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Endoscope Tracking System

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Original Objectives

- Research and gather data for the final concept that supports type and number of emitters to be used as well as the location of said emitters.
- Choose a key feature for concept validation and testing in a laboratory environment to demonstrate and show design feasibility.
- Build a functioning prototype with enough time to verify through research and testing.
- Test the functioning prototype using an enclosure representative of the human body to gather supporting measurements and positioning verification data.
- If time allows, test the functioning prototype using a high-end mannequin.

Requirements

- Due to COVID-19 the team was unable to perform further tests to determine if the precision of tracking requirement was met.
- The team was also unable to finalize the desired format for the Data Logging requirement due to COVID-19

REQUIREMENTS MATRIX						
REQ #	REQUIREMENT	DESCRIPTION	VERIFICATION	REQUIREMENT TYPE	AFFECTED REQUIREMENT(S)	COMPLETION STATUS
1	Precision of tracking	Needs to have a precision of within ± 5mm with a target goal of 1mm or less	Measurement	Performance	2,5,6	
2	Tracking method	Must be compatible with current equipment being used for procedures	Analysis	Functional	1,3,5,6	✓
3	Compatibility with existing technology	Must be compatible with endoscope provided to us by the sponsor, Dr. Stack	Analysis	Interface	1,2,8	✓
4	GUI Design	Graphical user interface must display distance into the body and the rotation of encoscope in 'real time' on lcd display	Demonstration	Functional	5	✓
5	Data Logging	Must record data that is digital to a file in a format prefered by the customer, per patient, for possible future procedure	Demonstration	Functional	4	
6	Cost	Cost of Materials under $2000 for prototype	Measurement	Functional	All	✓

Concepts

- Through the use of Analysis of Alternatives (seen below) the team discarded many initial concepts due to cost, viability, or health concerns.
  - These include ultrasound technology, RFID technology, and Radio Transmissions
- The concept that included the use of Rotary Encoders was expanded upon but later discarded due to the team foreseeing complications.

	Alternatives				
Quantitative Requirements (Weight)	RFID	Ultrasound	Radio Transmission	Optical Sensor	Rotary Encoding
Precision of tracking 1mm ± 5 mm (1.0)	1	0.5	0.7	0.8	0.7
Cost < $2000 (1.0)	1	0	1	1	1
Qualitative Requirements (Weight)					
Emission system can transmit through the human body (1.0)	0.25	0.5	0.5	0.75	0.5
Is compatible with existing endoscope technology (1.0)	0.5	1	1	0.75	0.75
GUI Design has "real time" x, y, z data (1.0)	1	1	1	1	1
Records x, y, z data for future procedure (1.0)	1	N/A	1	1	1
Emitters positions do not interfere with current equipment (1.0)	0.5	1	0.5	1	1
Total	5.25	4	5.7	6.3	5.95
Risks (Likelihood/Impact)					
Emitter system is not safe for the human body (L-M-H)	L/H	L/H	L/H	L/H	L/H
Poor accuracy (Lack of consistency, poor triangulation) (L-M-H)	M/M	M/M	M/M	L/M	M/M
Poor accuracy (Lost signal) (L-M-H)	M/H	L/H	M/H	L/H	L/H
Positioning outside of acceptable range (1 mm ± 5 mm requirement) (L-M-H)	H/H	M/H	M/H	L/H	L/H
Positioning does not work inside human body (L-M-H)	H/H	M/H	M/H	L/H	L/H
Team unable to manufacture reliable solution (L-M-H)	M/H	M/H	L/H	L/H	L/H
Team breaks budget (L-M-H)	L/M	H/M	L/M	L/M	L/M
Assumptions					
Miniaturization of components	RFID tag	glass probe	antenna	N/A	N/A
Feasibility	M	L	L	H	M
Issues	Lost signal	Cost/Feasibility	Lost signal/Accuracy	Accuracy	Accuracy

Problem Statement

There is a need to develop a method for tracking and recording the tip of an endoscope during a procedure where an ablation is made in the esophagus, so that the site of the ablation can be found easily during a follow up procedure.

Final Design/Results

The chosen final design uses two optical sensors, each gathering linear and rotational distance; these are placed on either side of the endoscope as it slides through the 3D printed housing.

