



Department of Electrical and Computer Engineering
Howard University
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EECE-401 Senior Design

Proposal for Swallowable Capsule Technology

Team Members:
Cimoya Collins
Gilbert Hopkins
Michelle Lilley
Ashley Wells

Instructor: Charles Kim, Ph.D.

Advisor	Name	Signature	Date
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Class Instructor	Name	Signature	Date
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Table of Contents

Introduction	3
Objective	3
Background	3
Outline.....	5
Problem	5
Problem Definition.....	5
Design Requirements	5
Current Status of Art	6
Engineering Approaches for Solution Generation.....	7
Tasks and Deliverables.....	8
Tasks	8
Deliverables	8
Project Management.....	9
Conclusion.....	10
References	12

Introduction

Objective

The objective of this proposal is to emphasize the impact that swallowable capsule technology has had, thus far, as well as in the future. Also, within this proposal a design challenge will be presented and a solution to the initial problem will be conveyed.

Background

Gastrointestinal (GI) diseases are ailments that affect over 3 million people in the United States alone. These diseases refer to ulcerative disorders of the upper gastrointestinal tract. The swallowable capsule technology is helping reveal GI tract mysteries in therapeutic and diagnostic applications, which has proven to be an exceptional breakthrough. These electronic microcomputer systems are now able to explore the GI tract and can transmit the information (temperature, images, pressure, and pH data) that was obtained through the sensors to an output.

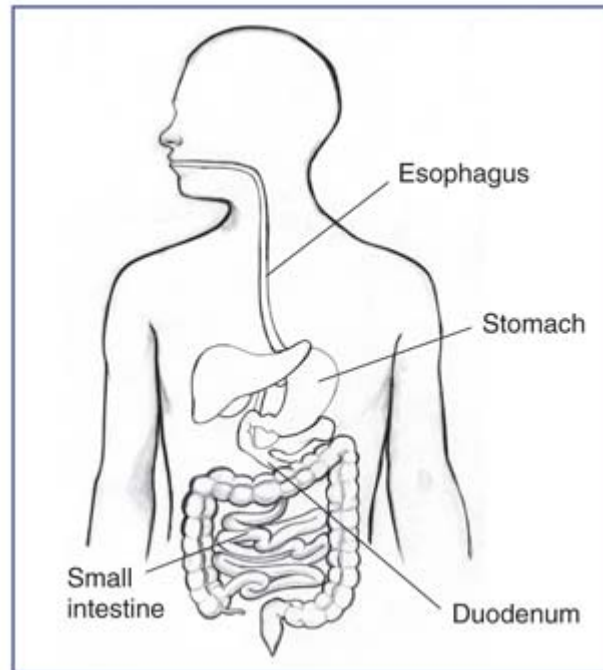
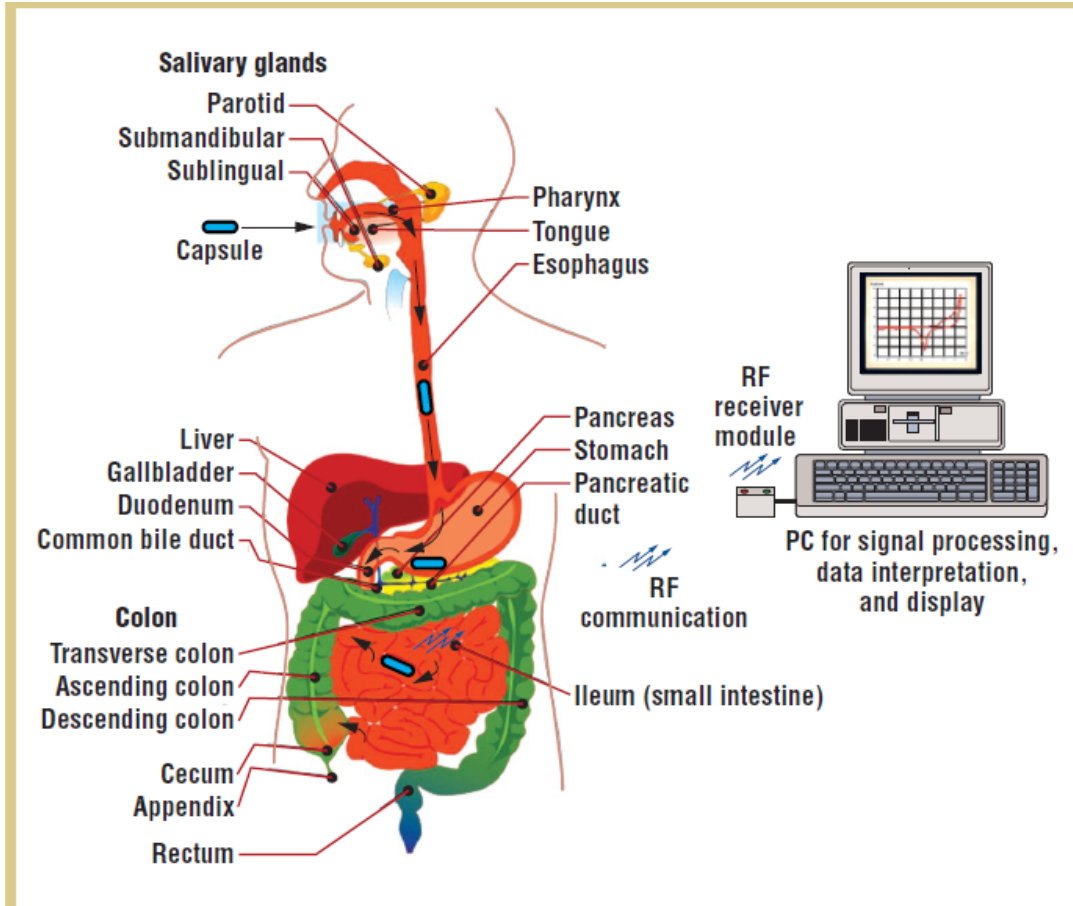


