LABORATORY FOR Computational Sensing + Robotics

JOHNS HOPKINS WHITING SCHOOL of ENGINEERING

Mobile Telesurgery Platform in Mixed Reality

Student: Guanhao(Dean) Fu
Mentor: Peter Kazanzides, Ehsan Azimi

Grand Goal

- Lower cost
- Sterile bedside operation(solo)
- Mobile

Novel Surgeon Console!

Non-sterile, stationary

Sterile, mobile

https://ciis.lcsr.jhu.edu/lib/exe/fetch.php?media=courses:456:2020:cis_ii_mobile_telesurgery.pptx

Project Goal

- Design a wearable system that
  - Captures surgeon's arm motion in 3/4DOF at tool (palm)
  - Can control state-of-the-art robot such as UR3 or dVRK
  - Has high precision in position control of the slave robot
  - Has a similar workspace as the Da Vinci's MTM
  - Has a way to recognize surgeon's intention to engage/disengage with the system (rules of engagement)

Deliverables

- Minimum Deliverable:
  - Joint measuring system that captures full motion of single human arm (3/4 DOF at tool), virtual demo in Rviz
- Expected Deliverable:
  - Physical demo of Teleoperation using UR3/dVRK, with rules of engagement clearly working
- Maximum Deliverable:
  - Achieve 6 DOF motion capture of human arm

Technical Approach

IMU

Pros:

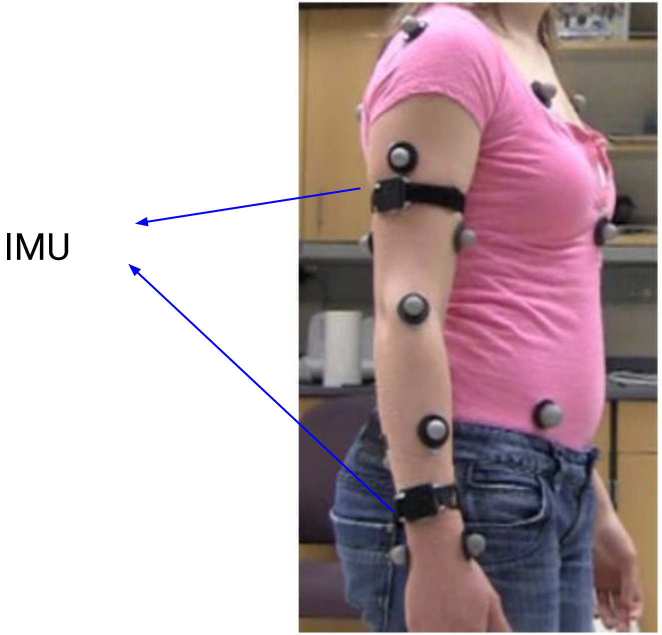
- Easy attachment
- Not Bulky

Cons:

- IMU Drift

  (human-in-the-loop operation may neglect this point)

Readings: [4], [5], [10], [11]



