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Towards Bimanual Operation of Magnetically Actuated Surgical Instruments

Yuanzhe Deng[1], Majid Roshanfar[2], Haley Mayer[1,2], Changyan He[3], James Drake[2], Thomas Looi[2], Eric Diller[1]

[1] Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Canada

[2] PCIGITI Lab, Hospital for Sick Children, Toronto, Canada

[3] School of Engineering, University of Newcastle, Newcastle, Australia

Heidelberg, Germany

September 3, 2024

BIOROB 2024 HEIDELBERG

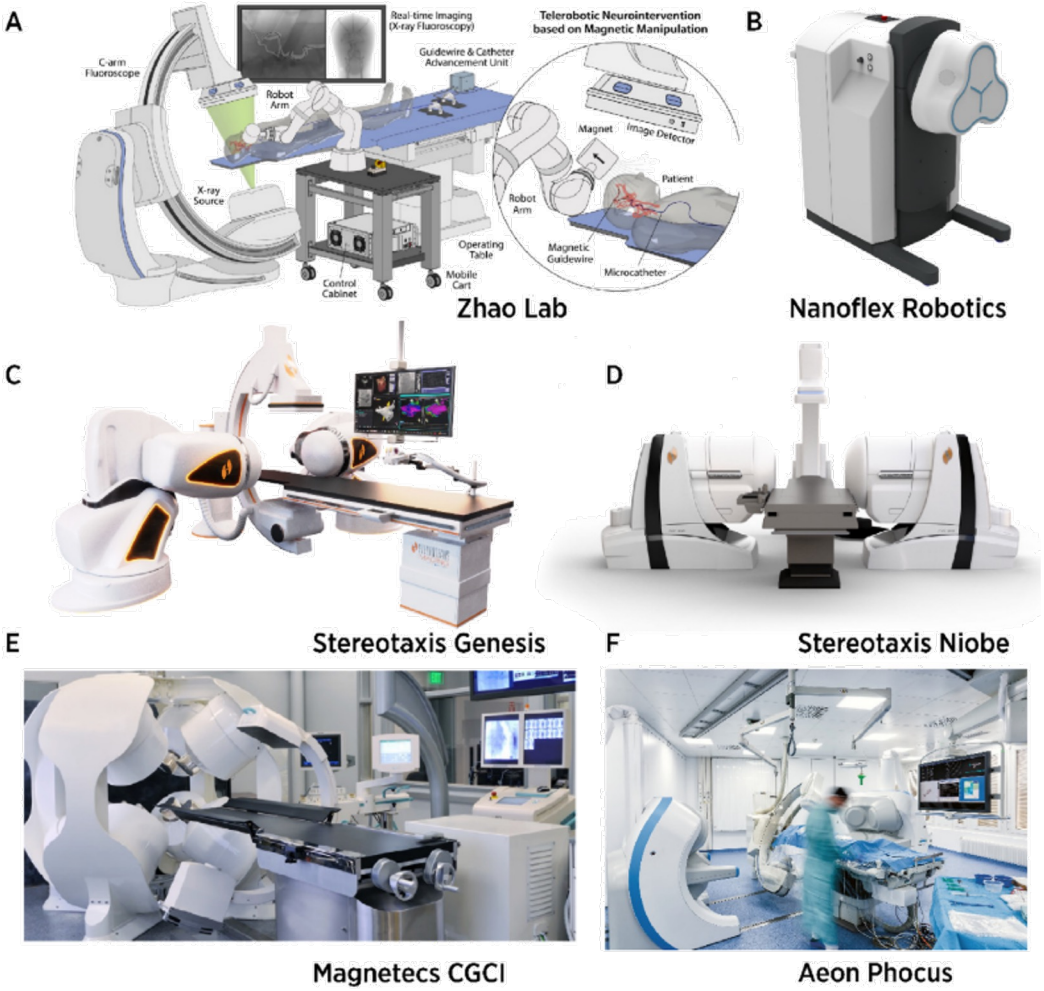
Minimally Invasive Surgery (MIS)

- Miniaturized surgical tools
- Minimized surgical traumas
- Robot-assisted MIS
  - Motion Scaling
  - Teleoperation

(Da Vinci 5, Intuitive)

Magnetosurgery

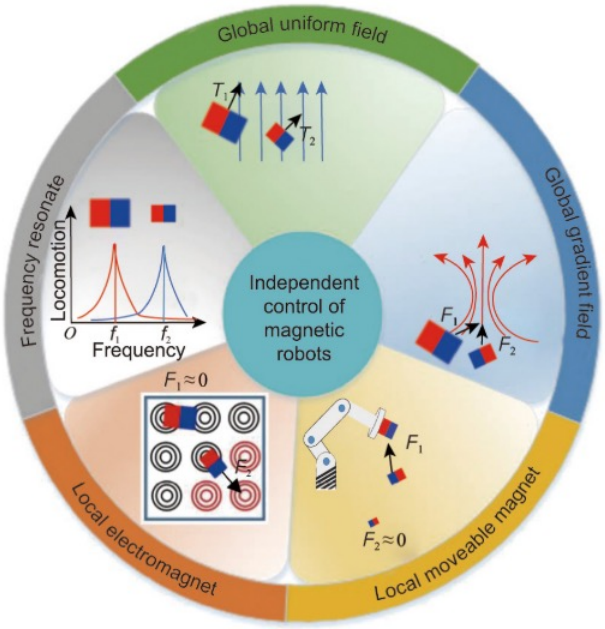
- Further miniaturized instruments
- Increased maneuverability
- Untethered operation