Figure 1 – The following is a gastrointestinal image of esophagus, stomach, small intestine, and duodenum.



ⁱⁱFigure 2 – The process of the capsule within the GI tract.

Outline

Within this proposal, the primary cause of the problem will be defined, along with the necessary requirements for the design and constrictions on our final solution. In addition, we will emphasize the affects this technology has already had on the human body by revealing some of the mysteries of the GI tract.

Problem

Problem Definition

The challenge for this swallowable capsule technology is to be able to design a micro-system that will eliminate the need for Endoscopy procedures, along with surgical procedures that could potentially follow. Due to endoscopy and surgical procedures being invasive, having to utilize anesthesia, potentially puncturing the esophagus and/or lining of the stomach, which could then lead to internal bleeding. This swallowable pill, in return, will be designed to give a more accurate diagnosis than the endoscopy procedure, will eliminate the endoscopy procedure, and eliminate the need for surgical procedures that detect certain issues within the body. Our swallowable capsule will be focused primarily on two classes of diseases:

- * Vascular and blood related
 - * Cholesterol Levels, Stomach (Internal) Bleeding
- * Digestive related
 - * Stomach ulcers, Acidity in stomach

Design Requirements

The constraints imposed on this project require that our proposed design must meet the following requirements:

- Internal Design of the Capsule:
 - pH sensor
 - Communication Standards
 - Medical Implant Communication Service: Operations in the 402-405 MHz range
 - Industrial Scientific and Medical bands such as 433.92 MHz are acceptable
 - Microcomputer
 - Communication system
 - Camera/ Video Camera
- Ember 250 Development Kit
 - ZigBee System on chip
 - 16 bit Microprocessor
 - Flexible antenna interface
 - Surface Mount Technology package
 - Integrated Memory
 - 128 kB of Flash
 - 5 KB of SRAM

- 2 serial controllers
- 2 sleep modes
- Interfaces
 - 1 UART
 - 1 Mbps
 - ADC: 4 Inputs
 - 13 Digital Inputs/Outputs
- Temperature:
 - Capsule must be able to withstand temperature greater than 98.6° F
- Wireless communication
- Size:
 - Capsule:
 - 1 cm wide
 - 15 mm long
 - Area: 2.6 cm³
 - Thickness of Camera: 1.4 mm
- Regulations and Standards:
 - FDA
 - HHS
 - ROHS
 - Restricts the use of certain hazardous substances in electrical and electronic equipment such as, Lead, Mercury, and Cadmium.
 - IEEE
 - 802.11 is a set of standards for implementing wireless local area network computer communication in the 2.4, 3.6 and 5 GHz frequency bands

