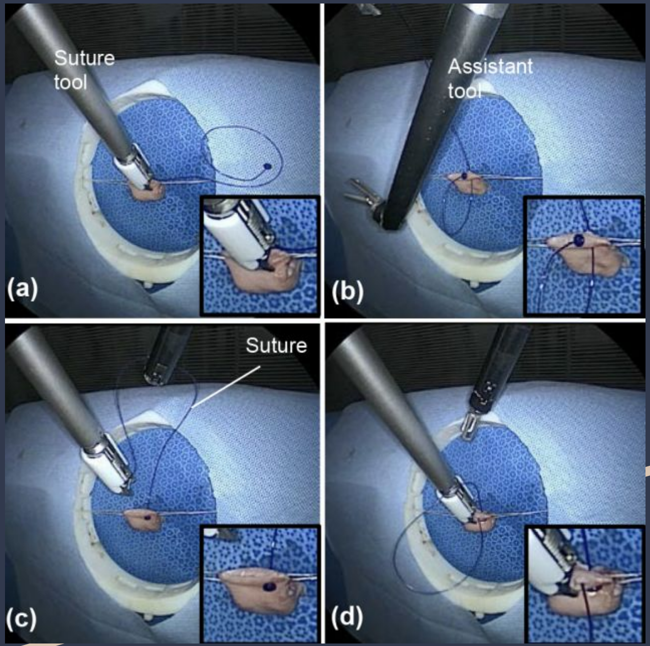
Team 11: Autonomous Suture Management Project Plan

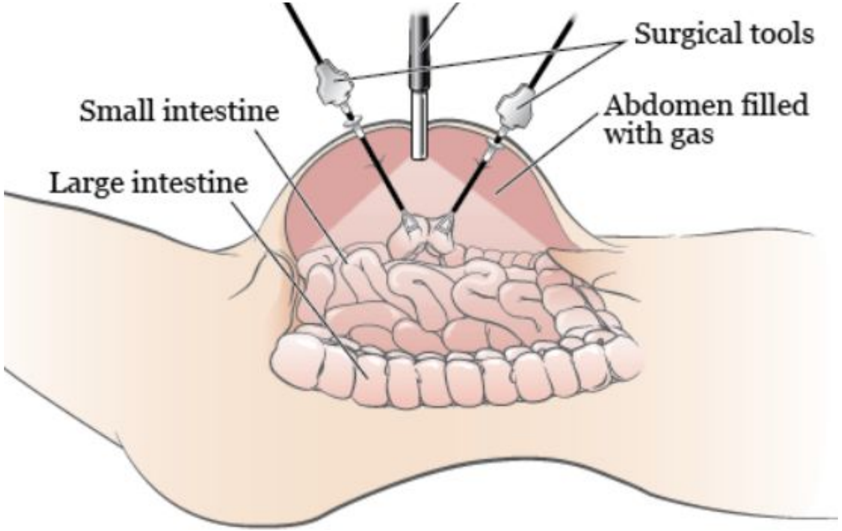
Team members: Nyeli Kratz, Nathan Van Damme, Jiawei Liu

