Mixed Reality Based Teleoperation and Visualization of Surgical Robotics

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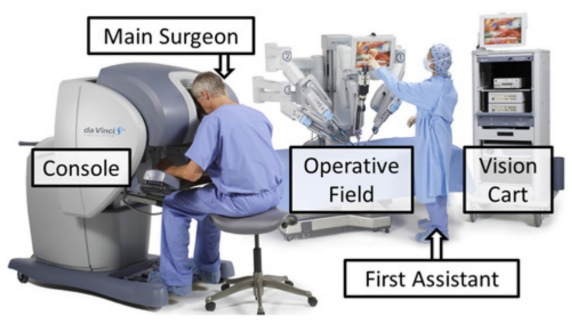
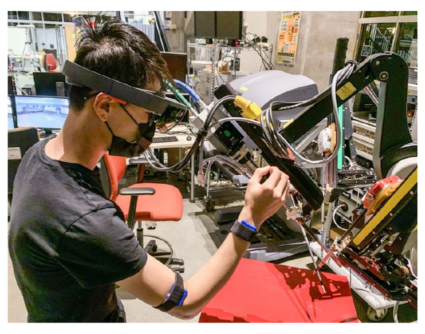
Background & Motivation

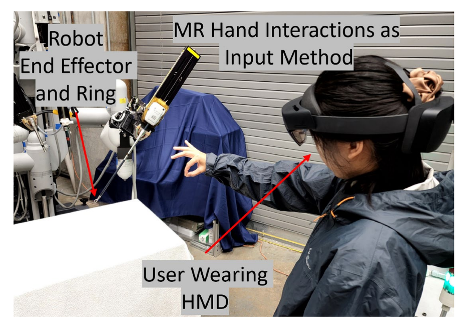
- Surgical robotic systems limit the mobility of surgeons[1][2]
- Mixed Reality (MR) can enable mobile teleoperation and visualization of endoscopes
- Prior work – Mobile teleoperation[1] & MR teleoperation[2]
  - Enable mobile teleoperation through IMUs or MR HMD



da Vinci system

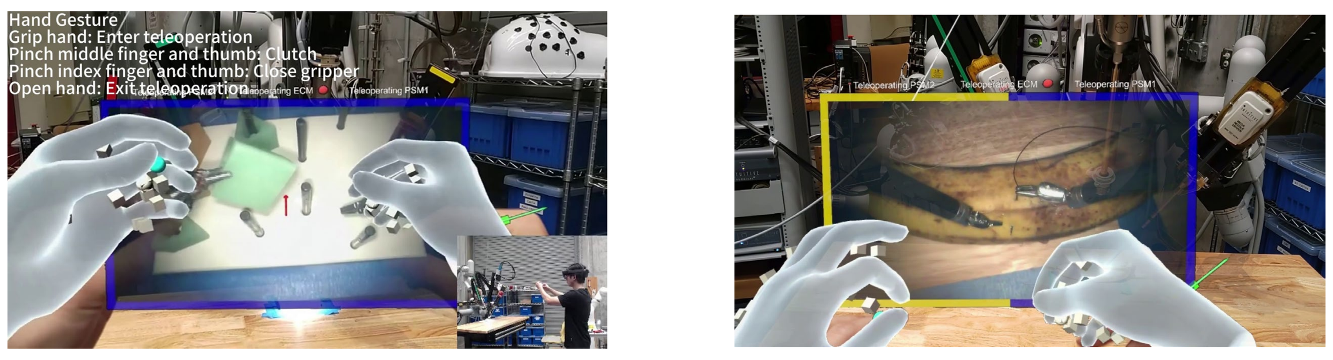


IMU teleoperation[1]



