Concentric Agonist-antagonist Robots for Neurosurgical Applications

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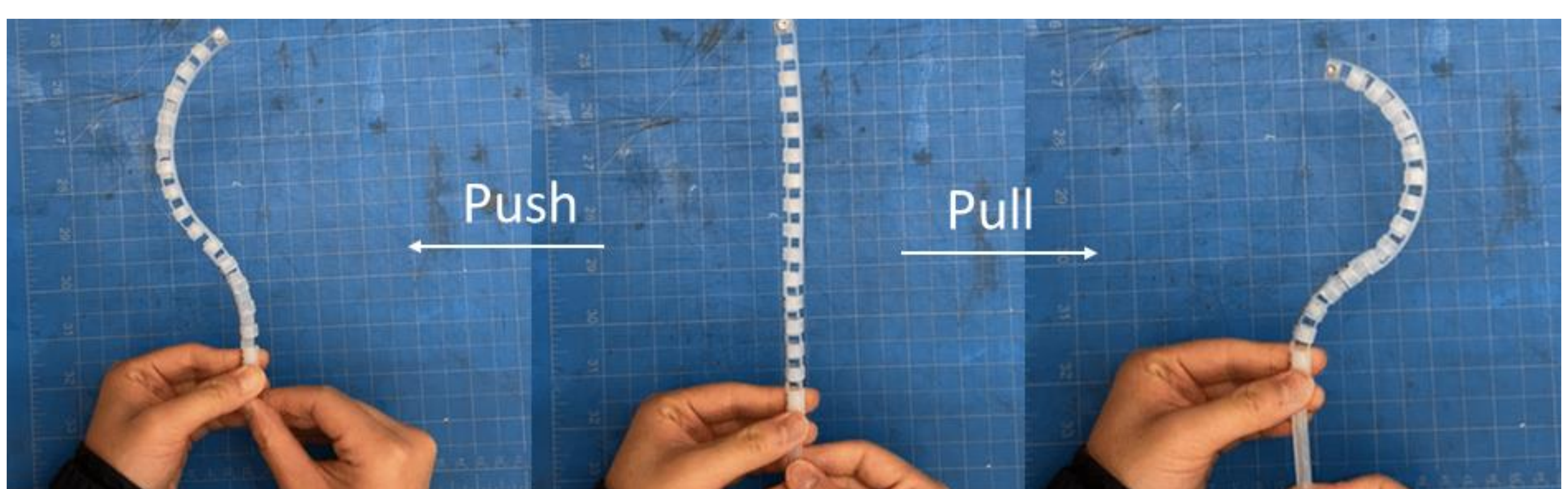
Introduction