Mentors: Prof. Axel Krieger, PhD. Candidate Michael Kam

Background

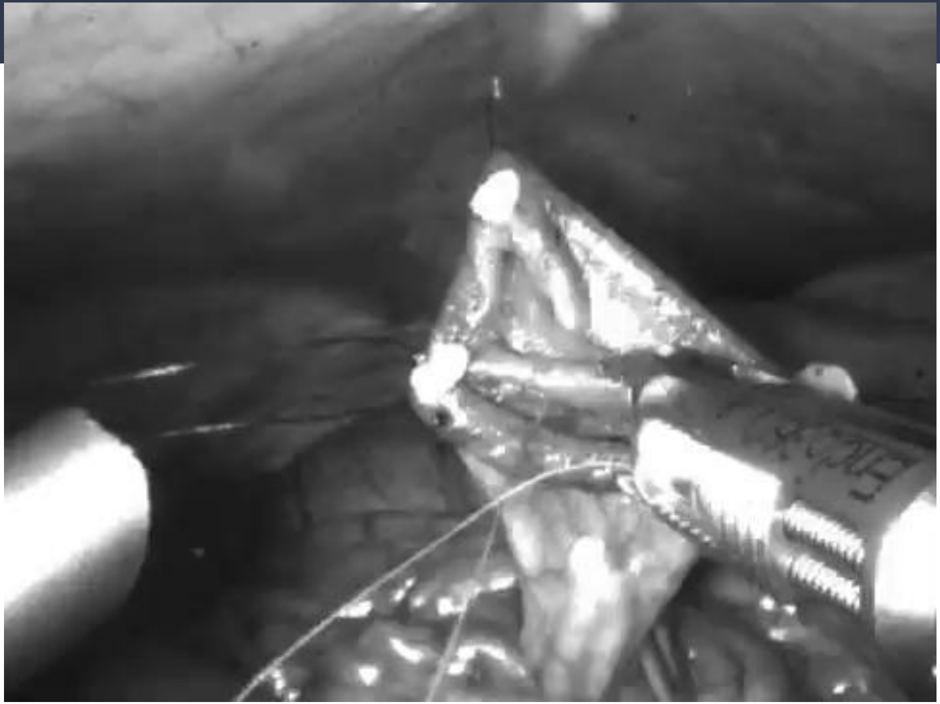


- Without proper sealing, an anastomotic leak occurs between the connection.
- Current STAR/Endo360 autonomous suturing requires a second assistant tool which is controlled by hand by a surgeon for suture tensioning management.
    - This means another incision in the abdomen and more work for the surgeon.