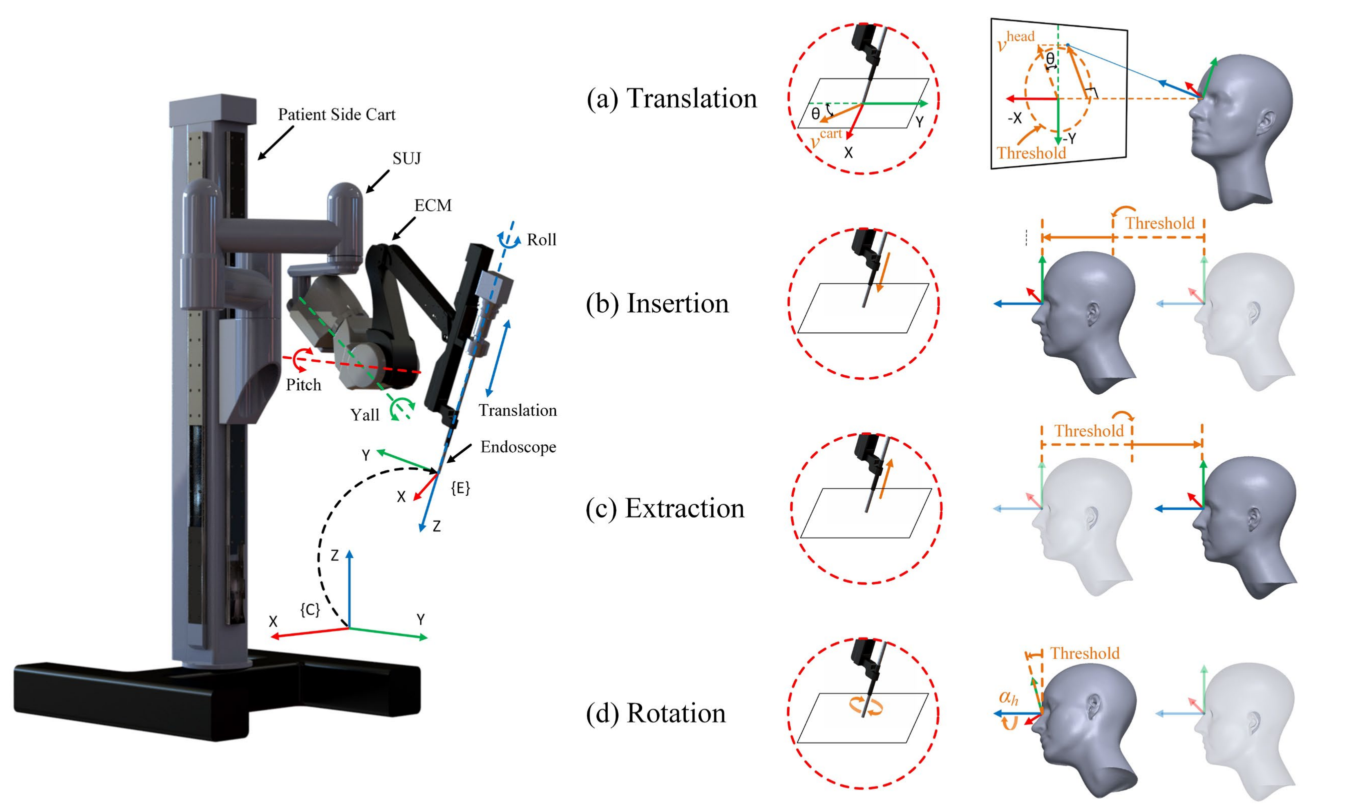
MR teleoperation[2]

- Provide extra mobility and flexibility to the user
- Single PSM teleoperation only
- Lack of stereoscopic video display
- ***Goal: Teleoperation of surgical robots and endoscopic video display***