[10]: El-Gohary, et al., 2012

Technical Approach by steps

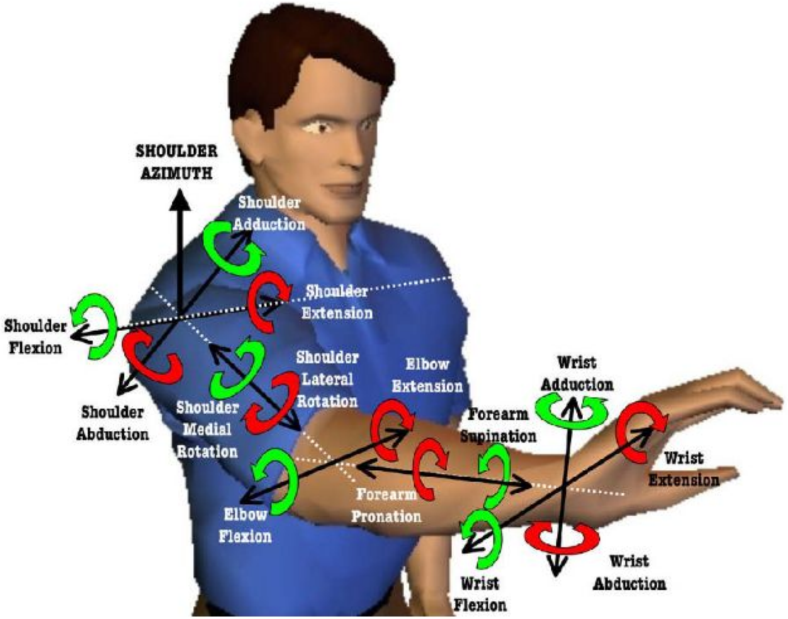
1. Develop kinematics algorithm to compute accurate joint angles of surgeons of different arm dimensions
2. Develop sensor fusion algorithm (if needed) for the IMU ordered
3. Define rules of engagement protocol
4. Implement all algorithms in ROS
5. Define calibration protocols to accommodate different surgeons' arm dimensions
6. Control UR3/dVRK using the system and debug all algorithms

IMU Details

- Type: Lp-research
- Interface: Bluetooth
- Amount: 2 for up to 4 DOF, 3 for 6 DOF
- Placement: Upper Arm, forearm, wrist
- Calibration: defined in calibration protocol

https://zenshin-tech.com/product/lpms-b2/

Human Arm Kinematics



[11]: D. Naidu, et al., 2011

Joint	DOF
Shoulder	3
Elbow	2
Wrist	2

“A human arm can be modeled as a 5 degrees-of-freedom (DOF) serial manipulator with geometric constraints, i.e. 3 DOFs are located in the shoulder joint, 1 DOF is in the elbow joint and the last DOF is on the forearm axis. The fifth DOF only contributes to the hand wrist orientation.” - [17] Taunyazov, T. et al., 2016

Minimum Deliverable: shoulder 3 + Elbow 2 = tool 4 DOF
Maximum Deliverable: above + wrist 2 = tool 6 DOF

Other Technical Details

- Kinematics algorithm: Calculate joint angles
- Sensor fusion algorithm: Eliminate excessive IMU drift if necessary
- IMU Drift: might not be impactful since teleoperation is human-in-the-loop
- Calibration: Establish calibration pose and protocols (hand-eye calibration)
- Algorithm assumption: Surgeon’s torso stays perpendicular to the ground

No encountered problems so far, everything is on track!

