Pill Cam Plan Presentation

Topic

Our goal is to exploit the PillCam's full potential by using MagnetoSuture technology since its motion currently relies on passive body movements rather than being actively controlled by a user or AI.

We will create an actively controlled PillCam using magnets on the device and electromagnets to steer the pill cam. Also, we will integrate the camera from the pill cam to control the movement without an external camera and hopefully be able to automate the movement of the PillCam using its camera.

The PillCam and MagnetoSuture are described in the background section below.

Team Members: Bharath Heggadahalli, Jack Yue, Mark Gonzales

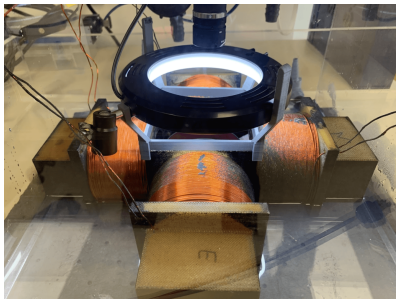
Mentors: Dr. Onder Erin, Dr. Axel Krieger

Background

PillCam

The PillCam is a minimally invasive device developed as an alternative to endoscopic devices. The pill cam is a capsule that you swallow and it contains a small camera. This camera captures images at a frame rate of 2 to 6 frames per second (fps) based on the capsule speed. The camera takes pictures as it passes through the body and transmits the pictures to a data recorder which is worn as a belt. The pill cam is used to produce clear images of the esophagus, stomach, small bowel, and colon. However, there is no robotic control on the PillCam so its movement is completely reliant on passive body movements. The pill cam comes in a model with a camera on one end and another model with a camera on both ends.

MagnetoSuture



MagnetoSuture is a device that consists of four electromagnetic coils in a plane separated by 90 degrees and it is able to use electromagnetic fields to control the motion of a magnet in the space between the coils. The current in each of the electromagnetic coils is controlled by a wireless remote controller and the current ranges from -20A to 20A each. By activating one of the coils, the electromagnetic field will align in the direction of that coil, moving the magnet in that direction. Using this wireless controller that controls all 4 of the coils, a magnet should be able to move in any direction within that space and also be able to rotate in any direction as well.

Additionally, this technology can be extended to include two more coils at the top and bottom in order to control an object in 3D space.

Relevance/Importance

The PillCam is becoming more popular because of its ability to capture internal images in a non-invasive manner. With the addition of magnetic control on the PillCam, we would be able to improve the device significantly which would lead to a higher usage rate of the PillCam.

Technical Approach

Mechanical Approach

Get the interior design of the PillCam to determine areas of free spaces for magnets, IMU, and wireless communication devices. 3D print the design of the PillCam and test different magnet locations on the interior to determine the locations that give the best control

Electrical Approach

Find an IMU that fits the size requirements provided by the PIllCam. Determine the best system of wireless communication, i.e. Bluetooth, RF, etc. Use a PCB to shrink the size of the IMU and communication device to be as small as possible.

Control System Approach

We want to determine the dynamics of the system and find out what can be controlled given magnet placement and changing magnetic fields. We then want to design and implement a control scheme that will allow the magnetic pill cam to move, this would be done using a PID control scheme that would be done with trial and error to determine what constants give a steady path following the system that is exponentially stable around the path.

Deliverables

Minimum

- Prototype of a magnetic PillCam with the ability to wireless send position and orientation data.
- CAD File and Code to command the IMU communication

Expected

- The prototype of the magnetic Pillcam with the ability to wireless send position and orientation data along with documentation
- Development and Implementation of a PID control scheme that allows the Pillcam to follow a trajectory
- Math and code to control the PillCam

Maximum

- The prototype of the magnetic Pillcam with the ability to wireless send position and orientation data along with documentation
- Development and Implementation of a PID control scheme that allows the Pillcam to follow a trajectory along with documentation
- A Publication in a Scientific Journal

Milestones

Phase 1a: Implementation of Magnet Placement in the PillCam (3/21)

Phase 1b: Implementation of IMU wireless data transfer (3/21)

Phase 2: Implementation of a Closed-Loop Feedback Control that uses the changing magnetic fields to follow a certain trajectory (4/11)

Phase 3: Manuscript Work (5/2)

Key dates & assigned responsibilities

Project Selection (Feb 8th) - All team members

Complete initial Pill Cam CAD modeling (Feb 20th) - Jack

Place Magnet and IMU orders (Feb 20th) - Bharath, Mark

Plan Presentation (Feb 24th) - All team members

Written Proposal (March 1st) - All team members

Initial CAD PillCam prototype (March 19th) - Jack

Magnet placement prototype (March 19th) - Bharath

IMU integration (March 19th) - Mark

Background Reports (March 29th) - All team members

Testing prototype and iterations with the magnetosuture system (April 20th) - All team members

Background Reading Presentation (April 26th) - All team members

Testing verification and validation (May 5th) - All team members

Final Presentation (TBD) - All team members

List of dependencies & plan for resolving

Pillcam Procurement: Alternative solution would be to simply utilize other models in the lab instead and use these will we order from alternate vendors. Even if we are unable to procure the specific model we are looking for, we can still use the CAD models and the currently available pill cams in the lab to test instead.

Magnet /IMU Procurement: Alternative solution would be to utilize magnets and IMUs from another company instead. Orders are currently being processed and shipped to the lab, but there are multiple vendors who would be able to supply the magnets and IMUs that we need in order to design the product. We can simply order from another vendor if our current vendor does not have the supply, or there is a delay in shipment.

Functional Magnetosuture System: Alternative solution will be to test our pill cams with individual magnets instead of using the magnetosuture system. The magnets that we will use as a replacement instead will be a good model to test the components of the magnetosuture individually, and this should not be a major concern while the system is being brought back online. The system is currently functional and not expecting any major upcoming updates.

Management Plan

Our management plan mainly focuses on properly organizing our files and documentation in specified locations as follows. All computer-aided designs will be constructed and stored with Onshape. All Arduino and python code will be uploaded and stored via Github. Any written documentation or presentations will be stored in a shared google drive folder as well. We plan to meet with our mentor every Tuesday from 7:30 pm - 8:30 pm on zoom or in-person depending on the needs of the meeting for that day. Communication with mentors and team members will be done primarily through email and slack.

Reading List

Adler, Samuel N, and Yoav C Metzger. “PillCam Colon Capsule Endoscopy: Recent Advances and New Insights.” Therapeutic Advances in Gastroenterology, SAGE Publications, July 2011, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3131168/.

Koprowski, Robert. “Overview of Technical Solutions and Assessment of Clinical Usefulness of Capsule Endoscopy - Biomedical Engineering Online.” BioMed Central, BioMed Central, 1 Dec. 2015, https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-015-0108-3.

“MPU-9250: TDK.” InvenSense, https://invensense.tdk.com/products/motion-tracking/9-axis/mpu-9250/.

StatPearls. “Capsule Endoscopy.” StatPearls, StatPearls Publishing, 12 Aug. 2021, https://www.statpearls.com/ArticleLibrary/viewarticle/18834.

Vedaei, Seyed Shahim, and Khan A. Wahid. “A Localization Method for Wireless Capsule Endoscopy Using Side Wall Cameras and IMU Sensor.” Nature News, Nature Publishing Group, 27 May 2021, https://www.nature.com/articles/s41598-021-90523-w.