The electrical schematic below (**Figure 1**) shows that the sensors (3) would each be connected to an Arduino Uno (1) which then sends the data to an Arduino Mega (2). The Mega would compare the data obtained by the sensors and then output the linear and rotational data to a LCD screen (5) where the data could be held through the press on the first pushbutton (4) or zeroed out by the press of a second pushbutton (4).

The 3D printed housing (**Figure 2**) consists of the mouth guard/bite block (1), hollow tube with ball and opening for sensor (2), housing that fits around the hollow tube and hold the sensor (3), a socket that holds the hollow tube and ball against the mouth guard (4), a lid for the sensor housing (5), and the sensor platform.

Figure 3 shows the assembled mouth guard/bit block(1) and housing for the hollow tube (2) connected to the housing for the Arduinos and LCD screen (3) which is then connected to a computer.

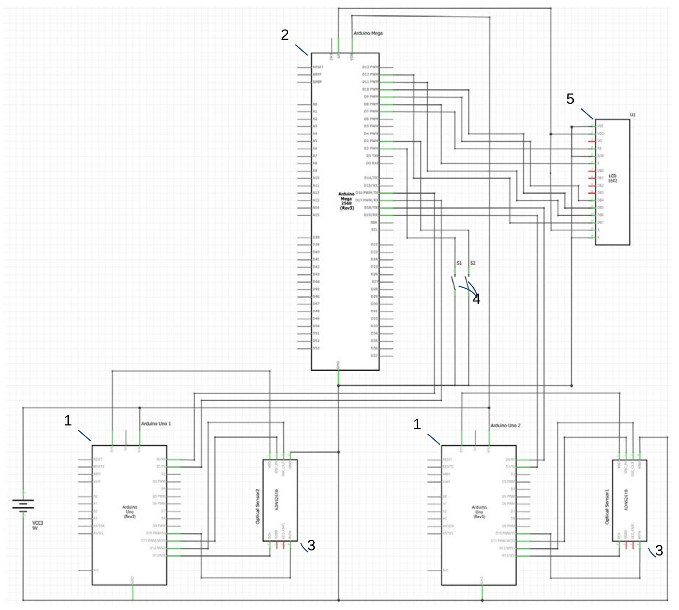

Figure 1

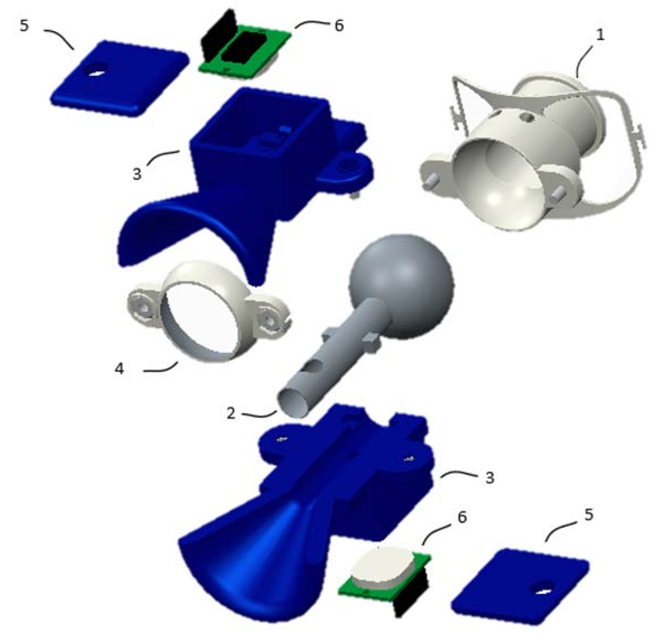

Figure 2

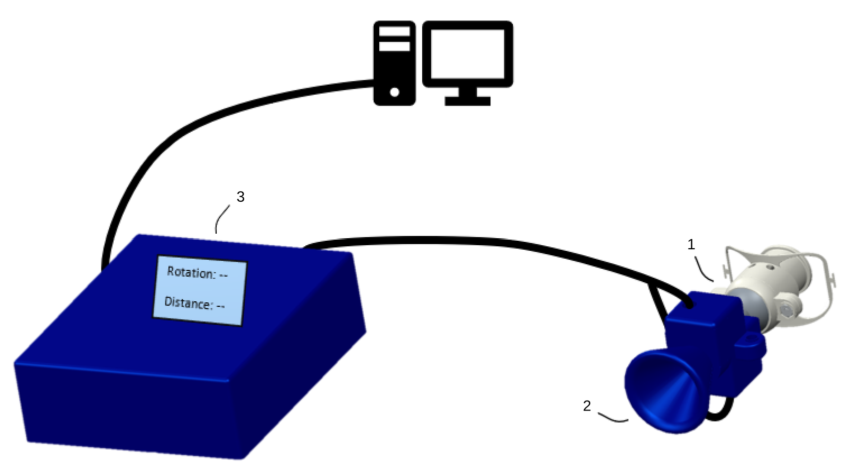

Figure 3

Rescoped Final Design

Due to COVID-19 the team was only able to produce a prototype with the circuit (**Figure 4**) consisting of two Arduino Unos (1), one optical sensor (2) and the LCD screen (3). **Figure 5** and **6** show the 3D printed housing and hollow tube.

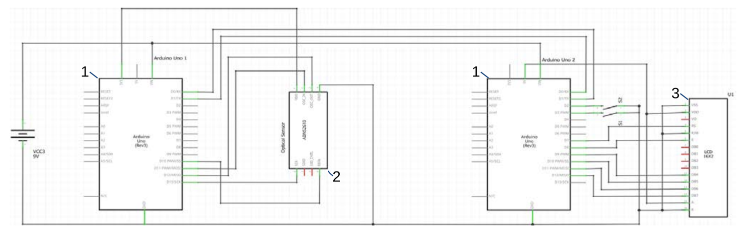

Figure 4

Figure 5

Figure 6

Preliminary Results

The team was able to perform some preliminary testing and the results of which are shown in the tables below.

Linear Testing Data						
	0-5 inch	0-10 inch	0-20 inch	0-10-5 inch	0-20-10 inch	0-20-5-10 inch
Test 1	5.08	10.24	21.26	5.26	10.08	10.04
Test 2	5.16	10.23	21.30	5.35	10.13	10.59
Test 3	5.14	10.17	21.33	5.33	10.04	10.36
Test 4	5.12	10.19	21.26	5.34	10.13	10.56
Test 5	5.11	10.21	21.17	5.18	10.08	10.46
Average	5.12	10.21	21.26	5.29	10.09	10.40
Std Dev.	0.025	0.025	0.056	0.064	0.033	0.199
Measured Value	5	10	20	5	10	10

Rotational Testing Data								
