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Use of the CRX10iA cobot for microparticles delivery inside the cochlea

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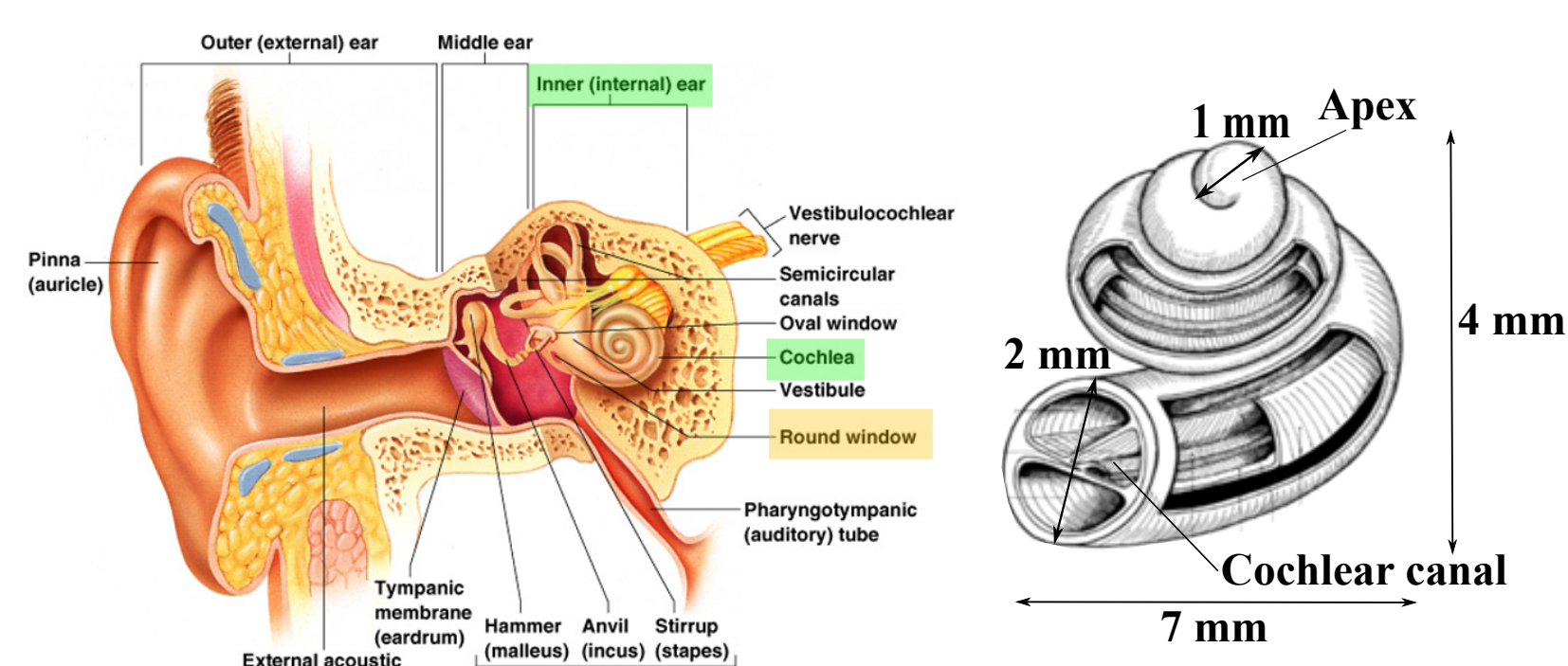
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MOTIVATION