(D. V. Kladko et al., *Smart Materials in Medicine*, 2023)

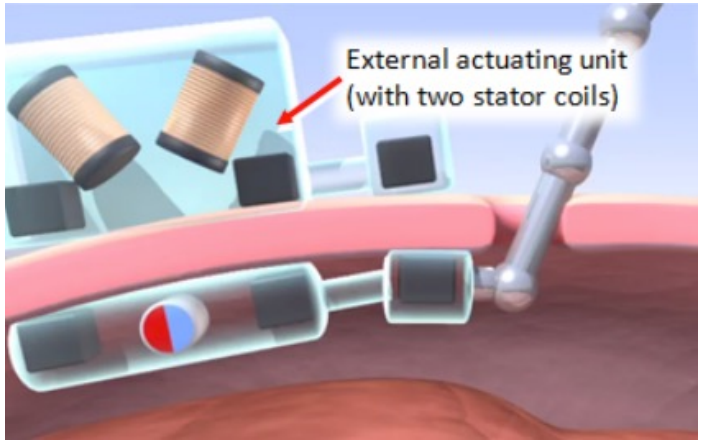
Bimanual Magnetic Actuation

Microrobots



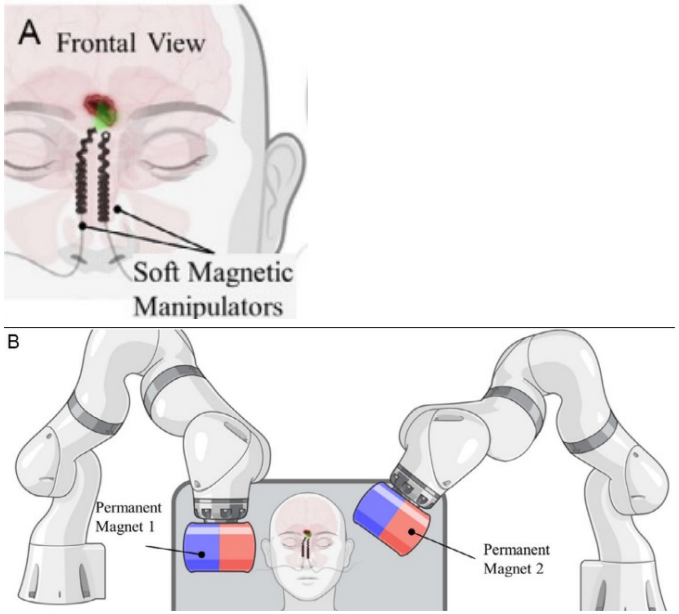
(M. Wang et al., *Engineering*, 2023)

Multiple local EM actuators



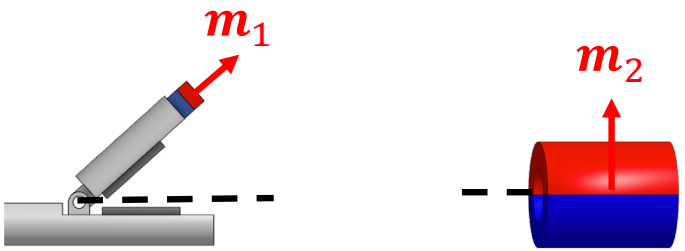
(F. Leong et al., *IROS*, 2017)

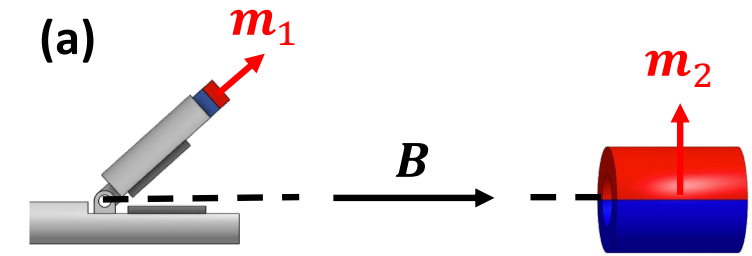
Special tool design



(Z. Koszowska et al., *Advanced Intelligent Systems*, 2023)

Can we develop a scalable approach for bimanual magnetic control?

