# 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 <u>single</u> 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

  (<u>human-in-the-loop operation may neglect this point</u>)

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



IMU

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

# Technical Approach by steps

1.  Develop <u>kinematics algorithm</u> to compute accurate joint angles of surgeons of different arm dimensions

2.  Develop <u>sensor fusion algorithm</u> (if needed) for the IMU ordered

3.  Define <u>rules of engagement</u> protocol

4.  Implement all algorithms in <u>ROS</u>

5.  Define <u>calibration protocols</u> to accommodate different surgeons' arm dimensions

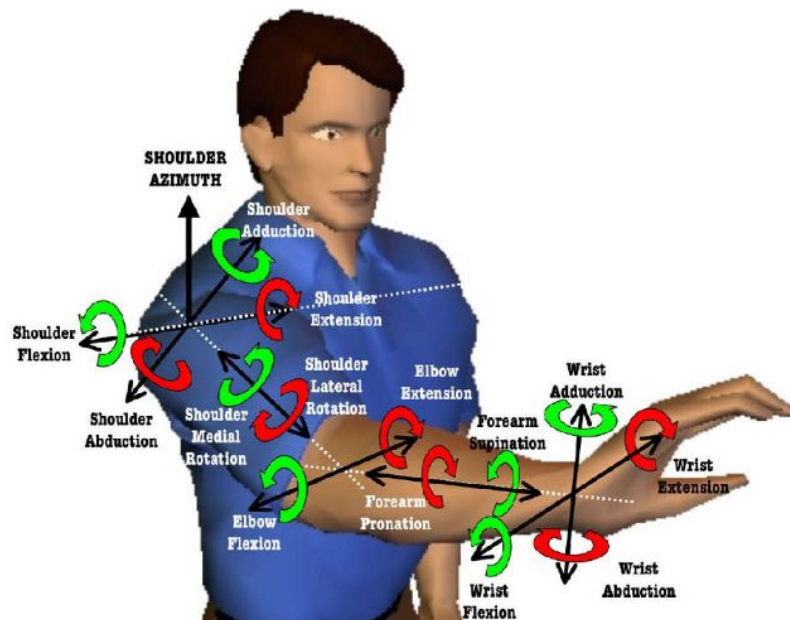6.  <u>Control UR3/dVRK</u> using the system and debug all algorithms

# 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



SHOULDER AZIMUTH

Shoulder Adduction

Shoulder Extension

Shoulder Flexion

Shoulder Lateral Rotation

Shoulder Medial Rotation

Shoulder Abduction

Elbow Extension

Elbow Flexion

Forearm Supination

Forearm Pronation

Wrist Adduction

Wrist Extension

Wrist Abduction

Wrist Flexion

[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
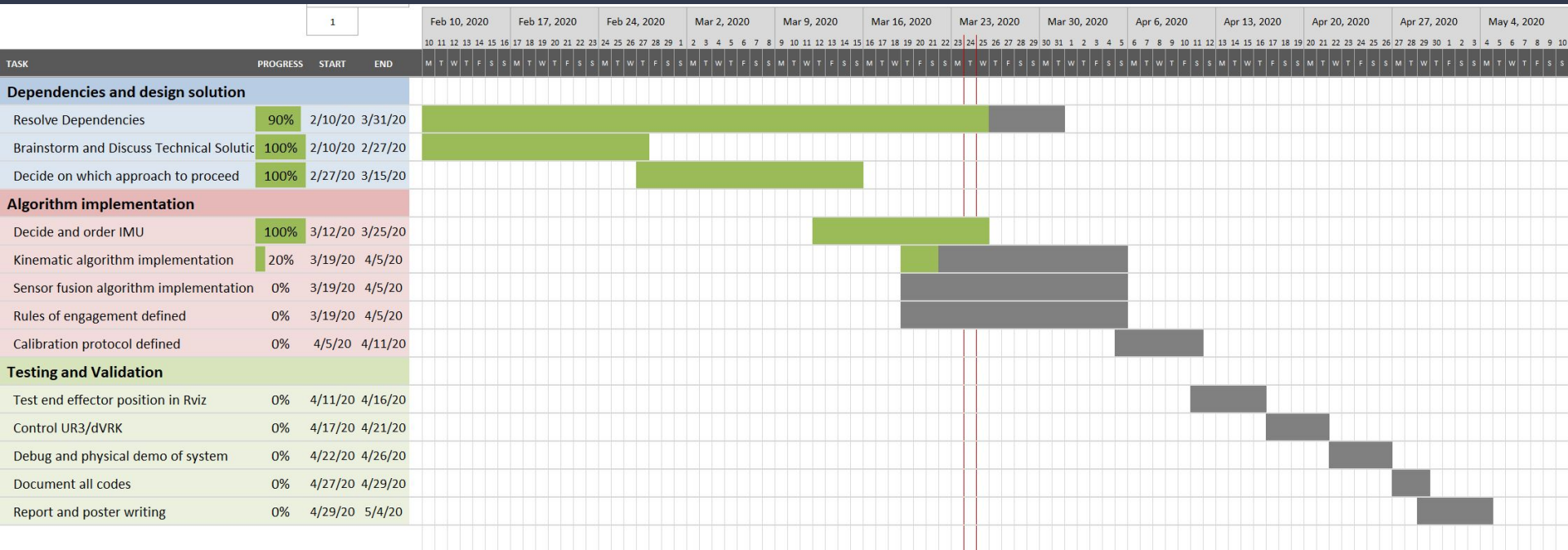
# Other Technical Details

- 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

| TASK | PROGRESS | START | END |
|---|---|---|---|
| **Dependencies and design solution** | | | |
| Resolve Dependencies | 90% | 2/10/20 | 3/31/20 |
| Brainstorm and Discuss Technical Solution | 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 | |
| Calibration protocols validated | 4/10/2020 | |
| Kinematic Measurement Validated | 4/16/2020 | Minimum Deliverable |
| 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
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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