiments, the engineers started with a rudimentary tabletop robot whose “eyes” used a novel 3-D ultrasound technology developed in the Duke laboratories. An artificial intelligence program served as the robot’s “brain” by taking real-time 3-D information, processing it, and giving the robot specific commands to perform.

“In a number of tasks, the computer was able to direct the robot's actions,” said Stephen Smith, director of the Duke University Ultrasound Transducer Group and senior member of the research team. “We believe that this is the first proof-of-concept for this approach. Given that we achieved these early results with a rudimentary robot and a basic artificial intelligence program, the technology will advance to the point where robots – without the guidance of the doctor – can someday operate on people.”

The results of a series of experiments on the robot system directing

catheters inside synthetic blood vessels was published online in the journal IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control. A second study, published in April in the journal Ultrasonic Imaging, demonstrated that the autonomous robot system could successfully perform a simulated needle biopsy.

Advances in ultrasound technology have made these latest experiments possible, the researchers said, by generating detailed, 3-D moving images in real-time.

The Duke laboratory has a long track record of modifying traditional 2-D ultrasound – like that used to image babies in utero – into the more advanced 3-D scans. After inventing the technique in 1991, the team also has shown its utility in developing specialized catheters and endoscopes for real-time imaging of blood vessels in the heart and brain.

In the latest experiment, the robot successfully performed its main task: directing a needle on the end of the robotic arm to touch the tip of another needle within a blood vessel graft. The robot's needle was guided by a tiny 3-D ultrasound transducer, the "wand" that collects the 3-D images, attached to a catheter commonly used in angioplasty procedures.

"The robot was able to accurately direct needle probes to target needles based on the information sent by the catheter transducer," said John Whitman, a senior engineering student in Smith's laboratory and first author on both papers. "The ability of the robot to guide a probe within a vascular graft is a first step toward further testing the system in animal models."

While the research will continue to refine the ability of robots to perform independent procedures, the new technology could also have more direct and immediate applications.

“Currently, cardiologists doing catheter-based procedures use fluoroscopy, which employs radiation, to guide their actions,” Smith said. “Putting a 3-D ultrasound transducer on the end of the catheter could provide clearer images to the physician and greatly reduce the need for patients to be exposed to radiation.”

In the earlier experiments, the tabletop robot arm successfully touched a needle on the arm to another needle in a water bath. Then it performed a simulated biopsy of a cyst, fashioned out of a liquid-filled balloon in a medium designed to simulate tissue.

“These experiments demonstrated the feasibility of autonomous robots accomplishing simulated tasks under the guidance of 3-D ultrasound, and we believe that it warrants additional study,” Whitman said.

The researchers said that adding this 3-D capability to more powerful and sophisticated surgical robots already in use at many hospitals could hasten the development of autonomous robots that could perform complex procedures on humans.

Source: Duke University