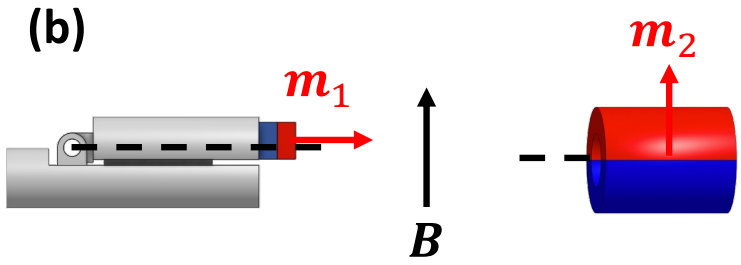




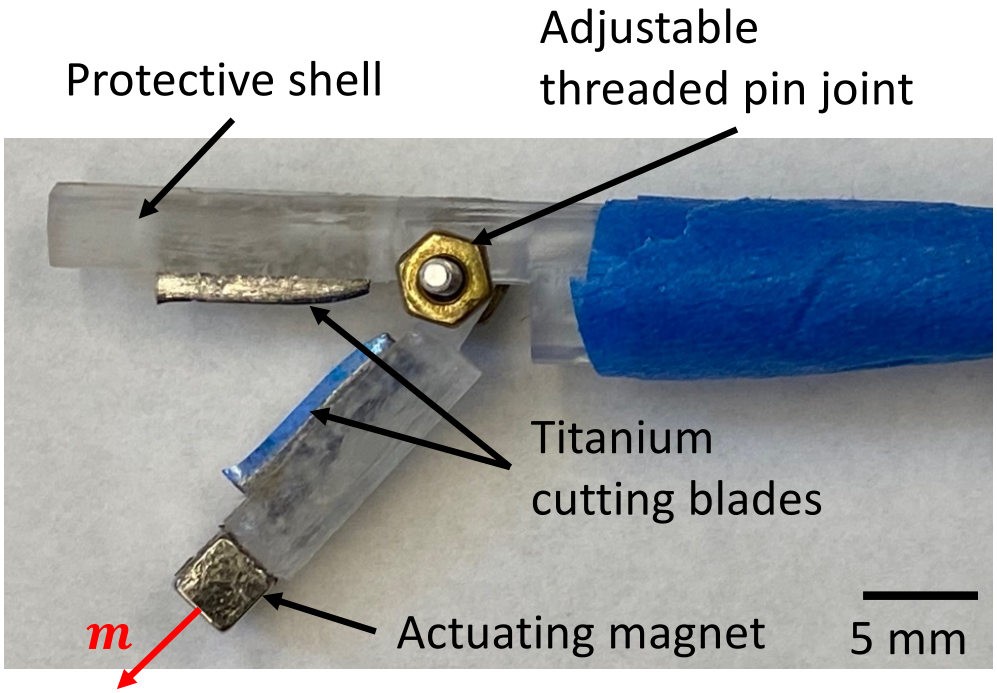
Magnetization direction of individual magnets, $\boldsymbol{m}$

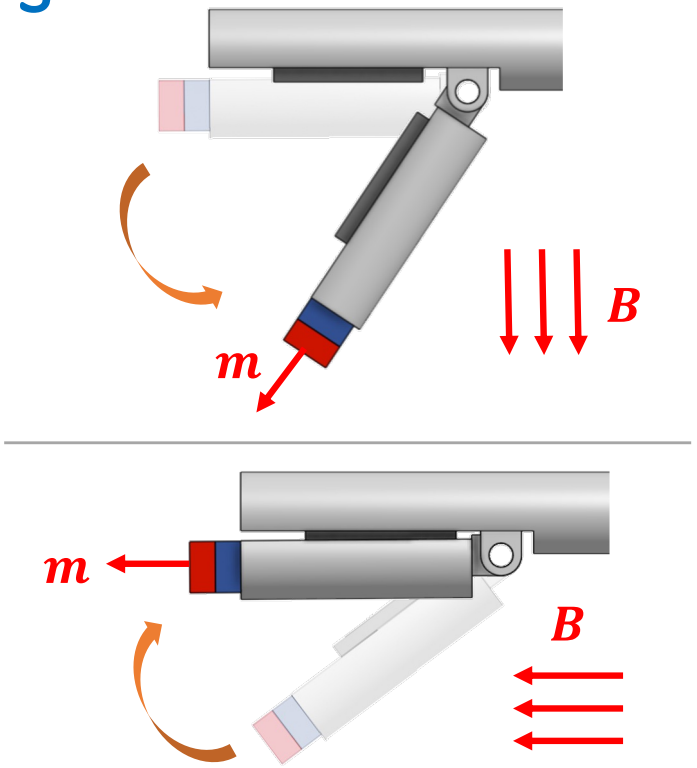
External magnetic field direction, $\boldsymbol{B}$