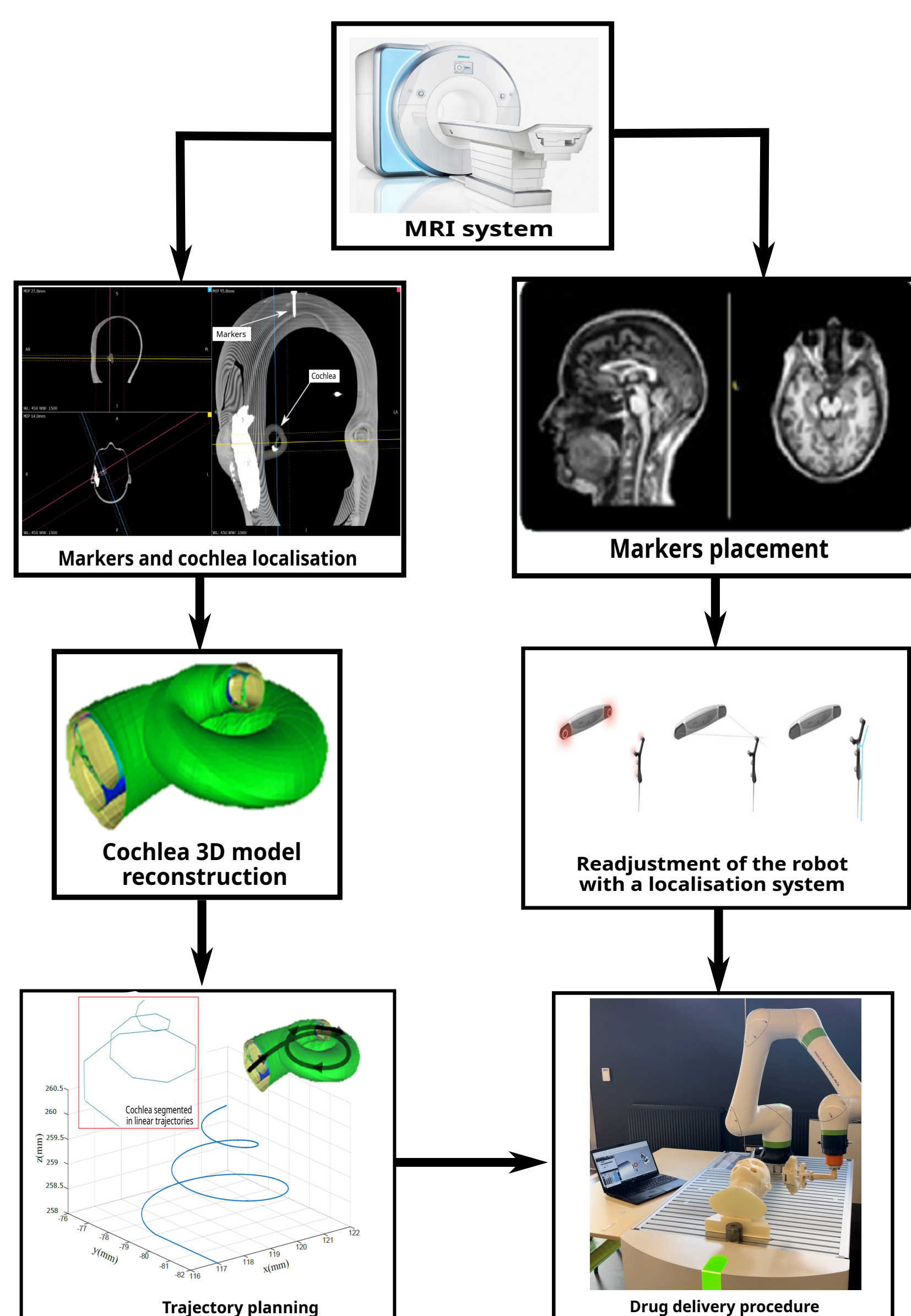
Nanotechnology has shown to be efficient for targeted ear therapy. The use of magnetic nanoparticles, as a drug carrier system, actuated by permanent magnets has proven its capacity to ensure accurate targeting.



The aim of this work is to study the capacity of a cobot-based platform to meet the clinical need to deliver drugs into the inner ear. The robotic challenge is to ensure the position control of a magnetic end-effector while guaranteeing safety.

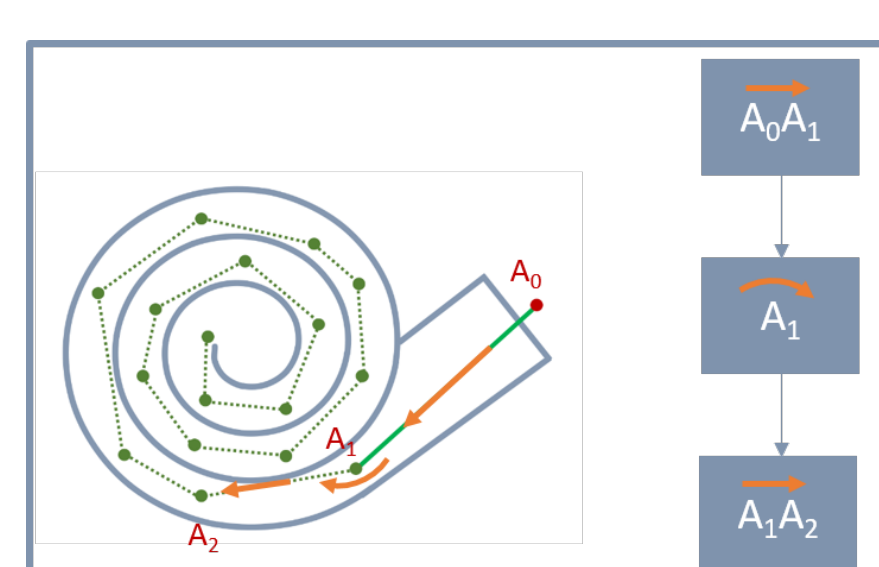
CLINICAL PROTOCOL

A preoperative phase is required to collect patient's anatomical and biological data. These data allow to generate a dedicated and optimal trajectory as a means to virtually simulate the process of direct drug delivery in the cochlea. This helps improve the diagnosis' quality and evaluate the treatment's effectiveness.