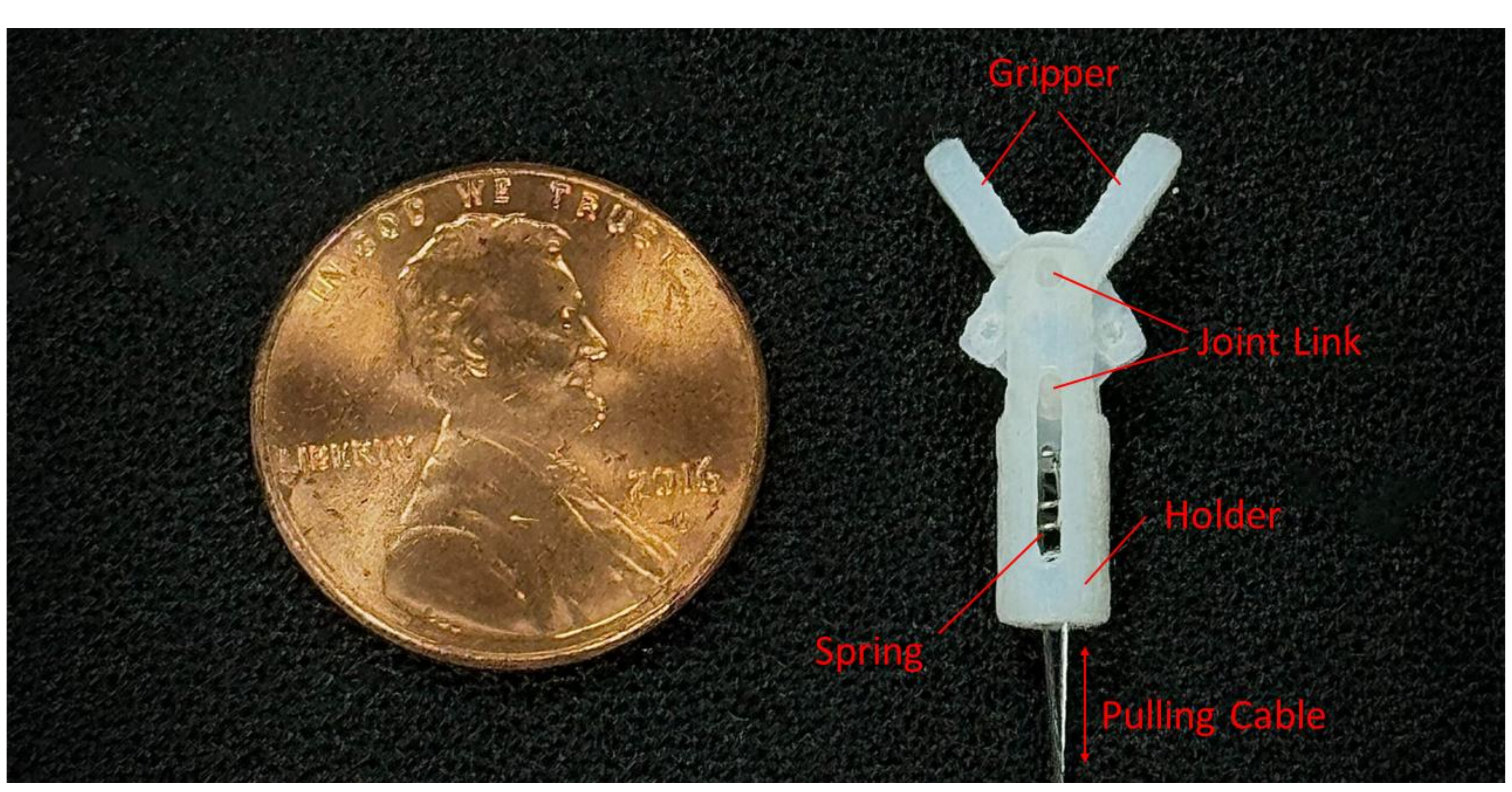
Studying and imitating the mechanisms of movement found in nature can significantly enhance the agility of neurosurgical robots in narrow or complex environments. This is particularly valuable for neurosurgical procedures that require precise positioning and manipulation within the intricate structures of the brain. **Concentric Agonist-Antagonist Robots (CAAR)**[1], by emulating the movement patterns of invertebrates in nature, hold substantial potential in the field of neurosurgery. Our objective is to develop a miniature end effector equipped with two CAARs, designed to carry out surgical actions as directed by a surgeon, through its end-mounted gripper.

Design

Two Concentric Agonist-Antagonist Robots (CAARs), each with an external diameter of **5 mm**, extending from a holder of **12 mm** in diameter[2]. They achieve various deformations through the push and pull actions of inner rods within them[1]. Additionally, both CAARs are capable of **rotation** movements within the holder, expanding the working space of each CAAR. Through coordinated control of the two CAARs, complex and precise movements are accomplished in neurosurgical operations.