Torque: $\boldsymbol{T = m \times B}$



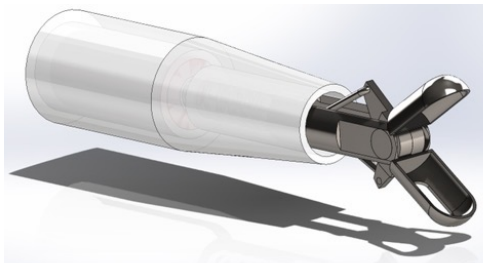
Magnetically Actuated Scissors

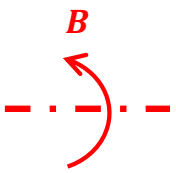




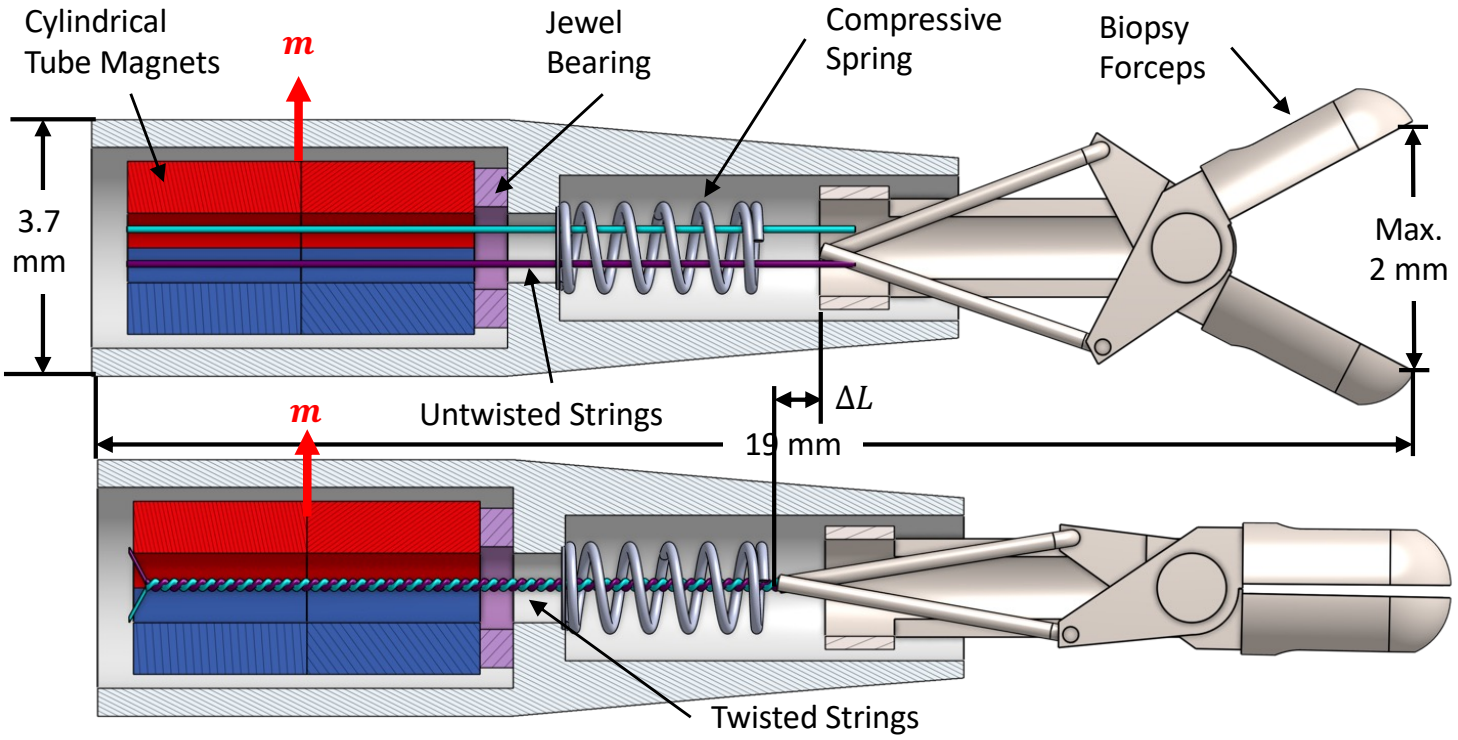
(O. Onaizah et al., *ICRA*, 2019)