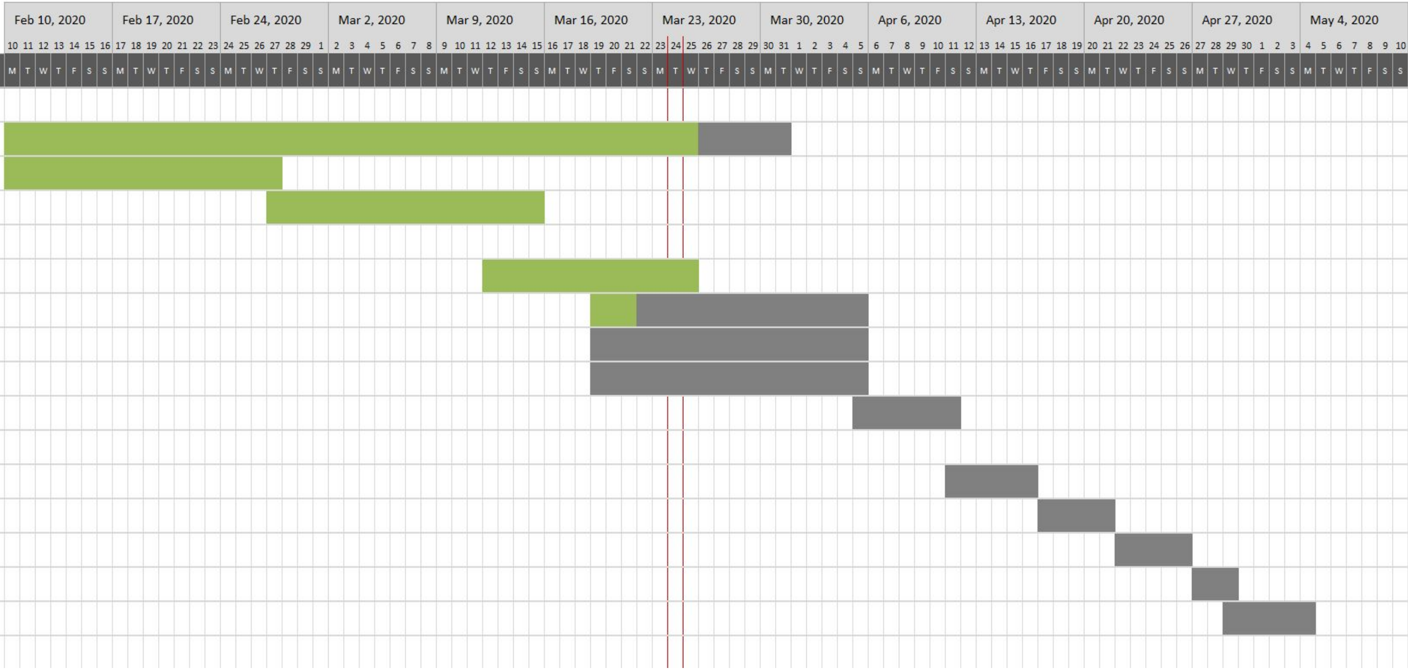
Updated Dependencies

Dependency	Solutions	Deadline	Backup Plan	Affect what	Status
Lab Access	Contact Dr. Kazanzides to sign paperwork	2/15	Ask mentors to open doors to the lab when needed	UR3 and dVRK Access	Completed
Software License	Use WSE Solidworks license	2/11	Use older version on my personal PC	Whole project	Completed
UR3 Access	Contact Dr. Kazanzides	3/15	Use dVRK	System validation and testing	Completed
dVRK Access	Contact Anton	3/25	N/A	System validation and testing	In progress
Algorithm Implementation	ROS on personal PC	3/25	Contact mentors to use lab machines	System realization	Completed
Parts Delivered	Contact Dr. Kazanzides	3/31	None	System realization	In Progress

Updated Timeline

1

TASK	PROGRESS	START	END
Dependencies and design solution			
Resolve Dependencies	90%	2/10/20	3/31/20
Brainstorm and Discuss Technical Solutic	100%	2/10/20	2/27/20
Decide on which approach to proceed	100%	2/27/20	3/15/20
Algorithm implementation			
Decide and order IMU	100%	3/12/20	3/25/20
Kinematic algorithm implementation	20%	3/19/20	4/5/20
Sensor fusion algorithm implementation	0%	3/19/20	4/5/20
Rules of engagement defined	0%	3/19/20	4/5/20
Calibration protocol defined	0%	4/5/20	4/11/20
Testing and Validation			
Test end effector position in Rviz	0%	4/11/20	4/16/20
Control UR3/dVRK	0%	4/17/20	4/21/20
Debug and physical demo of system	0%	4/22/20	4/26/20
Document all codes	0%	4/27/20	4/29/20
Report and poster writing	0%	4/29/20	5/4/20



Key Dates/Milestones

Milestones	Complete Date	Overall Status
Design Solution Decision Made	3/15/2020	Completed
Algorithm Implemented	4/5/2020	
Kinematic Measurement Validated	4/10/2020	Minimum Deliverable
Calibration protocols validated	4/16/2020	
Successful Physical Demo	4/26/2020	Expected Deliverable
6 DOF w/ extra IMU Implemented	4/28/2020	Maximum Deliverable
Complete Documentation	5/4/2020	