LAGRANGE POINT

The magnetic field, generated by the effector, presents characteristic points called "Lagrangian points". However, only the second one is exploitable. Indeed, magnetic forces converge to L_2 and cancels out at this point. It is then easy to trap magnetic particles by pushing or pulling them from, or to, L_2 Lagrangian point.

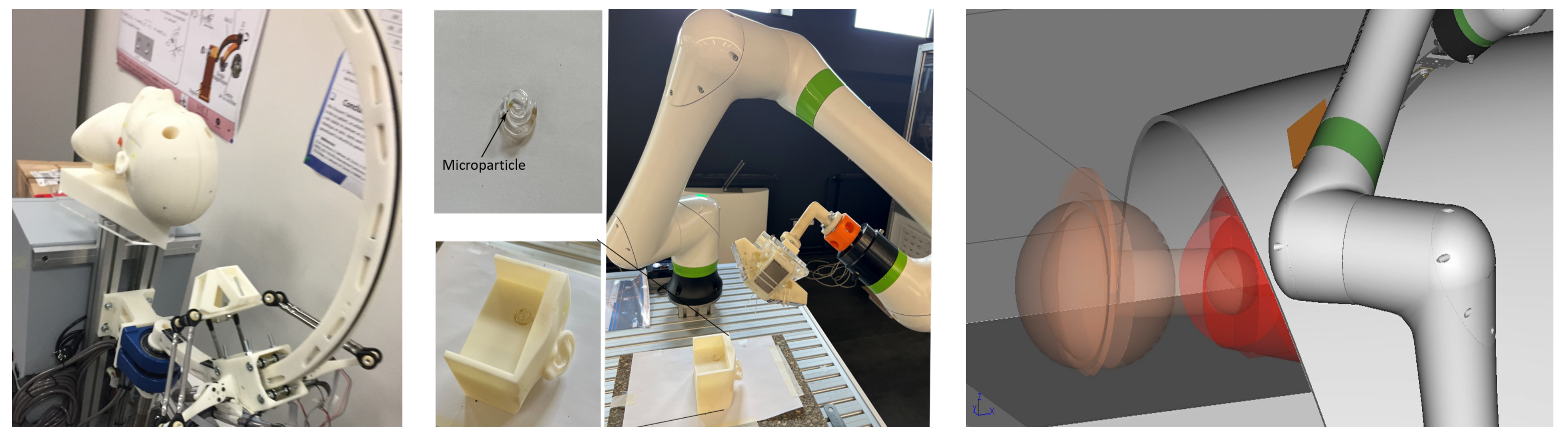


EXPERIMENTAL TRIAL PROTOCOL

A virtual platform was developed for laboratory experimentation including a virtual patient's head, a real size glass facsimile cochlea, the magnetic effector and a manipulator.

In our previous work, a **5 DoF manipulator** dedicated to inner ear drug delivery was developed. However to fully meet the medical requirements in terms of safety but also accuracy, we propose a novel approach using a **cobot**.

A virtual cell was created with *Roboguide* in order to validate the process and optimize the trajectory.



PATH PLANNING

The robot cycle is a succession of push/pull and turn motions. Four control modes are considered. 1 - The push or pull motions : we used a pseudoinverse control to define the joint parameters where d_e is the desired end-effector displacement (dim 5) and dq the joint motion's vector.

$$d_e = (dx, dy, dz, 0, 0)^t \quad \text{and} \quad dq = J_1^+(q) \cdot d_e$$

2 - The turn movements between 2 pushes or 2 pulls : L_2 must remain in the same position.