Twisted-String Actuated (TSA) Gripper



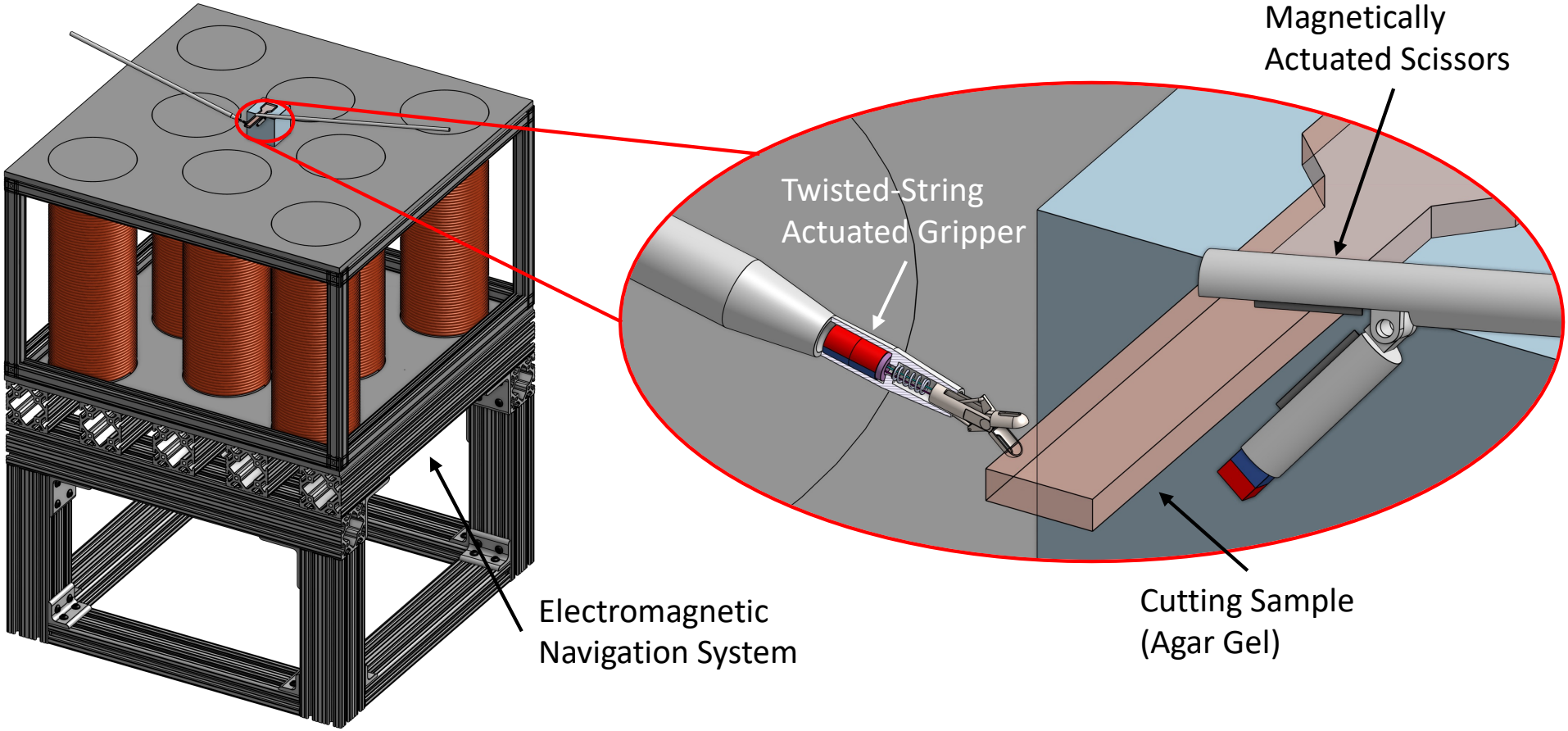


Actuated by Rotating Magnetic Field

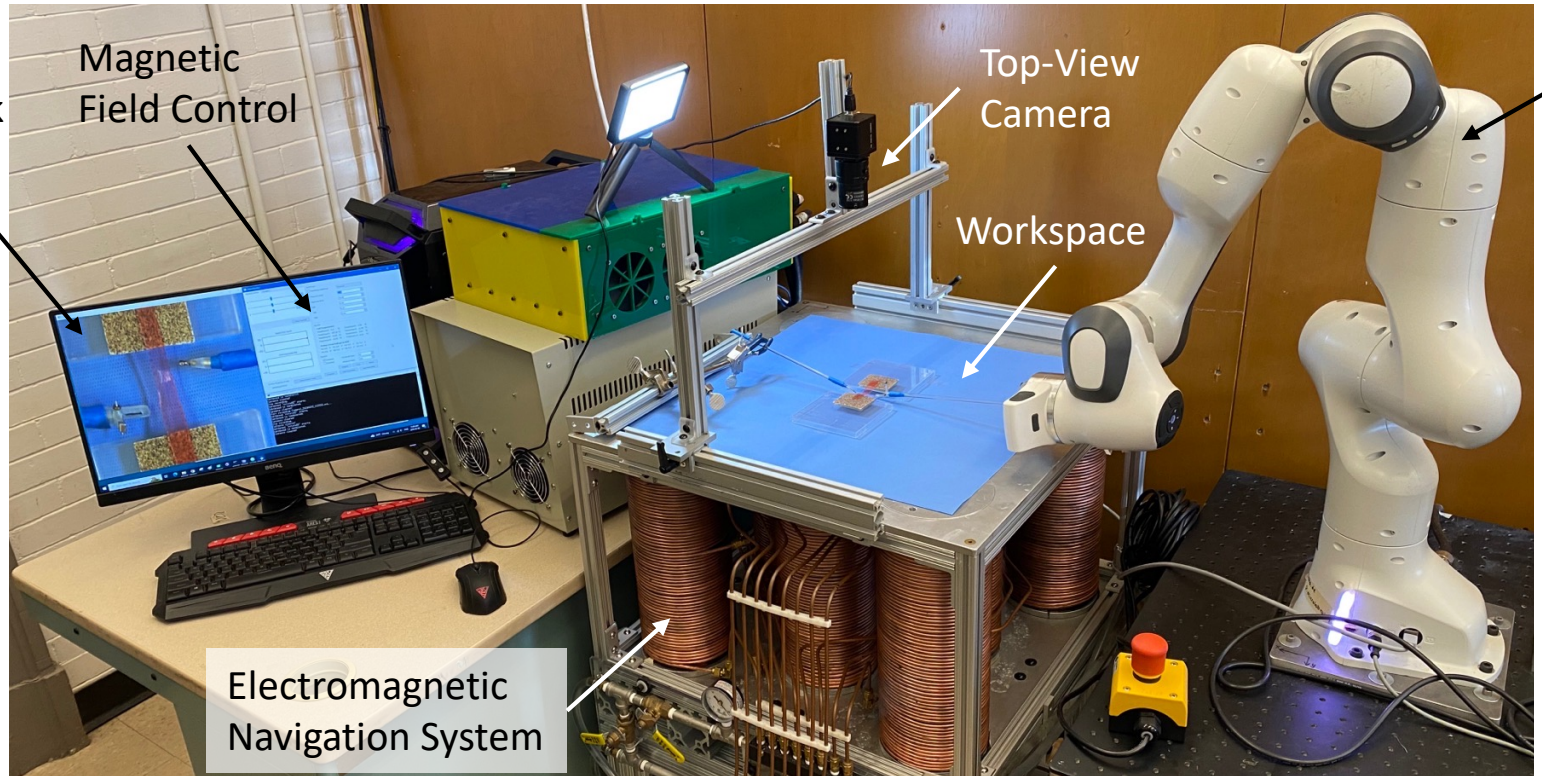


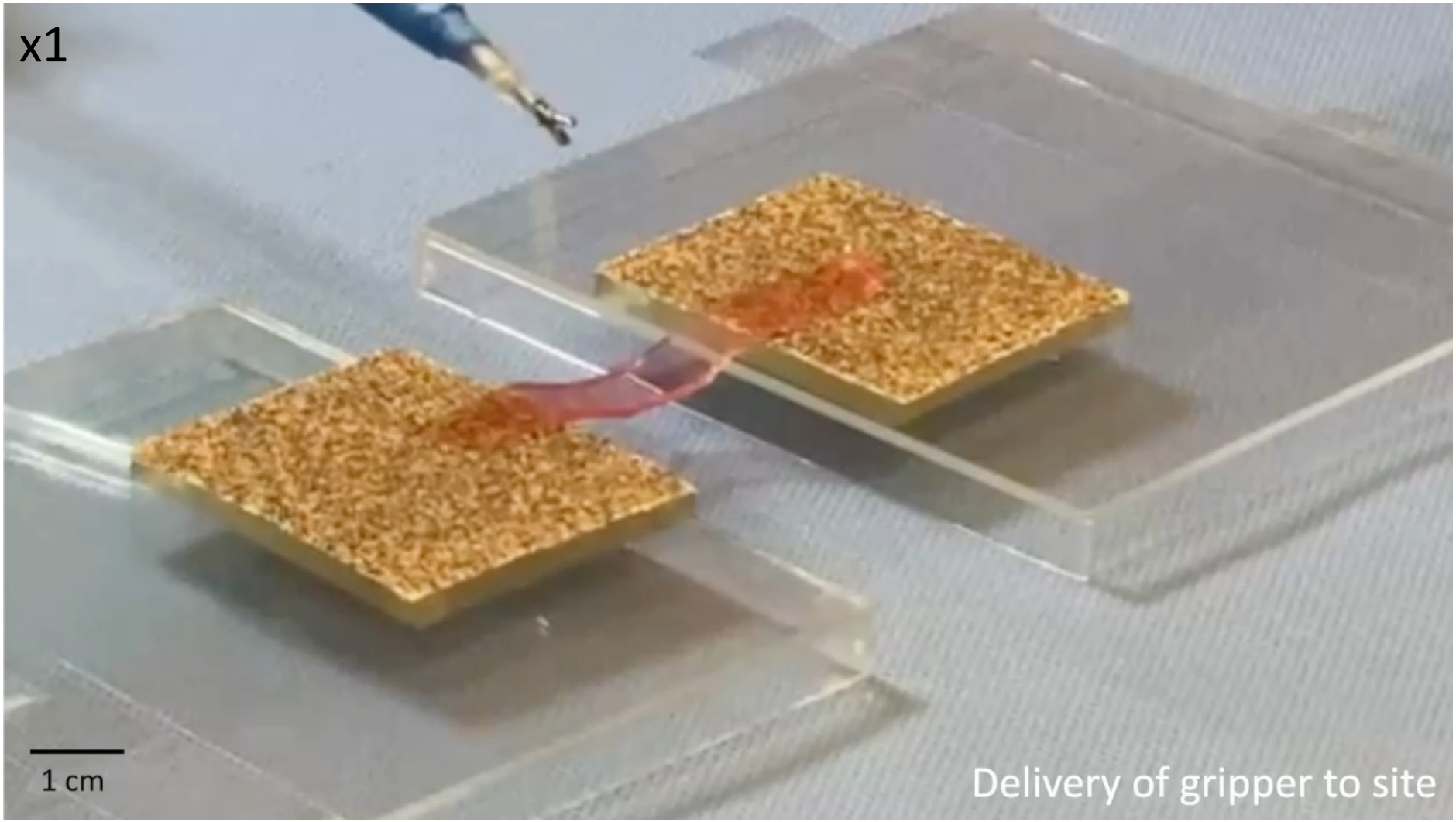
(H. Mayer et al., *Hamlyn Symposium on Medical Robotics*, 2024)

Demonstration Setup



Demonstration Setup




x1
1 cm
Delivery of gripper to site

Discussion

- **Limitation**: gripper cannot be actuated independent to scissors
- **Future work**: exploration of a wider range of instruments and bimanual surgical tasks
- **Future work**: use of untethered tools → generate magnetic field gradients for movement control
- **Outlook**: diversification of magnetic actuation modes for future design of surgical tools

Thank you!