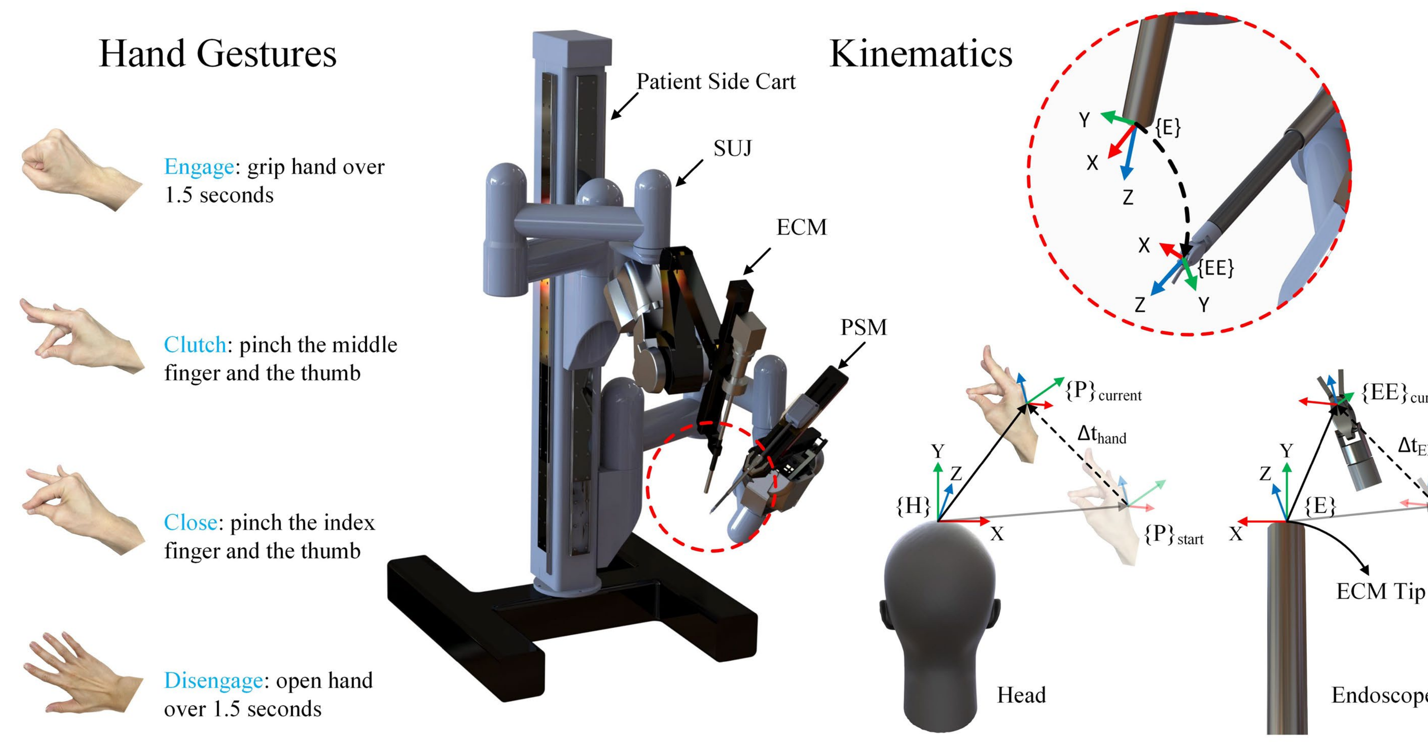


MR based teleoperation and visualization system implemented on peg transfer task and banana suturing task.

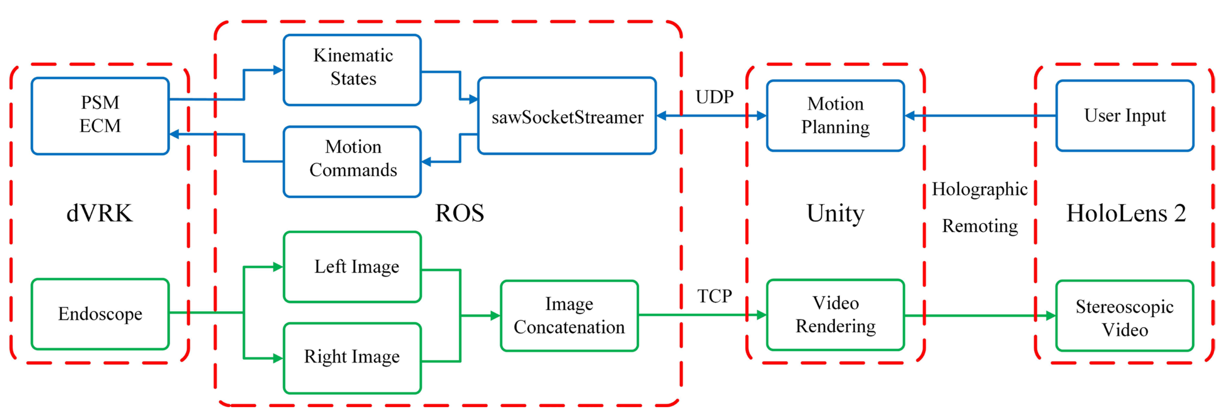
System Description



Endoscope teleoperation scheme.



