

A 2DOF MR-compatible Interventional Robot for Pulmonary Artery Catheterization: Design and Evaluation

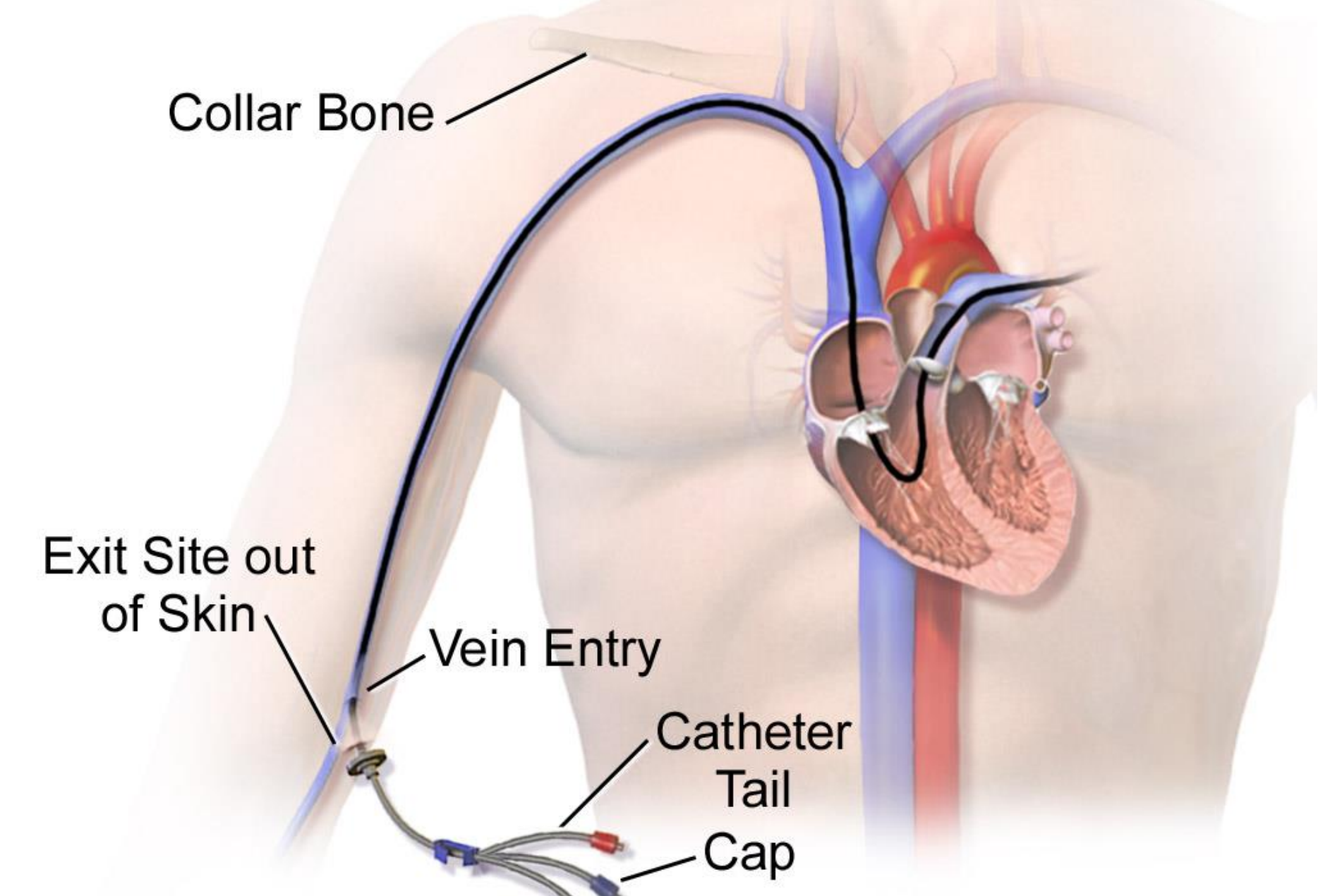
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Background

- Cardiovascular disease (CVD) is now emerging as the leading cause of death for humans.
- One effective procedure to treat cardiovascular diseases is cardiac catheterization. Catheterization under X-ray fluoroscopy is now being used successfully. However, this approach still poses a serious radiation to the surgeon.
- The last twenty years have seen increasing use of magnetic resonance imaging (MRI) scanners for providing imaging for procedure. The development of a corresponding MR-compatible catheterization robot is warranted.



Aim

- Develop of an MR-compatible cardiac catheterization robot, accompanying catheter digital twin model to satisfy these clinical needs.
- Functional testing of the assembled robot is expected to show successful translation and rotation of a catheter as required.
- Robot can be compatible with MRI Machine and robotic pulmonary catheterization enabled in the clinic.