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yuanzhe.deng@mail.utoronto.ca

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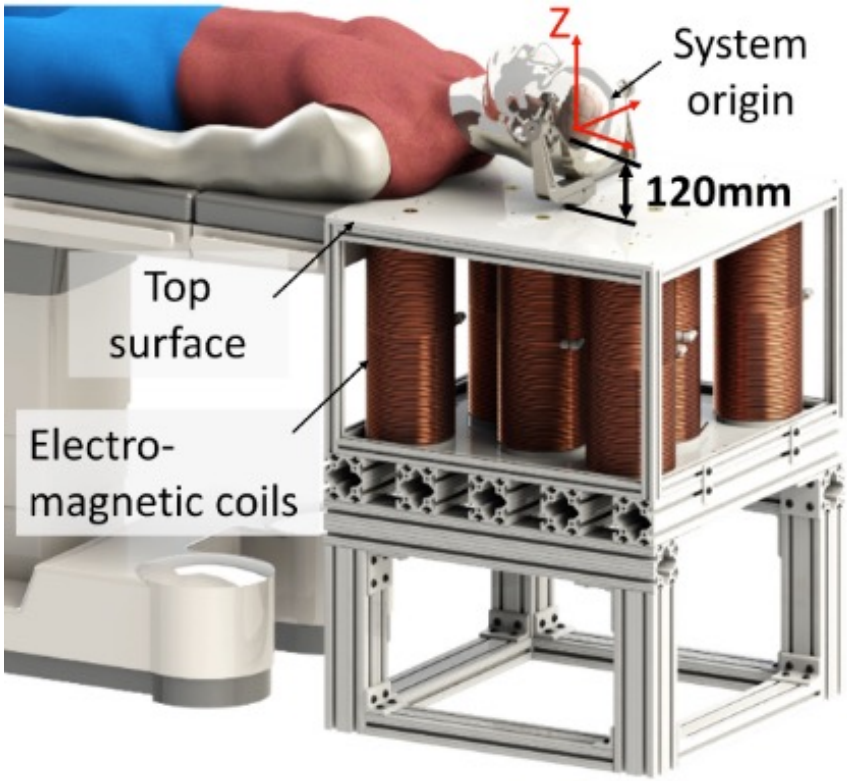
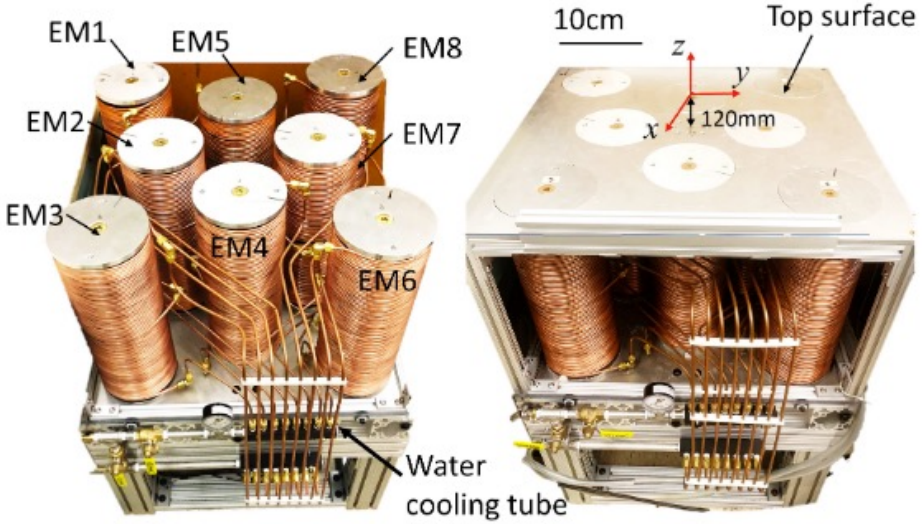
Electromagnetic Navigation System



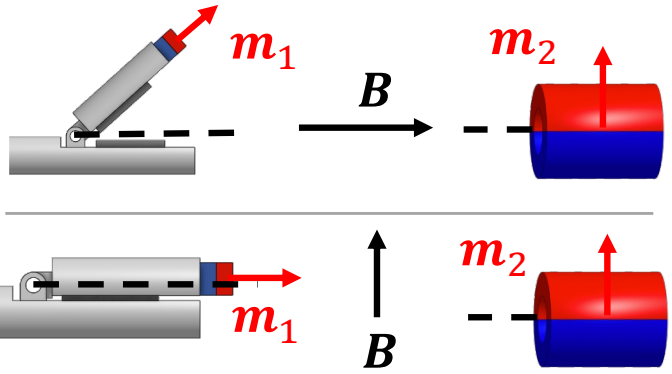
(A. Schonewille et al., *IEEE Trans. Med. Robot. Bionics*, 2024)