Reading List

1. P. Kazanzides, E. Azimi, Intuitive Surgical - Technology Research Grant Proposal
2. Surgical Asepsis and the Principles of Sterile Technique, https://opentextbc.ca/clinicalskills/chapter/surgical-asepsis/
3. L. Qian, A. Deguet, Z. Wang, Y. Liu and P. Kazanzides, "Augmented Reality Assisted Instrument Insertion and Tool Manipulation for the First Assistant in Robotic Surgery," 2019 International Conference on Robotics and Automation (ICRA), Montreal, QC, Canada, 2019, pp. 5173-5179.
4. Sabatini AM. Estimating three-dimensional orientation of human body parts by inertial/magnetic sensing. Sensors (Basel). 2011;11(2):1489–1525. doi:10.3390/s110201489
5. Determine Orientation Using Inertial Sensors, MATLAB, https://www.mathworks.com/help/fusion/gs/determine-orientation-through-sensor-fusion.html
6. Jarrassé, N., & Morel, G. (2011). On the kinematic design of exoskeletons and their fixations with a human member. Robotics: Science and Systems, 6, 113–120. https://doi.org/10.7551/mitpress/9123.003.0019
7. D-H https://robotacademy.net.au/lesson/denavit-hartenberg-notation/
8. D-H http://www.aeromech.usyd.edu.au/MTRX4700/Course_Documents/material/lectures/L2_Kinematics_Dynamics_2013.pdf
9. IMU https://stanford.edu/class/ee267/lectures/lecture9.pdf
10. El-Gohary, M., & McNames, J. (2012). Shoulder and elbow joint angle tracking with inertial sensors. IEEE Transactions on Biomedical Engineering, 59(9), 2635–2641. https://doi.org/10.1109/TBME.2012.2208750
11. Naidu, D., Stopforth, R., Bright, G., & Davrajh, S. (2011). A 7 DOF exoskeleton arm: Shoulder, elbow, wrist and hand mechanism for assistance to upper limb disabled individuals. IEEE AFRICON Conference, (September), 1–6. https://doi.org/10.1109/AFRCON.2011.6072065
12. Wong, C., Zhang, Z. Q., Lo, B., & Yang, G. Z. (2015). Wearable Sensing for Solid Biomechanics: A Review. IEEE Sensors Journal, 15(5), 2747–2760. https://doi.org/10.1109/JSEN.2015.2393883
13. Lopez-Nava, I. H., & Angelica, M. M. (2016). Wearable Inertial Sensors for Human Motion Analysis: A review. IEEE Sensors Journal, PP(99), 7821–7834. https://doi.org/10.1109/JSEN.2016.2609392
14. Steidle, F., Tobergte, A., & Albu-Schäffer, A. (2016). Optical-inertial tracking of an input device for real-time robot control. Proceedings - IEEE International Conference on Robotics and Automation, 2016-June, 742–749. https://doi.org/10.1109/ICRA.2016.7487202
15. Kim, Y., Leonard, S., Shademan, A., Krieger, A., & Kim, P. C. W. (2014). Kinect technology for hand tracking control of surgical robots: Technical and surgical skill comparison to current robotic masters. Surgical Endoscopy, 28(6), 1993–2000. https://doi.org/10.1007/s00464-013-3383-8
16. Tobergte, A., Pomarlan, M., Passig, G., & Hirzinger, G. (2011). An approach to ulta-tightly coupled data fusion for handheld input devices in robotic surgery. Proceedings - IEEE International Conference on Robotics and Automation, 2424–2430. https://doi.org/10.1109/ICRA.2011.5980120
17. Taunyazov, T., Omarali, B., & Shintemirov, A. (2016). A novel low-cost 4-DOF wireless human arm motion tracker. Proceedings of the IEEE RAS and EMBS International Conference on Biomedical Robotics and Biomechatronics, 2016-July, 157–162. https://doi.org/10.1109/BIOROB.2016.7523615

Backup slides: User Study

- IRB (Existing IRB by Dr. Kazanzides will cover this project)
  - Assisted Teleoperation - generic
  - Complete Online training
  - Send the certificate to Dr. Kazanzides
- Design user study
  - Experimental platform(task)
  - Analysis

Backup slides: Management Plan

- Meetings: Bi-weekly meeting with mentors
- Budget: ~$500