Current Status of Art

One of the first successes in swallowable technology was the Ingestible Thermometer Pill, developed, with support from NASA, in the late 1980's at John's Hopkins University. The intent was to monitor the core temperatures of astronauts in space. This pill later came to be known as CorTemp, and was used to monitor body temperatures of those in more strenuous situations such as fire-fighters, deep sea diving, and the military. There has also been success with imaging in capsule endoscopy. One company, Olympus Optical, was one of the first to receive a patent in this are for their capsule. The Olympus capsule used a magnetic field outside of the body to control tracking. Issues with Olympus' first capsule were proper illumination of the area and the capsule needed to be open to retrieve images.

Looking at new ways of tracking nowadays, the University of Calgary, has developed a capsule that contains a capacitive MEMS accelerator. The capsule transmits the signal conditioned from the accelerometer to an external module for processing. "Through successive mathematical integrations, the propagation velocity and the capsule's displacement can be retrieved." The problem with this development right now is the acceleration levels of the

stomach limits the capsule to currently only being used in the esophagus. Acceleration in the stomach exceeds the micro-accelerometers' monitoring range. Some techniques of determining location include placing antennas around the body and measuring signal strength at the antenna. Also there is another technique that involves the use of ultrasound waves, "the capsule can emit ultrasound waves for external detection, or echo waves emitted externally."

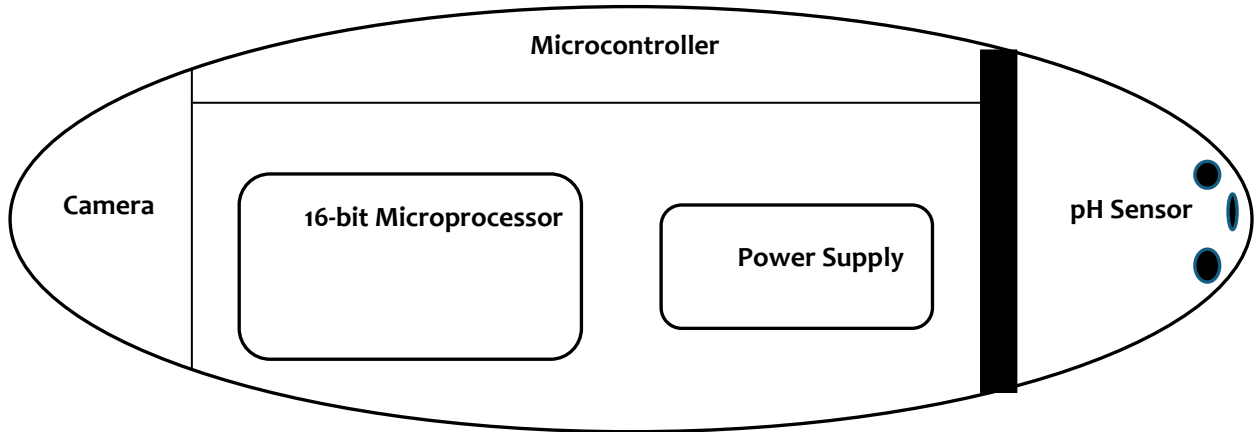
Currently Swallowable Capsule Technology is used to monitor core body temperature. With the number of heat-exhaustion-related deaths increasing in American football, many US National Football League teams have begun to use this technology to help track and regulate core body temperature. More recently, the pill has been used in other sports including soccer and hockey and in areas such as firefighting, deep-sea diving, and the military. Swallowable Capsule Technology is also used in endoscopy. Capsule endoscopes couple one or more imaging devices with a lighting source to capture images of the GI tract, including the small intestine. For the patient, such capsules offer a convenient examination with minimal preparation and immediate recovery. The main vendors are Olympus Optical, Given Imaging, and the RF System Lab. Some of the latest capsules created by Olympus Optical have excellent image quality, brightness adjustment, real-time video viewing, and the ability to activate and deactivate the capsule. Given Imaging has developed a similar endoscopy

Engineering Approaches for Solution Generation

The complex and detail design of the swallowable capsule brings many challenges from the engineering perspective. The size, weight, and the durability of the capsule play a major role in tackling the tasks of constructing the swallowable capsule. The initial idea was for the internal design to be constructed of sensors, a signal conditioner, power supply, and a communication system. Due to constraints of having a small power supply within in a small capsule doesn't necessarily follow the idea of "safety". Having a sensor can also lead to challenges, such as how small can we make the sensor in order for it to work and withstand the body temperature without malfunctioning.

