Background Reading Report

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A localization method for wireless capsule endoscopy using sidewall cameras and IMU sensors.

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We chose to look at this paper because we were looking for a way to localize our PillCam in the body, and after some research, this is one of the papers that came up. Our goal with our project is to control a PillCam within the body, and in order to do this, knowing the location and orientation of the device at all times is necessary. This is a fairly relevant paper to our project as this is also using a camera in endoscopic procedures that is able to tell its location in the body, very similar to what our goal is with this sensor. We looked at this paper for ideas on how to have and send the geographic coordinates of the PillCam. This paper did end up showing us different design choices than what we ended up going with but allowed us to see what sensors and transceivers were in use in similar projects. The many similarities in the project allowed us to both consider alternative approaches and some of the design flaws within their selection.

<u>Technical Summary</u>

The endoscopic device has 4 cameras, a battery, an IMU, a microcontroller, and an RF transceiver. The device ended up being 3.5 cm x 3.5 cm x 4.0 cm in size to make room, especially for the batteries in the system. The whole system was run through an ATmega32U4 microcontroller using both I2C and SPI to connect between the cameras and the IMU. The sidewall cameras which were stationed on each of the walls were motion measurement cameras that had a resolution of 18 x 18 pixels. The IMU was an MPU9250 which has a gyroscope, magnetometer, and accelerometer. The RF transceiver was a Lora RF module operating at 433 Hz.

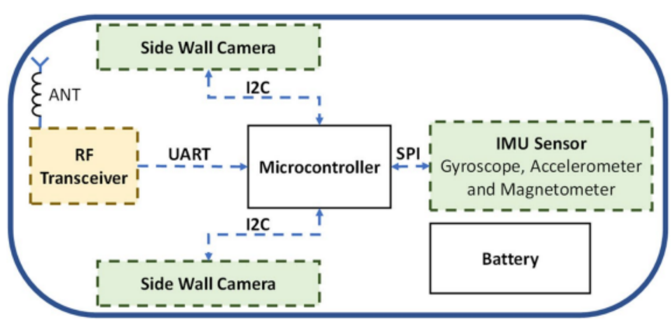


Figure 1. Schematic overview of the capsule.

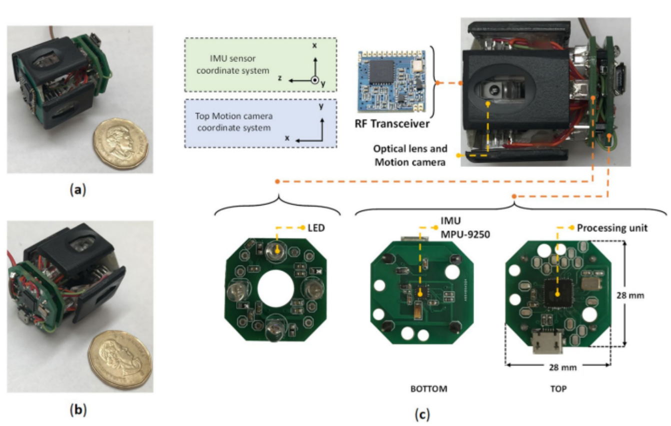


Figure 2. (**a**, **b**) Capsule prototype designed in the lab (**c**) Various parts of the lab prototype.

They used the IMU predominantly for the orientation of the device. IMU is an integrable device so to compensate for the error in the gyroscope over time the accelerometer and magnetometer were used to compensate for the gyroscope data. They took different calibration data at the beginning for the magnetometer so they could add the proper bias terms in the magnetometer to get back any magnetic fields that it might sense. All the data was put into the different calculations (Integration for gyroscope, Arctan calculations for Accelerometer and Magnetometer) and these were put into a Kalman Filter to calculate the best guess for the roll pitch and yaw of the system.

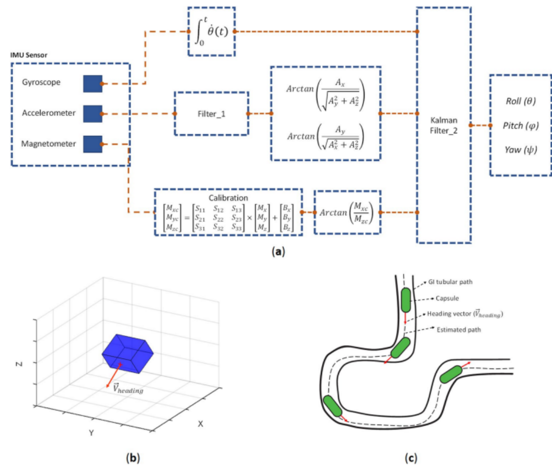
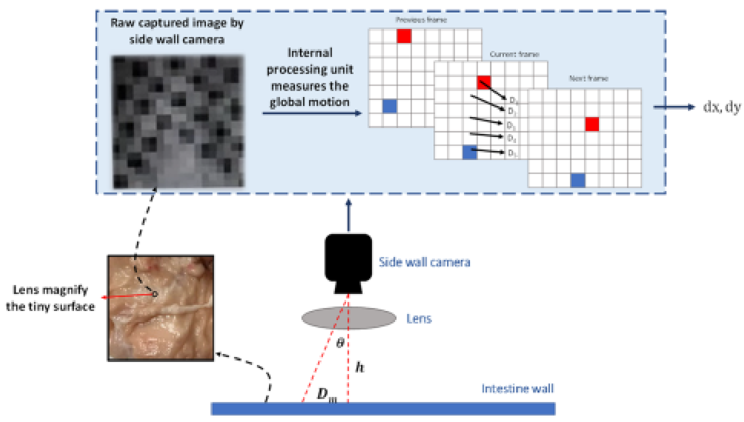


Figure 6. (**a**) IMU sensor fusing schematic, (**b**) 3D orientation result and (**c**) overview of the fusion algorithm.