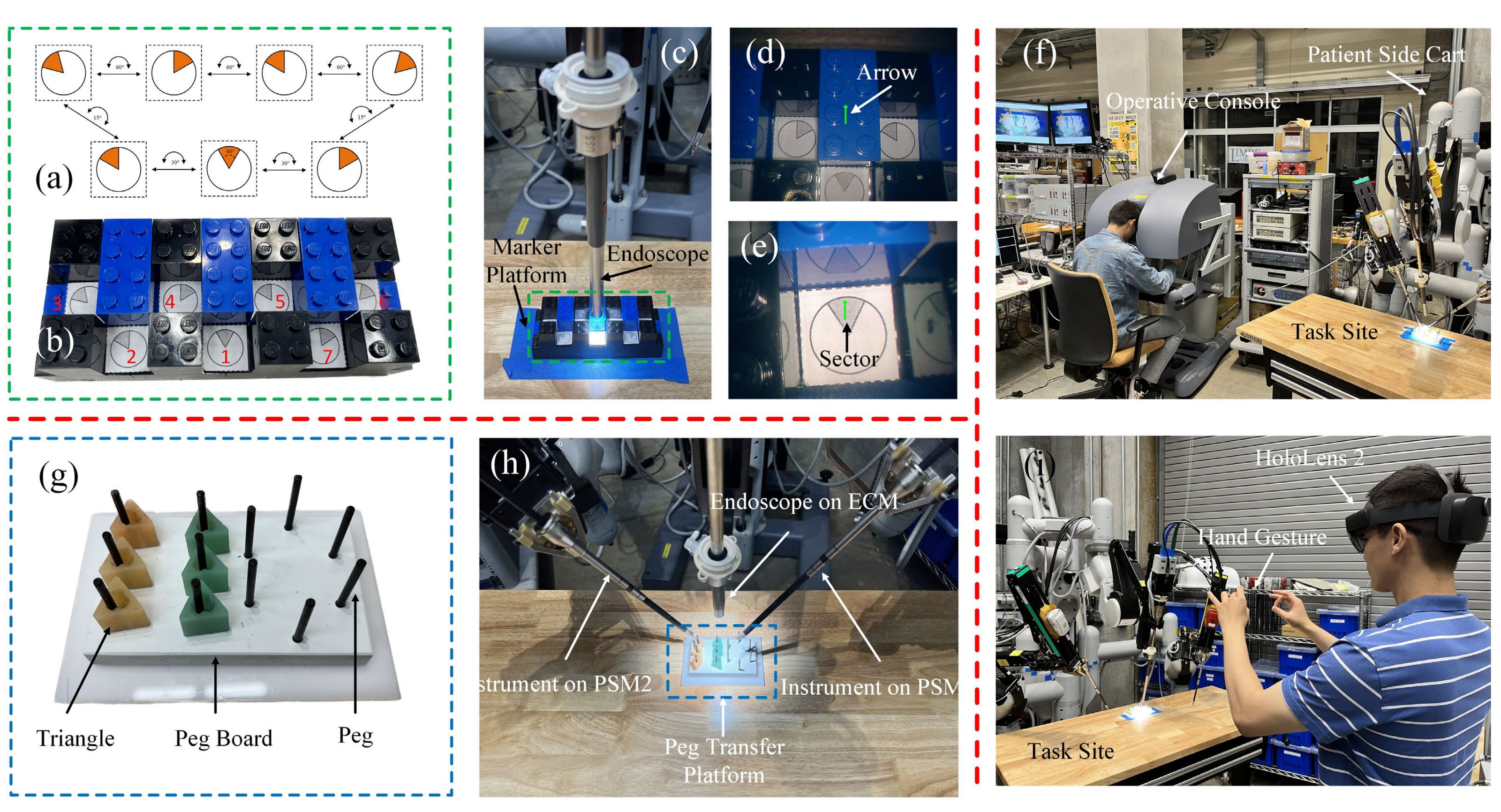
Instrument teleoperation scheme.



The network architecture between dVRK and HoloLens 2.

- *Endoscope teleoperation: Decouple the movement of the endoscope into planar translation, insertion, extraction, and rotation.*
- *Instrument teleoperation: Four hand gestures are used to engage, clutch, close, and disengage the instrument.*
- *Endoscope video streaming and rendering: Stream the video via the ROS network and use Holographic Remoting on HoloLens 2.*