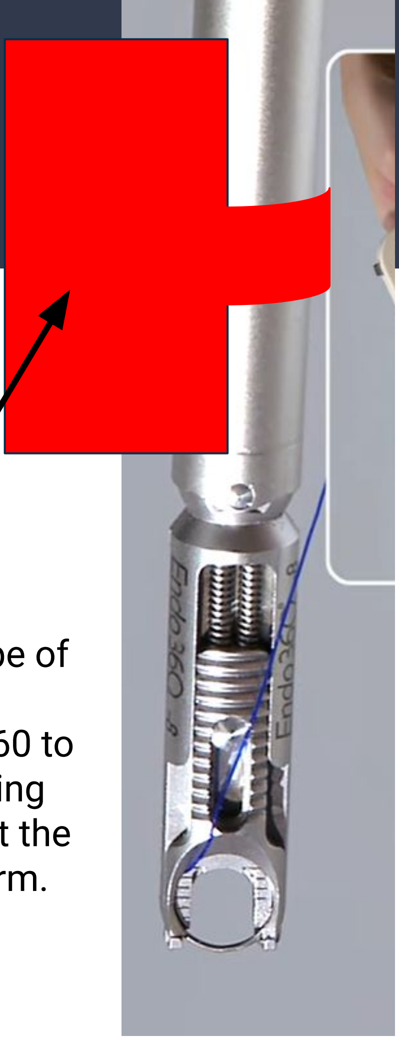


[1] Diagnostic Laparoscopy

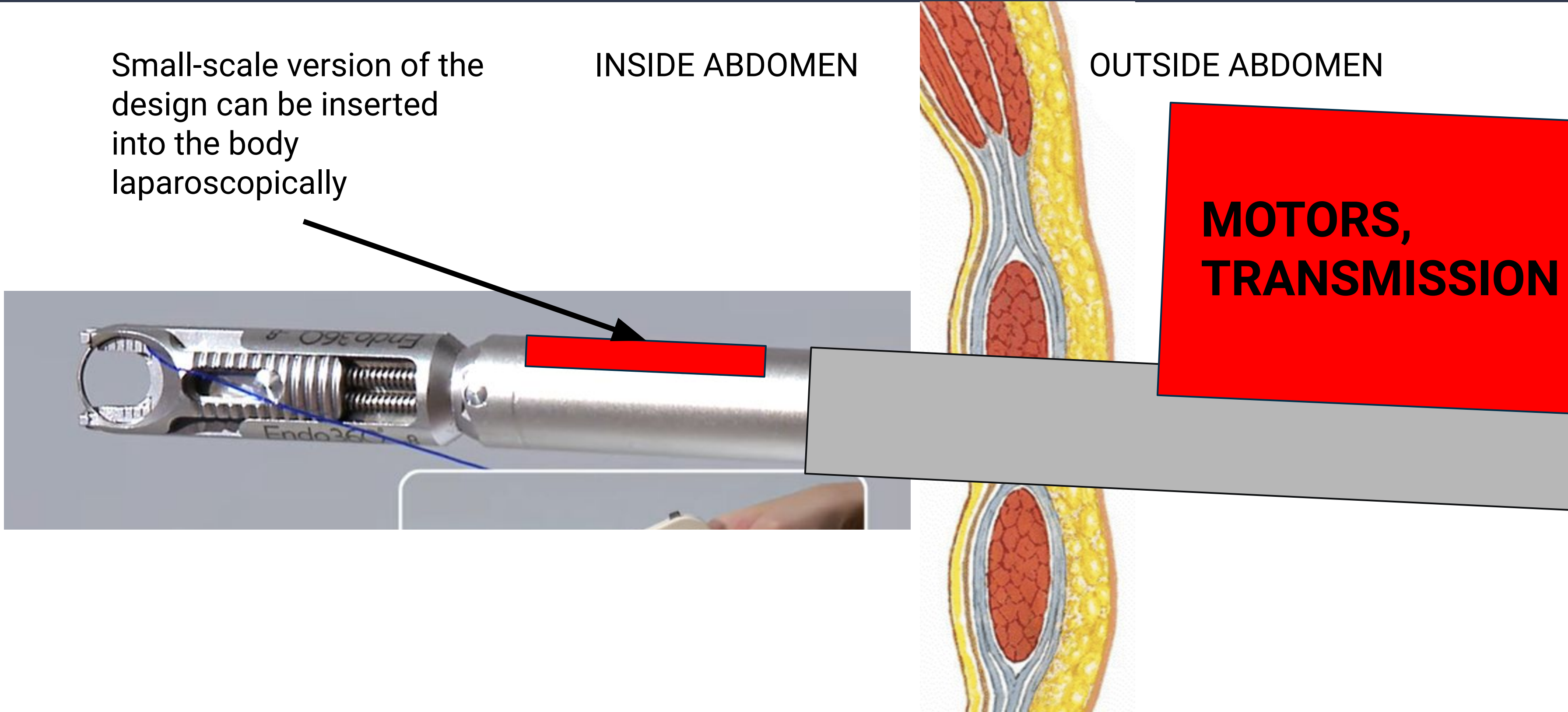
Prior work and Opportunity



Large-scale prototype of our mechanism will attach to the Endo360 to manage the tensioning of the suture without the need for a second arm.