(**b**)

The cameras work similarly to optical mice that take an in-depth look for tiny markers on the image and a processor analyzes the change in marker location to give a motion-captured vector. Inside the camera, there are three components: motion sensor (monochromatic camera), optical lens, and lighting source. The camera would take a picture every 20 ms and by looking at the global motion of pixels it would be able to measure the global motion of the camera giving a motion vector. The image shows the procedure of this by taking the average change between the pixels and getting the average motion vector. The camera was able to pick up motion in all but parallel pattern walls.

The procedure used a porcine intestine and moved the camera system through the intestine and gathered the position, velocity, and rotation data from the device, and compared it to ground truths.

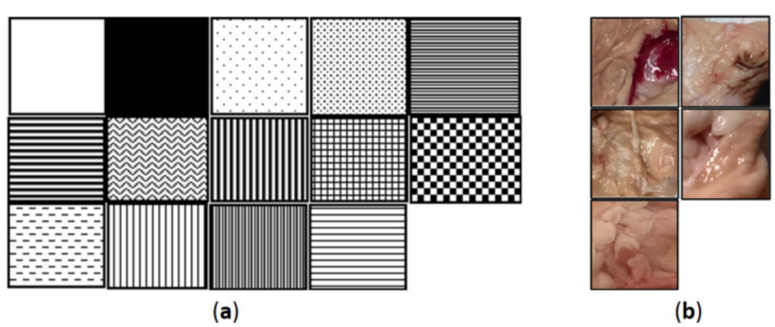
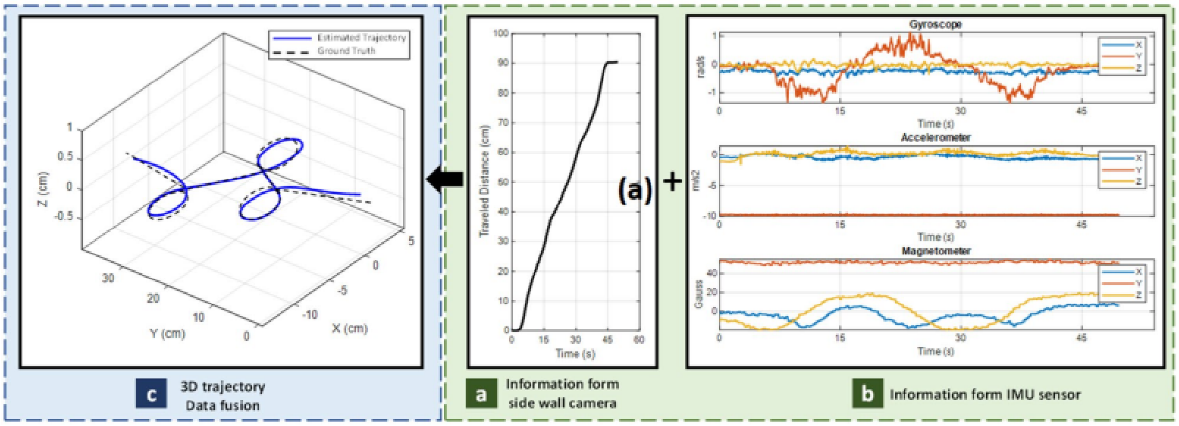


Figure 7. (**a**) Basic patterns, (**b**) WCE-like colored patterns.



(c)

Figure 17. 3D tracking for several trajectories. In each item, traveled distance, IMU data and computed trajectory are reported.

The results with putting the whole system together had good results having fairly low error for the ground truth from the estimated path.

<u>Analysis</u>

Pros:

The paper had great results with being able to localize within the body regardless of the overall body moving. This gave great insight into what needs to be taken into account for the magnetic PillCam localization system implementation. The authors were also very candid with their descriptions of their results. They included both their successful movements with the device along with the limitations on what the device can actually do in the real-world environment. This gives a lot of useful information in determining which parts of their algorithm would be beneficial in the PillCam localization method. They were also able to test the device on several types of skin and tissue, and their tests can serve as a starting point for some of the tests that this PillCam project would also have to complete in the future.

Cons:

The one issue we had with this paper is this device is intended for use in the body, however, it is about a 4-centimeter cube in size. This size does not seem very consumable from a practical standpoint, but if it is able to be made at a consumable size, this would be a great system to have made. Several adjustments may be necessary when the device is at a smaller size, but using this model it should still work at a consumable size.

Additionally, in this paper, they use a four-camera topology with the IMU sensor in order to create their localization algorithm. We would not be able to use this 4-camera topology in our localization algorithm because the PillCam we are using only has one camera and the MagnetoSuture device that we are using to control the PillCam only has a top-view camera. Our goal is to control the device and accurately track its location using only the IMU unit and the camera on the PillCam, but we can use the camera on the MagnetoSuture for our initial testing. Thus, the algorithm detailed in this paper may be difficult to directly implement in our work, but the general idea and pieces of the process can be used.

Summary:
Overall, this was a very insightful paper that included many similarities with our project which we could reference as we proceed with our implementation. The pitfalls outlined within the paper along with the challenges that the researchers documented were very helpful with our own implementation of the device, and the steps moving forward have been influenced by some of the results in the paper.

Reference

Vedaei, S. S., & Wahid, K. A. (2021, May 27). *A localization method for wireless capsule endoscopy using side wall cameras and IMU sensor*. Nature News. Retrieved April 5, 2022, from https://www.nature.com/articles/s41598-021-90523-w