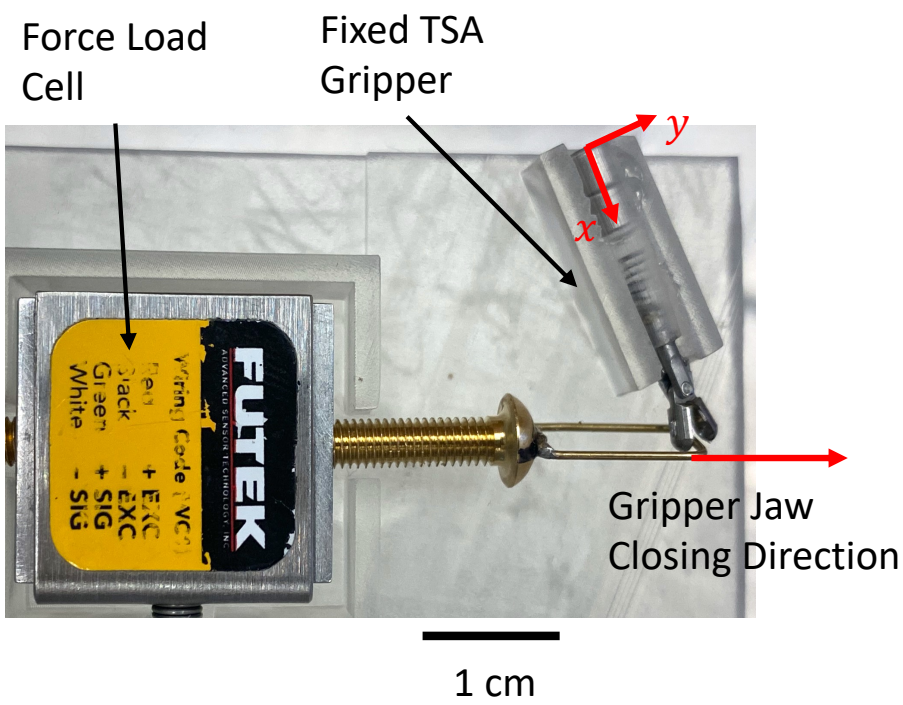


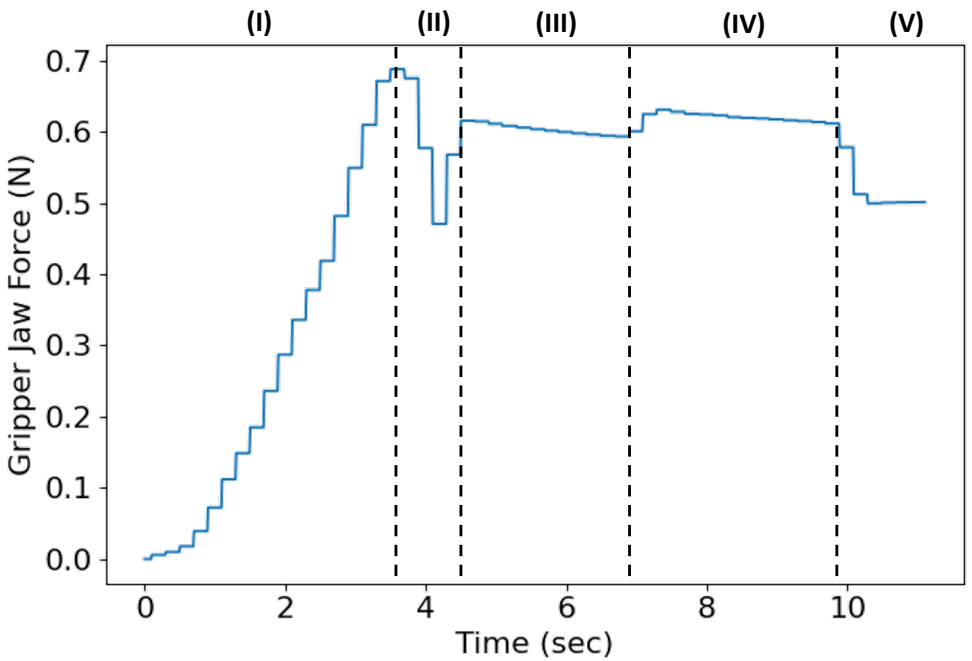
CALIBRATED MAXIMUM MAGNETIC FIELDS (UNIT: MT)

		max B_x	max B_y	max B_z
Uniform control	B_x	11.7	0.0	0.0
	B_y	0.0	11.4	0.0
	B_z	0.0	0.0	19.3
Non-uniform control	B_x	38.0	0.0	0.0
	B_y	0.0	38.2	0.0
	B_z	0.0	0.0	47.8

Bimanual Magnetic Control







Bimanual Magnetic Control