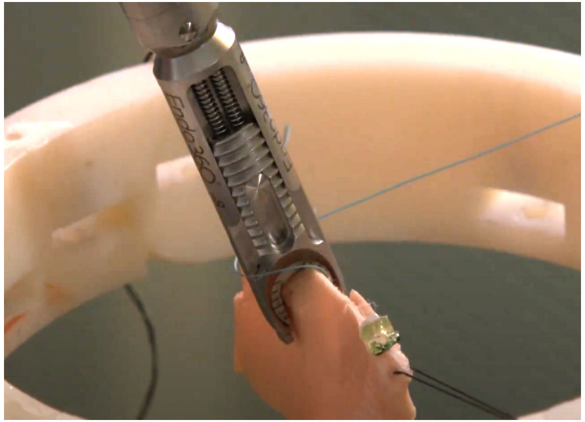


Ultimate goal - small-scale prototype



Current Robotic Approach

Robotic motion control for suturing

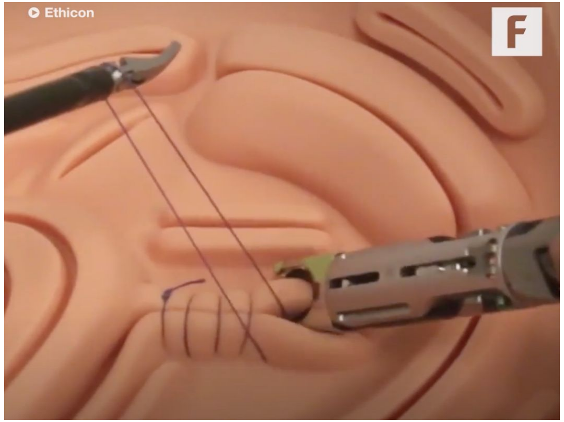


Autonomous

Motorized circular needle for stitch placement

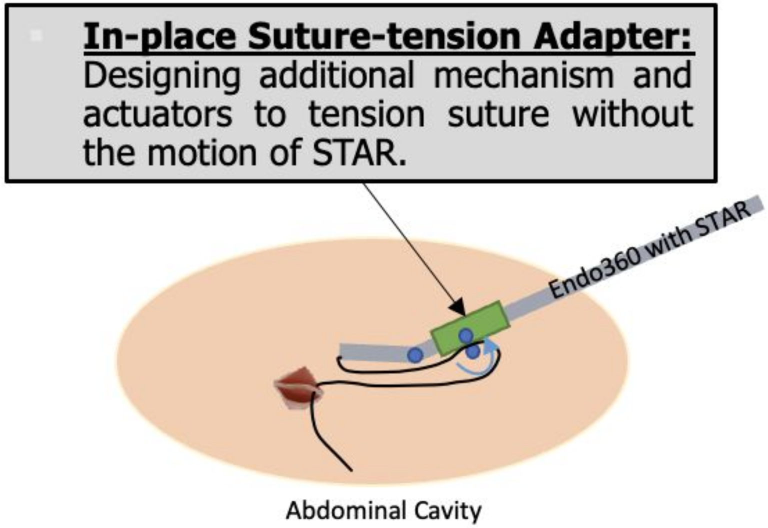
Autonomous

Assistant tool for suture tensioning



Autonomous/Manual

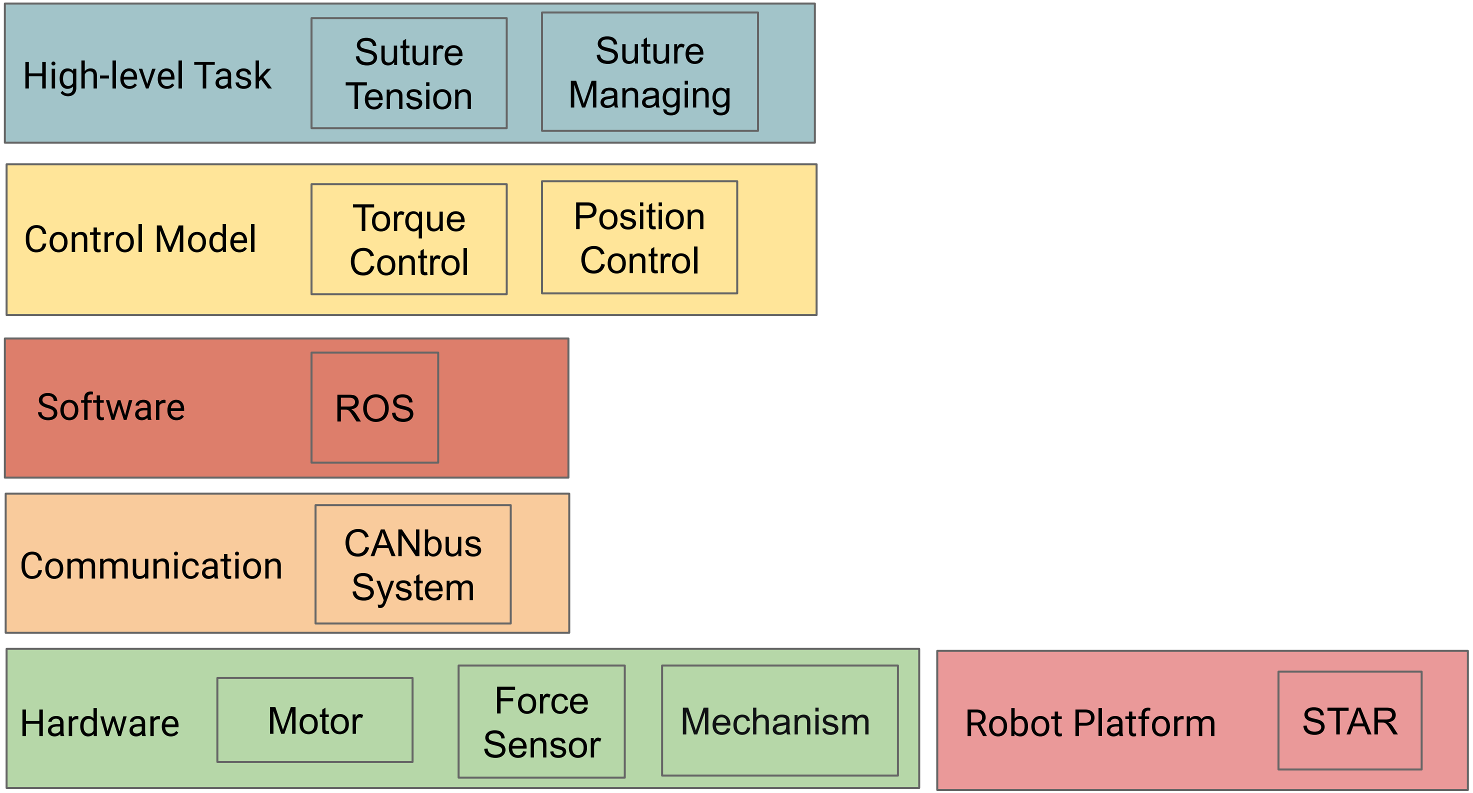
Proposed Technical Approach



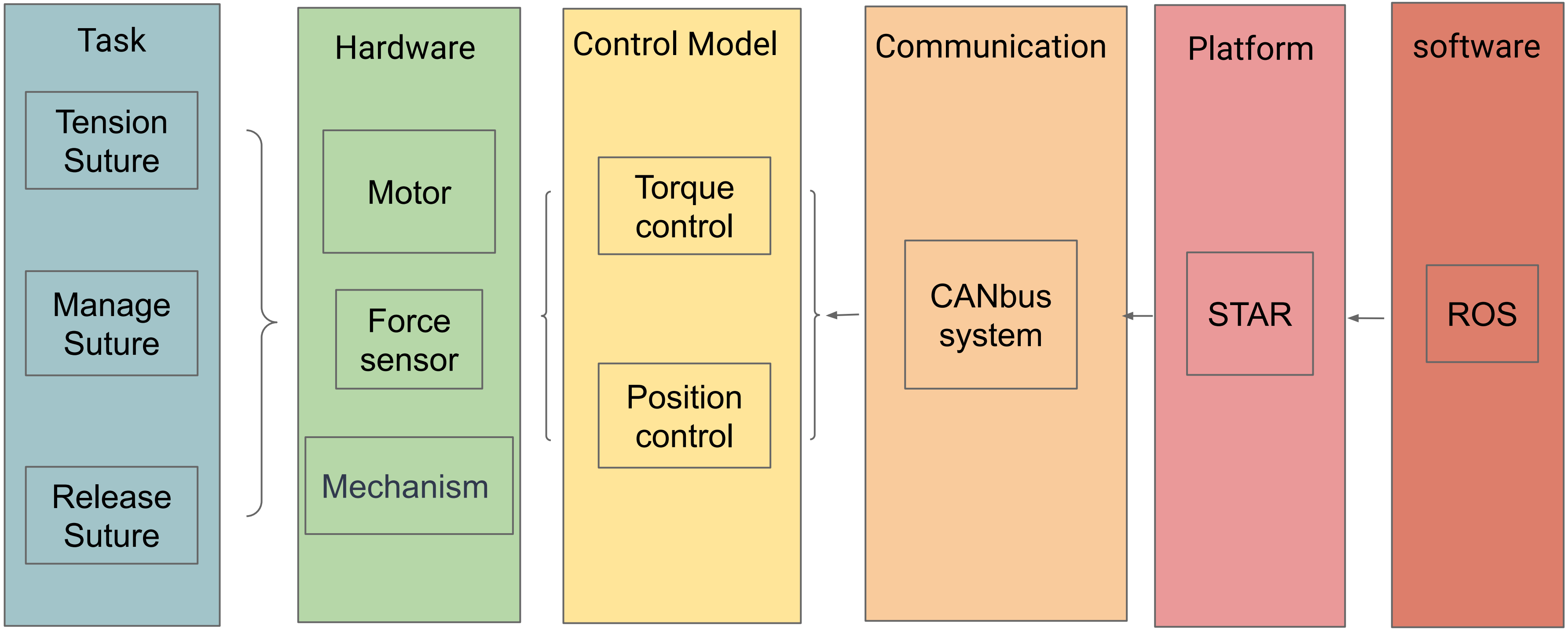
Autonomous workflow of suture management:

1. Grasp and bring suture to a secure location
   Design a mechanism (e.g., gripper) to grasp the suture
2. Apply suture tension
