Researchers describe integrated robot system for ultrasound-guided prostate percutaneous intervention

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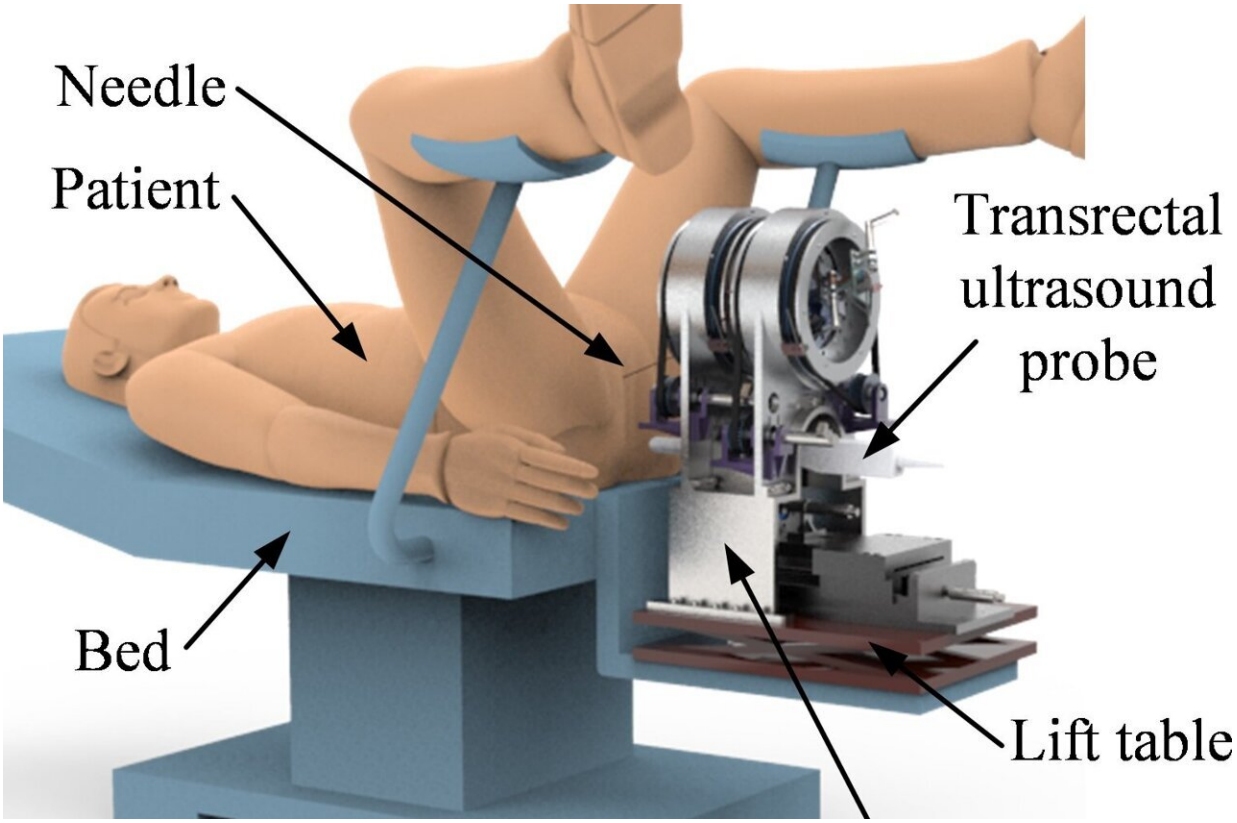

Configuration of 8-DOF robot system for ultrasound-guided prostate percutaneous intervention. Credit: Jiawen YAN , Bo PAN , Yili FU

A research team from Harbin Institute of Technology has proposed a

novel and effective robot system for ultrasound-guided prostate percutaneous intervention. The 8-joint robot system can realize a full-automatic control for prostate insertion, which can be potentially applied to prostate diagnose and treatment such as biopsy and brachytherapy. This study published in the journal *Frontiers of Mechanical Engineering* on January 27, 2022.

As the patient group with prostate disease increases greatly in recent years, the novel and rigid robot system provides a hopeful alternative for automatic intervention process with fewer attempts and trauma, and also less dependence on operators' experience.

"The compact system makes use of the limited space for prostate insertion operation. The robot system contains 8 joints for independent control of ultrasound probe manipulation, needle positioning and needle insertion. The employed parallel structure, importantly, can avoid potential collision between the structure and patient," said by assistant professor Bo Pan, the author of the study.

The research group of Profs. Yili Fu and Bo Pan is one of the pioneer research groups studying medical imaging-guided surgery robot systems in China. The robot systems are designed to meet the complex requirements in surgical process and increase the rate of success. "Applying intelligent systems to assist doctors to realize operations with reduced difficulties is an effective approach to improve our medical treatment process," said by Pan. And this time, the study group is focused on the ultrasound-guided prostate insertion process.

Ultrasound-guided prostate insertion is a generally used process to diagnose and treat prostate diseases. During the insertion process, a doctor needs to scan the gland, insert the needle and check the accuracy at the same time. A tablet can help doctors reduce the operation difficulty; however, it restricts the insertion flexibility. Also, repetitive

attempts are usually needed to increase the accuracy, which lead to bigger trauma and discomfort to patients. The 8-joint robot system proposed in this work is aimed at achieving the whole process automatically.

"The challenging point is that the system should contain all the needed functions with compact and rigid design," explained by Pan. The newly designed system accommodates ultrasound probe and insertion needle. The transrectal ultrasound probe can be manipulated to insert and rotate for prostate scanning; the needle can be orientated and positioned for pose adjustment, and automatically inserted according to the operator's order. All the motions are independent to realize a high reflexibility. The design also considered the general requirements of medical robot design such as self-locking and easy sterilization.

"The parallel structure for needle pose adjustment is a novel design and increases the system rigidity. However, it also needs careful calibration," said by Pan. Calibration is the model parameter identification process and is important for accurate control. Parallel structure calibration cannot be accomplished using universal approaches, and an effective approach is usually related to the specific model. In the work, the researchers propose particle swarm optimization based on the parameter informative values (InfoPSO) for error identification in the calibration process. PSO is a nonlinear optimization method with rapid calculation speed, but the calculation results reasonability cannot be guaranteed without a real-time supervision. Combined with parameter characteristics, the identification accuracy can be improved.

In the work, the research group built up a prototype to show the functionality. Verification experiments prove that the robot system is able to realize motions needed in the targeting process. By applying the calibration method, a reasonable and reliable control process is built up, and the average error can be limited to 0.963 mm for insertion point, to

1.846 mm for target point.

"There is a long way to go from a prototype to product, especially for a medical device. But all the efforts take us closer to it. In the next step we will focus on the rigidity improvement and elaborate manufacturing and assembling. The work is promising to be applied in practical one day in the near future," Pan said confidently. The research team will continue in improving robot system design and carry out more medical robot systems.

More information: Jiawen Yan et al, Ultrasound-guided prostate percutaneous intervention robot system and calibration by informative particle swarm optimization, *Frontiers of Mechanical Engineering* (2022). DOI: 10.1007/s11465-021-0659-x

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