Pulmonary artery phantom

Methodology and Mechanical Design

MR-compatible robot based on hydraulic actuation is stable but subject to hysteresis. The ultrasonic motor is non-magnetic, with compact construction. It is an effective option for the development of MR-compatible catheterization robots.

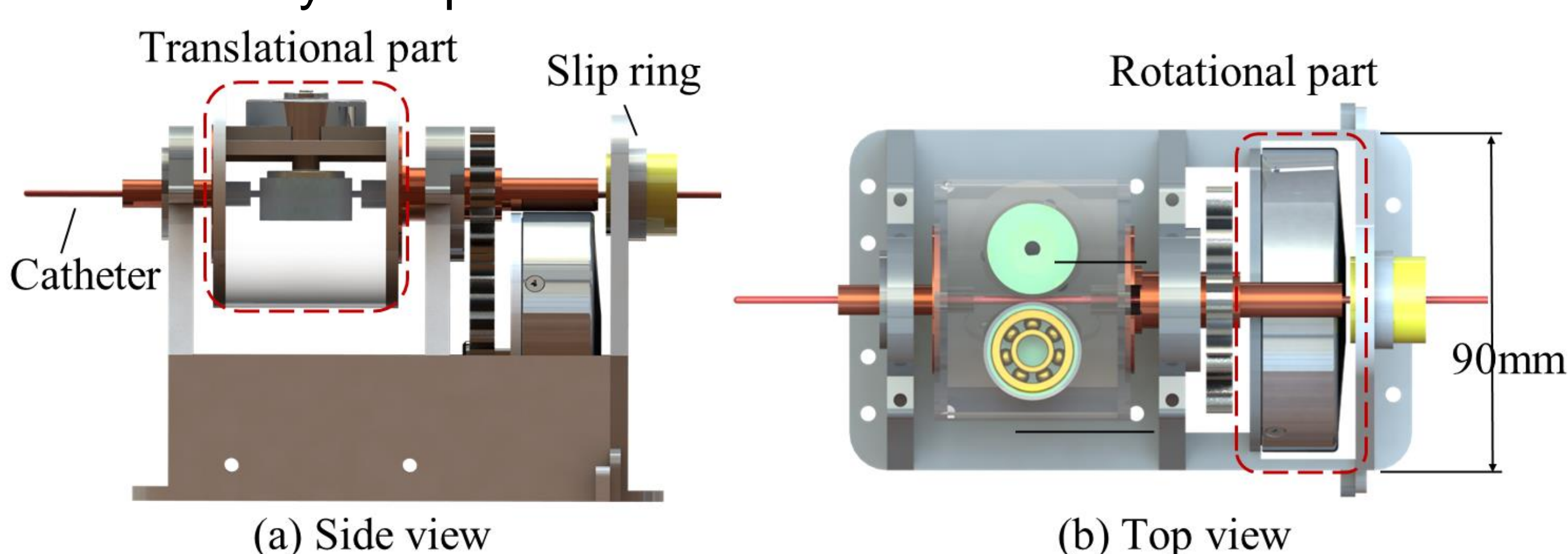
- High speed
- High precision
- High stability
- MR compatibility



Design of MR-compatible catheter robot that can achieve rotation and translation by using an ultrasonic motors and soft actuators.