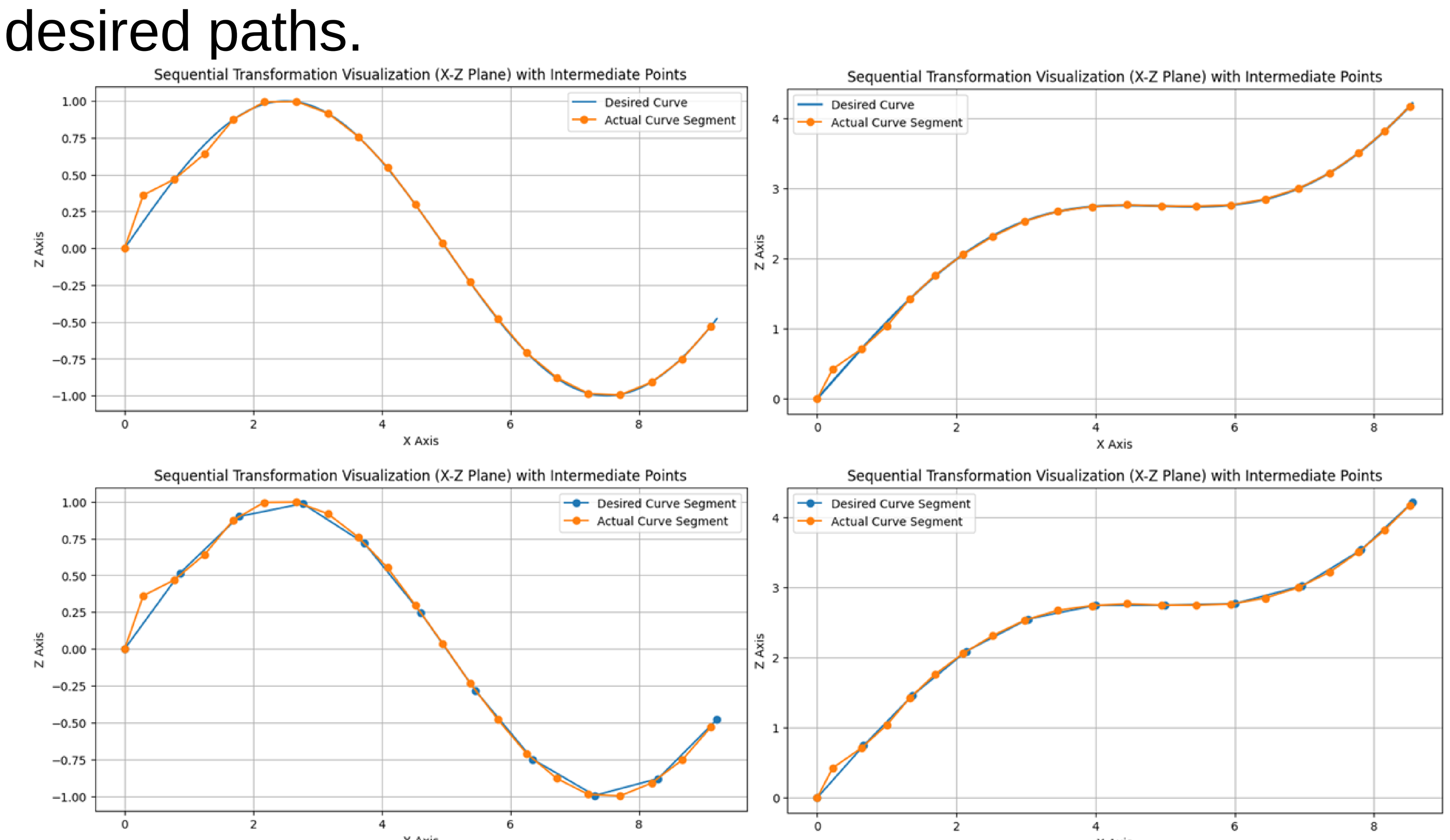


We also engineered a micro gripper that remains in an open state through a **spring** within its structure[3]. The gripper closes and grasps objects when the cable is pulled.



Optimization

Due to the complex environment of neurosurgical operations, we propose that it is necessary to pre-program the mechanical structure of the CAAR to ensure it performs tasks effectively within the target environment without causing collisions. Therefore, we determined a **Desired Curve Segment** based on the conditions of the task, which is how we want the robot to deform under specific inputs. Through optimization of the mechanical structure **with quantities and positions of notches** in the CAAR, we can achieve an **Actual Curve Segment**, which is the deformation of the robot under specified inputs[4]. As observed in our simulations, the points of the actual curve segment almost fall on the desired curve segment, indicating the potential of the design to follow desired paths.



Future Work

In current robot design, all structures are fabricated using Objet 3D printing. In the future, to create a more robust robotic system, we plan to use laser cutting to cut nitinol tubes based on optimized notch quantities and dimensions. Additionally, there's a need to design a compact, high-precision robotic control system to synchronize with the entire operation of the neurosurgical robot.

References

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