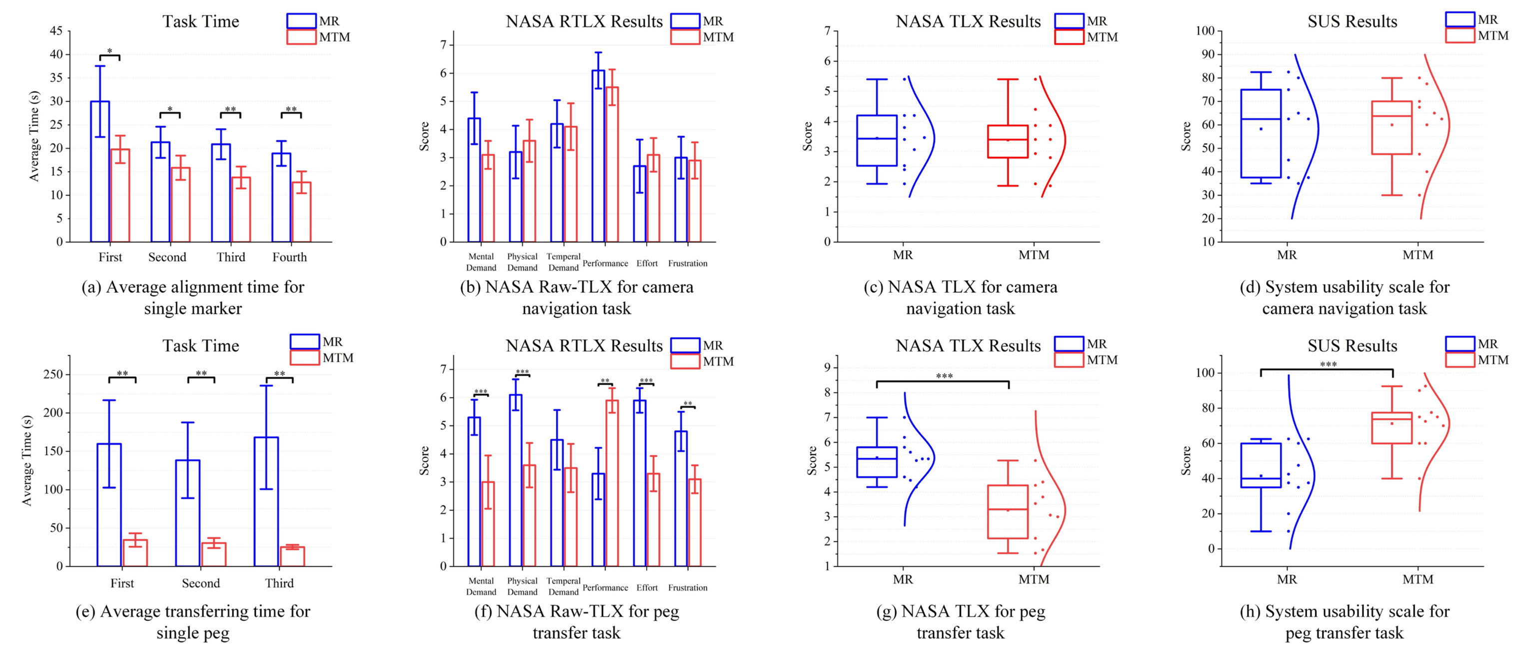
Experiment & Results



Endoscope navigation task (a-e) and peg transfer task(g-h). Endoscope navigation task : (a) Seven markers embedded with rotated sectors. (b) Marker platform housing markers. (c) The endoscope is positioned above the marker platform. (d) An arrow is overlayed on the endoscopy video. (e) The alignment of the arrow with one of the sectors. Peg transfer task: (g) Components of the peg transfer platform. (h) Task site with peg-transfer platform, endoscope, and instruments. (f) and (i) are users performing the tasks using conventional console and the MR method, respectively.

Table of Evaluation results for the endoscope navigation task and peg transfer task. A total of 10 endoscope navigation tasks and 10 peg transfer tasks were conducted, including 3 pilot tasks for each task type.

Tasks	Statistics	Average Time (s)				NASA TLX		SUS	
		MR			MTM	MR	MTM	MR	MTM
		Pilot	Revised	Overall					
Endoscope Navigation	Mean	29.49	19.88	22.76	15.54	3.44	3.39	58.25	60.00
	Std	11.46	7.67	9.88	5.62	1.02	1.08	18.26	16.16
Peg Transfer	Mean	280.00	102.07	155.45	30.11	5.38	3.27	41.5	71.25
	Std	99.50	68.61	113.38	13.19	0.84	1.23	17.61	15.29



Evaluation results for the endoscope navigation task and peg transfer task. (a) and (e) show the average time taken to align one marker and transfer a triangle in each trial, respectively. (b), (c), (f) and (d) show the NASA (R)TLX results. (d) and (h) denote the usability scale in the two tasks.

Discussion & Conclusion

- *We proposed a novel teleoperation and visualization method based on MR and implemented it on the dVRK with the use of HoloLens 2.*
- *To evaluate the viability of the system, we conducted a camera navigation task and peg transfer task.*
- *The teleoperation scheme for the endoscope is comparable to the conventional method whereas the it has limitations in the peg transfer task, primarily due to inaccurate hand gesture recognition.*

Future Work

- *Improve the hand gesture recognition and video display quality.*
- *Conduct experiments that further shows the advantages of the system.*
- *Implement the system in other teleoperated robots.*

References

[1] Fu, G., Azimi, E., & Kazanzides, P. (2021). Mobile teleoperation: Feasibility of wireless wearable sensing of the operator's arm motion. In 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 4238-4243). IEEE.

[2] Chen, An Chi, Muhammad Hadi, Peter Kazanzides, and Ehsan Azimi. "Mixed Reality Based Teleoperation of Surgical Robotics." In 2023 International Symposium on Medical Robotics (ISMR), pp. 1-7. IEEE, 2023