- Endless rotation
- Endless translation
- Extremely compact

Rotational part and Translational part

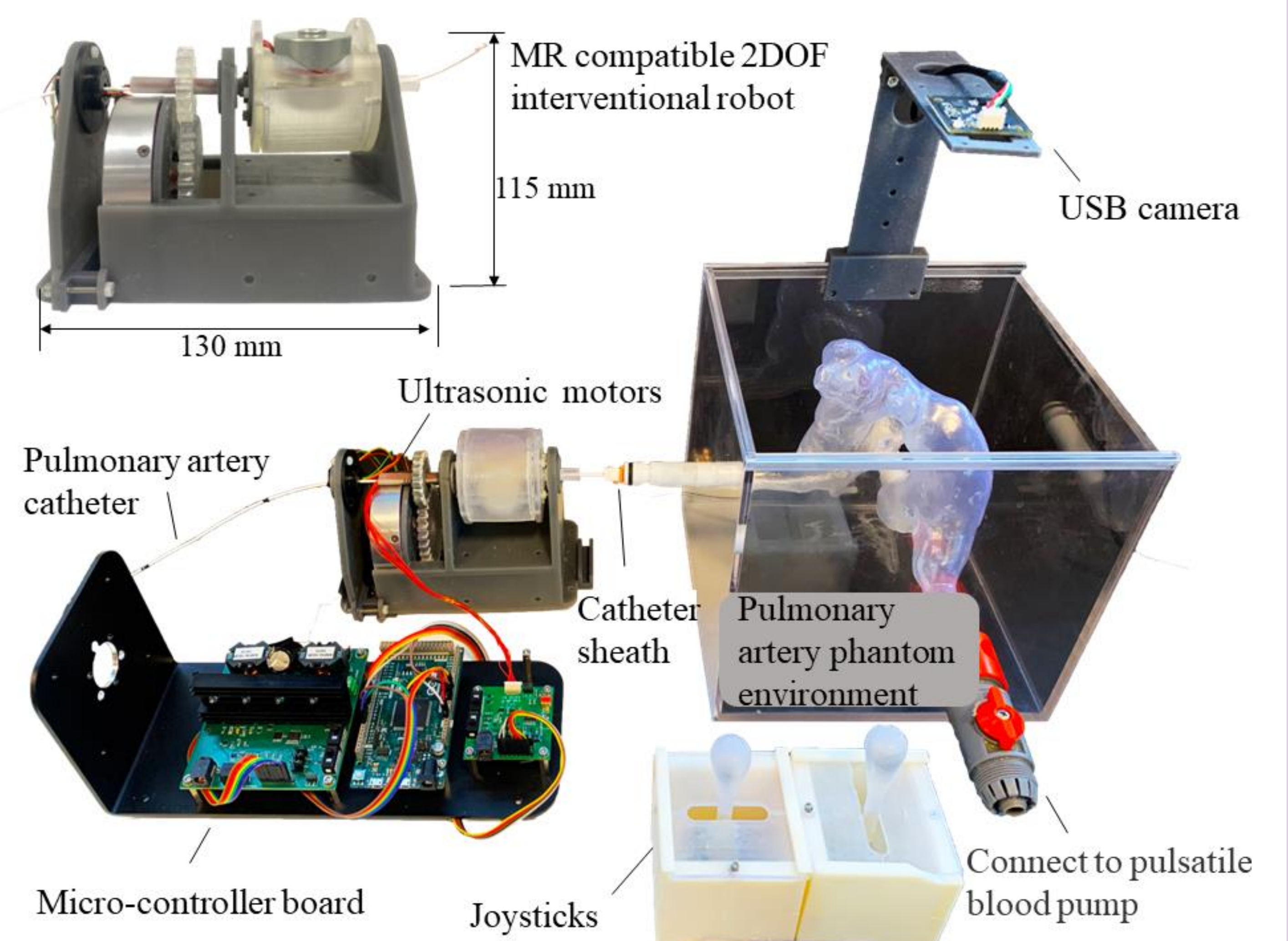


(a) Side view

(b) Top view

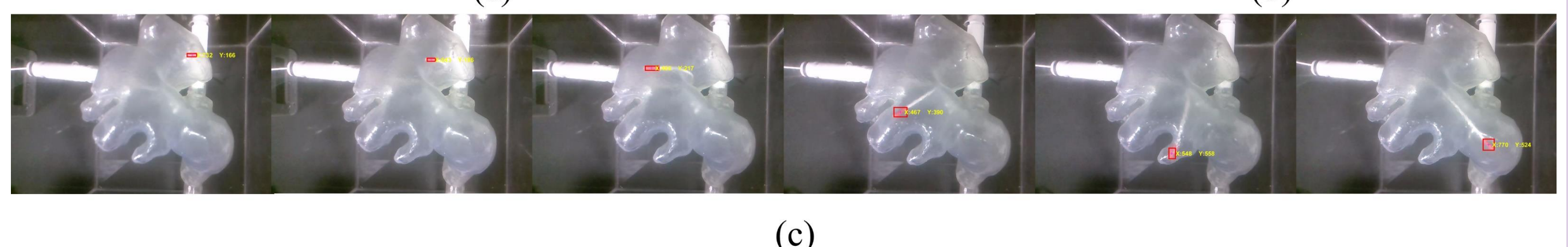
Experimental Setup and Results

Overall MR-compatible catheterization robotic system.



Experimental results:

- When the robot is in motion, there is only a 1.9% loss in SNR therefore it can be demonstrated to be MR-compatible.
- 2D tracking can be achieved using blob analysis and the position of the balloon can be output in real-time.



Conclusion

- The robot allows simultaneous and continuous translation and rotation of the catheter.
- All components of the robot manipulator are made of non-magnetic materials and their MRI compatibility has been experimentally verified.