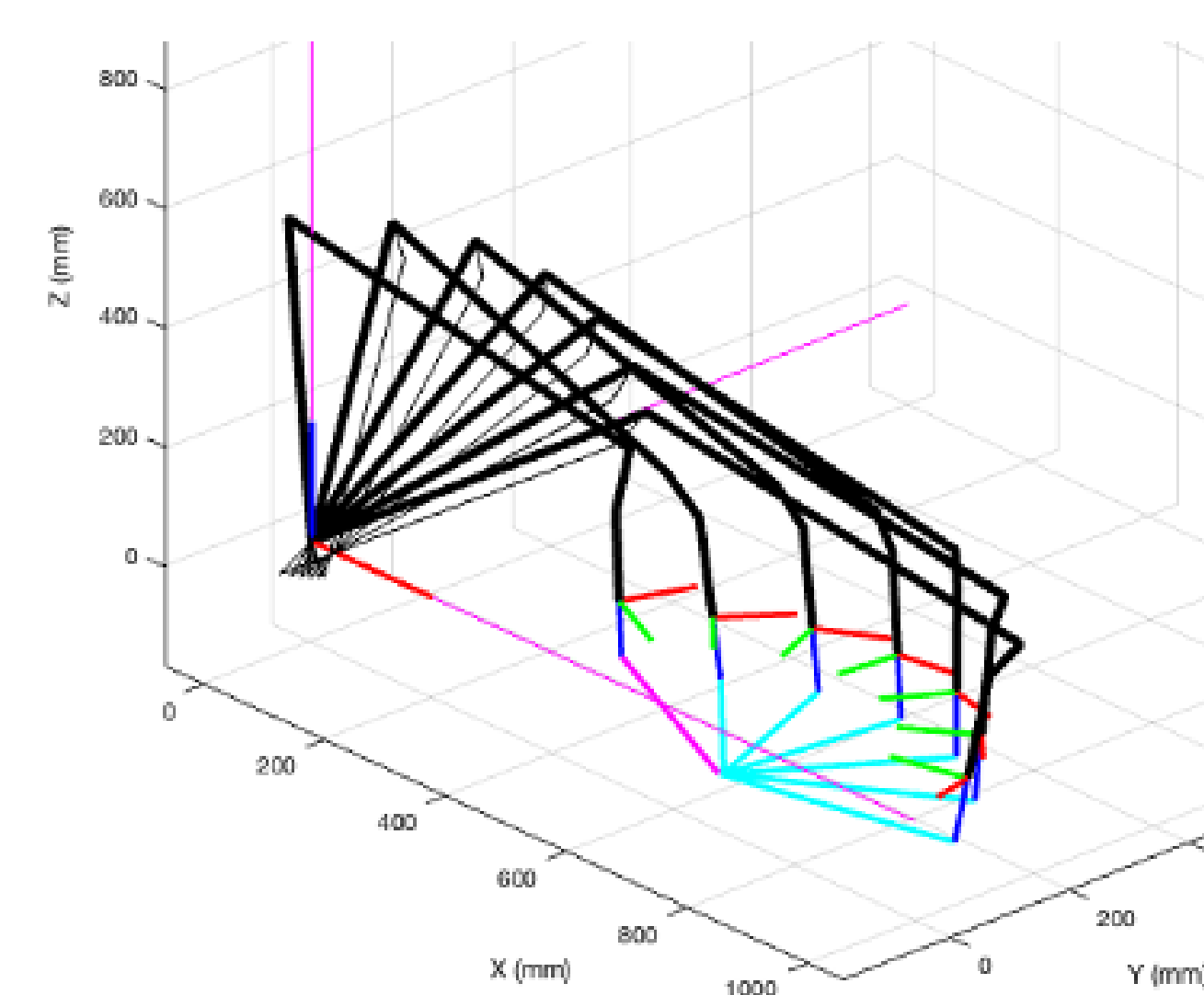
$$d_e = (0, 0, 0, d\alpha, d\beta)^t \quad \text{and} \quad dq = J_1^+(q) \cdot d_e$$

3 - Reconfiguration movements between a push and a pull or vice versa: as the range of motion is large, to preserve the L_2 immobility we performed the movement in N steps. At each step i :

$$d_e(i) = (0, 0, 0, d\alpha/N, d\beta/N)^t \quad \text{and} \quad dq(i) = J_1^+(q(i-1)) \cdot d_e(i)$$

4 - The robot approach movement towards the first position of the treatment : we used a pseudoinverse control (J_1^+) combined with the projection operator P to define the joint parameters in the first position where k is a gain coefficient and $q_0 = \partial(\det)/\partial q$

$$dq = J_1^+(q) \cdot d_e + P(q) \cdot k \cdot q_0$$



EXPERIMENTS AND RESULTS

We demonstrated in this work the ability of the complete system to navigate a magnetic particle inside a glass cochlea, by pushing or pulling it. This makes it possible to consider a magnetic-cobotic procedure to ensure targeted drug delivery into the inner ear, meeting safety requirements.

