Actuation and Control of a Steerable Catheter for Mitral Valve Repair

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Introduction: Structural Interventional Cardiology (SIC)

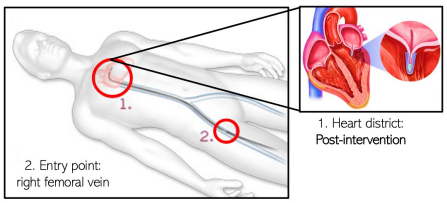


Fig. Transcatheter Mitral Valve Repair via MitraClip system

SIC procedures: treatment of Structural Heart Diseases (SHDs).

SIC procedures' **drawbacks**: not ergonomic and technically demanding, steep learning curve, unclear view of the anatomical scene [1].

The **MitraClip (MC) system** is considered as the Gold Standard for the percutaneous treatment of Mitral Regurgitation [2],[3].

Objectives

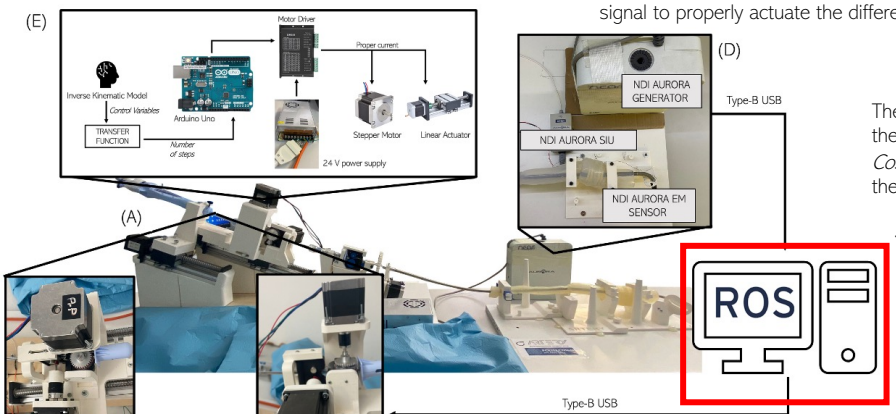
(1) Design a **robotic support platform** for the commercially-available MC system®

(2) Develop a **remote control algorithm** that autonomously drives the MC system

Materials: Development of the Integrated System

Proposed Integrated System

(E) The **controller** Arduino Uno receives, as input, the displacements that has to be given to the tendons and the linear insertion (i.e. Control Variables), after proper conversion, from the computation of the **Inverse Kinematic Model,** and produces as output the PWM signal to properly actuate the different motors.



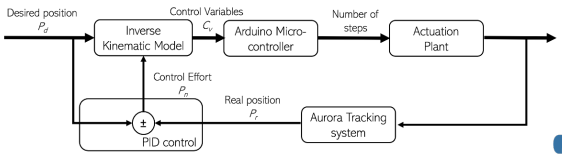
The **Inverse Kinematic Model** of the catheter, based on the combination between *Constant Curvature* (CC) and *Cosserat Rod Theory* (CRT) [2], sequentially translates the points of the path into the **Controls Variables**,

The *hardware* integration is performed in the **Robot Operating System** (ROS) framework [4], with a communication frequency of 40 Hz.

The *software* components are developed in Python Language exploiting Visual Studio.

(A), (B) and (C) Global 3D printed system with details: the **robotic actuation system** was designed in Solidworks environment, 3D printed and integrated with the actuators. The experimental setup is also composed by the NDI Aurora electromagnetic tracking system (D), which is exploited in the control section

Methods: Control Algorithm

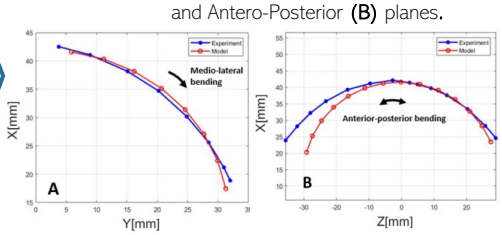


Integrated control:

- **Inverse Kinematic Model**'s computation of the Control Variables;
- **PID control**: position adjustment based on the position error, i.e. difference between the Desired Position and the Real one

Results: Model validations

Recorded Trajectory (blue) vs Model prediction (red), Medio-Lateral **(A)** and Antero-Posterior **(B)** planes.

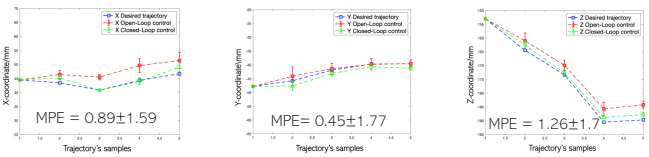


Average error:
1.55 ± 2.03 mm

Results: Integrated system

Mean Position Error [mm] among 4 sampled points of the path

Average corrections on X and Z directions: 2.63±1.59 mm and 2.18±1.7 mm respectively.



The developed control algorithm, that involved the use of an Inverse Kinematic Model and a PID position control, is able to reduce the MPE with an average value of **32.68%,** considering all the directions.

Conclusion and Discussion

This work presents the preliminary results of a **robotic-assisted system** comprised of an analytical **inverse kinematic model** based on the combination between CC and CRT that autonomously guide the system to the target, with a proper correction generated by the **PID control**.

References

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Collaborations