   Design a mechanism to apply tension to suture via motors
3. Stop suture tension
   Detect the completion of suture tension and stop the process
4. Release/Drop suture
   Release the suture from the mechanism to allow STAR to place the next stitch

Technical Approach



Technical Approach



Deliverables

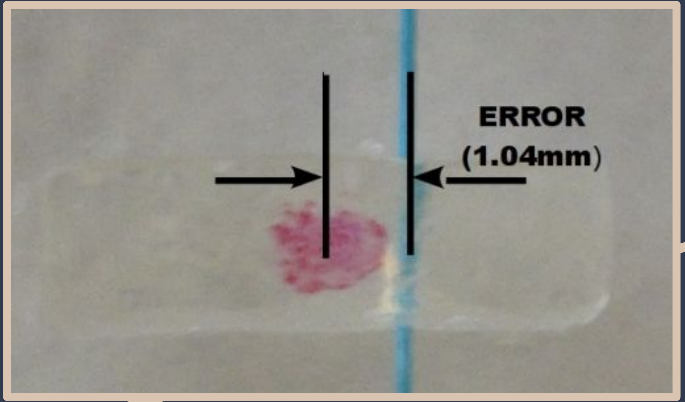
1. Minimum: Large-scale prototype demonstrating mechanism that is made of 3D printed materials and off-the-shelf parts and controlled by Arduino.
    a. Prototype must be able to catch thread, tension, and release thread on the Endo360 with STAR robot outside of the body.
2. Expected: Test and improve large-scale prototype and also CAD model of small-scale prototype (can be inserted into the abdominal cavity laparoscopically in a 25mm diameter hole)[2].
    a. Implement CANbus control of large-scale prototype.
    b. Test large-scale prototype against current dual-arm approach of the Endo360 with STAR robot.
3. Maximal: Small-scale physical prototype (can be inserted into the abdominal cavity laparoscopically in a 25mm diameter hole) works with the Endo360 with STAR robot.
    a. Prototype will be tested against current dual-arm approach of the Endo360 with STAR robot.
    b. Verify functionality of prototype on various tissue thicknesses.
    c. Conference publication