	30 degree cw	30 degree ccw	45 degree cw	45 degree ccw	60-45 degree cw	60-45 degree ccw	60-30-45 degree cw	60-30-45 degree ccw
Test 1	28.72	29.87	41.75	35.62	49.02	44.43	44.43	41.75
Test 2	26.81	27.96	42.51	42.51	47.87	43.66	43.66	45.58
Test 3	28.34	27.19	43.28	42.51	43.66	44.81	44.43	44.43
Test 4	28.72	26.81	45.96	44.43	49.79	45.96	45.58	44.43
Test 5	28.34	27.58	42.90	38.68	44.43	43.66	45.96	44.81
Average	28.19	27.88	43.28	40.75	46.95	44.50	44.81	44.20
Std Dev.	0.71	1.07	1.43	3.17	2.47	0.85	0.84	1.30
Measured Value	30 degrees	30 degrees	45 degrees	45 degrees	45 degrees	45 degrees	45 degrees	45 degrees

* On March 16, 2020 classes and labs were closed to students due to the COVID-19 Pandemic. Without access to fabrication and testing equipment, Objectives and Deliverables were modified accordingly.

Modified Objectives

- The team was able to get enough viable data from the tests to conclude that the design was viable. Moving from in person to online was not much of an hinderance due to positive test results.
- The team began to operate via zoom video chat meetings with a heavy concentration on online communication and collaboration.
- The overall development process for the project was brought to a halt after the COVID-19 quarantine, although the team was able to get enough results to bring it to a conclusion.
- Plans to remove hysteresis were limited by the health crisis, and would have helped improve accuracy.

Summary

The team was able to navigate the unique challenges of developing a prototype of a precision instrument to track the position and movement of an endoscope. The team was also able to test and refine this prototype up up to the point at which the COVID-19 crisis prevented it from iterating further.

Team & Acknowledgements

- Sean McNamara – Electrical and Computer Engineering Technology
- Jesse Moore – Electrical Engineering
- Samantha Brooks – Electrical Engineering
- Josh Gibson – Mechanical Engineering
- Dr. Philip Stack – Sponsor
- Dr. Martin Tanaka – Mentor