There are various aspects that go into making sure that all the devices that make up the system can withstand the body temperature of the human and still function properly. The first step encounters what materials are needed, for instance a camera, fiber optic cables, and, LEDs. With those materials arise the challenge size and how one is able to fit this complicated system in an item small enough to swallow. By understanding the meaning of the capsule many look at the Nanotechnology point of view having something so small yet powerful to produce proper efficiency. One point of consideration is whether the capsule is reusable. Can engineers make a product that can be reused and still produce an efficient output? Hence the approaches of using fiber optic cables, and LEDs within the design; which can withstand numerous trials and still return accurate results.

Our Potential Capsule Design:



Tasks and Deliverables

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Task	Member(s) Assigned to Task	Date of Task Assignment	Expected Date of Completion	Actual Date of Completion
Research Swallowable Capsule Technology	All Members	October 2011	On-Going	
Evaluate Potential Solutions	All Members	October 2011		
Select Best Solution for Problem	All Members	October 2011	Late November 2011	Early December 2011
Develop Slides for Proposal Presentation	All Members	November 2011	November 1 st , 2011	November 2 nd , 2011
Presentation Run Through	All Members	November 2011		
Go to Nanotechnology Lab	All Members	January 2012		
Develop Capsule		February/ March 2012		
Test Capsule		March 2012		

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We will have designed and built a working swallowable capsule tested by a team member. Images taken from the team member will also be shown. Along with the model and images we will have:

- Budget Analysis
- Report on Swallowable Capsule technology

Item	Price
EM-250 Development Kit	\$2500*
SMT Components (i.e. transistors, resistors)	\$50
Fiber Optic Cables	\$25
Camera/Video Camera	\$10
Pill Capsule	\$5
Cost of Etching	\$50
Total	\$2640

Project Management

Milestone	Scheduled Date
Initial Proposal: Version I	November 2011
Initial Proposal: Presentation	November 2011
Written Proposals: Version II	November 2011
Written Proposal: Version III	November 2011
Final Proposal Presentation	December 2011
Evaluation/ Selection of Design	December 2011
Final Written Proposal	December 2011
Peer Evaluations	December 2011
Finalize Design	December 2011
Ordering of Components	December 2011
Commencement of Development of Design	January 2012
Testing of Project	March 2012
Documentation of Project	March 2012
Presentation Slides	March 2012
Draft Project Presentation	March 2012
Final Project Presentation	April 2012

Conclusion

Swallowable capsule technology is currently on the rise to being a form of biomedical technology being used to make grand impacts in not only the science and engineering fields of study, but definitely how problems in the health and medical fields are handled as well. There are many successes and advantages that go along with this swallowable capsule technology. Some of these pros include the diminution in unnecessary invasive operations. Also, the images taken from inside the body will allow the site of the problem to be more easily identified and the necessary steps can be taken. The challenge for this swallowable capsule technology is to be able to design a micro-system that will give a more accurate diagnosis than the endoscopy procedure, will eliminate the endoscopy procedure, and eliminate the need for surgical procedures that detect certain issues within the body. Our swallowable capsule will be focused primarily on two classes of diseases. Those diseases include Vascular and blood related (i.e., Cholesterol Levels, Stomach (Internal) Bleeding) and Digestive related (i.e., Stomach ulcers, Acidity in stomach).

We will have a working model built by April 5th, 2012 in preparation for the final presentation on Electrical and Computer Engineering Day.

References

McCaffrey, C.; Chevalerias, O.; O'Mathuna, C.; Twomey, K. (2008, Jan.) "Swallowable-Capsule Technology." *Pervasive Computing, IEEE*. [Online]. 7.(1), pp. 23-29. Available: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4431853 [October 2, 2011].

ⁱ National Digestive Diseases Information Clearinghouse. "Upper GI Endoscopy." Internet: <http://digestive.niddk.nih.gov/ddiseases/pubs/upperendoscopy/>, May 2009 [October 3, 2011]