Timeline

	February				March				April				May			
Preliminary research and brainstorming																
Literature review																
Assess functionality of current design																
Brainstorming																
Choose a design concept to move forward with																
Design				DR1			DR2									
CAD modeling																
Prototyping																
Order parts																
Fully assemble prototype																
Control																
Mount into test setup																
Implement control method																
Test performance of prototype vs. dual-arm approach																
Final Report																

Testing Plans

S. Leonard, A. Shademan, Y. Kim, A. Krieger and P. C. W. Kim (2014)



- Evaluation of suturing:
  - Catch needle
    - Number of failed attempts
  - Tension cable
    - Speed of tensioning cable [5]
    - Force of tensioning cable (experimentally 1N)
  - Release needle
    - Number of failed attempts
- Test suturing vs. current dual-arm approach on synthetic skin testing setup [3, 4, 5].
  - Time per suture
  - Suture depth accuracy
  - Force of tensioning
  - Number of failed sutures
  - Workspace comparison

Dependencies

Dependency	Need	Status	Follow-up	Contingency	Deadline
Existing device	Preliminary research	Acquired - assembled	N/A	N/A	2/15/2023
Solidworks CAD software	Design	Acquired	N/A	Use Creo parametric	2/15/2023
3D printers	Prototyping	Acquired - BME Design studio	N/A	Get training to use Wyman 3D printers	2/15/2023
Off-the-shelf hardware (motors, encoders, etc.)	Prototyping	Dr. Krieger's lab will fund this; and we will order parts when design is finalized (see timeline)	Mentor Michael Kam will help us.	N/A	4/10/2023
Synthetic skin + testing setup	Testing	Acquired - in Dr. Krieger's lab	N/A	N/A	4/10/2023
CANbus control system	Control	Acquired - made by Michael Kam	N/A	Arduino-based control	4/10/2023

Management Plan

- Weekly meetings with mentor Michael Kam Fridays 4pm
    - Dr. Axel Krieger can join these meetings as needed (likely biweekly)
- Team meetings on weekends for prototyping

References

1. “Diagnostic Laparoscopy.” *Memorial Sloan Kettering Cancer Center*, 21 May 2019, https://www.mskcc.org/cancer-care/patient-education/laparoscopy.
2. Tsai, A. Y., & Selzer, D. J. (2010). Single-port laparoscopic surgery. *Advances in Surgery*, *44*(1), 1–27. https://doi.org/10.1016/j.yasu.2010.05.017
3. H. Saeidi and J. D. Opfermann and M. Kam and S. Wei and S. Leonard and M. H. Hsieh and J. U. Kang and A. Krieger. “Autonomous robotic laparoscopic surgery for intestinal anastomosis.” Science Robotics, 2022. https://doi.org/10.1126/scirobotics.abj2908
4. S. Leonard, A. Shademan, Y. Kim, A. Krieger and P. C. W. Kim, "Smart Tissue Anastomosis Robot (STAR): Accuracy evaluation for supervisory suturing using near-infrared fluorescent markers," 2014 IEEE International Conference on Robotics and Automation (ICRA), Hong Kong, China, 2014, pp. 1889-1894, doi: https://doi.org/10.1109/ICRA.2014.6907108
5. S. Leonard et al., "Vaginal Cuff Closure With Dual-Arm Robot and Near-Infrared Fluorescent Sutures," in IEEE Transactions on Medical Robotics and Bionics, vol. 3, no. 3, pp. 762-772, Aug. 2021, doi: https://doi.org/10.1109/TMRB.2021.3097415