DEPARTMENT OF
BIOMEDICAL ENGINEERING

MARQUETTE UNIVERSITY

MEDICAL COLLEGE OF WISCONSIN

SENIOR DESIGN PROJECTS 2020

ON THE COVER: CAD rendering (inset) and final prototype (main photo) of the *Heart Kart* used to increase mobility and independence of pediatric patients with ventricular assist devices awaiting heart transplants. Details of this project can be found on page 19.

to our industry partners

We are pleased to present the Biomedical Engineering Senior Design Projects completed during the 2019-2020 academic year with the joint department between Marquette University and the Medical College of Wisconsin.

The Department of Biomedical Engineering at Marquette University is dedicated to preparing students for their professional and personal lives after graduation. Undergraduate students can specialize in biomechanical, bioelectrical, or biocomputer engineering. In addition to courses in engineering, mathematics, and the life sciences, students are required to complete several design challenges in the freshman year and a year-long project-based capstone design course in the senior year. Students develop their teamwork skills, learn about the product development process used in industry, and are made aware of the unique requirements and constraints of medical device design. They consider legal and regulatory issues, use standards where applicable, conduct economic analyses, and learn about packaging, sterilization, and testing of medical devices. Several project deliverables, similar to those used in industry, are required. This capstone design experience provides students with the knowledge base and skill sets needed to be effective contributing members of a medical device company, clinical engineering department, or academic research laboratory, and create value for their customers.

This was the fourth year of our new joint Department of Biomedical Engineering between Marquette University and the Medical College of Wisconsin. This year we continued our 15-year collaboration with the Milwaukee Institute of Art and Design (MIAD). Four of our project teams collaborated with industrial design students from MIAD during the spring semester. This was the ninth year of external funding for service learning, assistive technology, and other projects. We appreciate this support made possible by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering and the Marquette University Strategic Innovation Fund.

During the spring semester, the global COVID-19 pandemic presented several challenges to the successful completion of senior design projects. A lack of prototyping resources and test equipment and space, and sudden shift to virtual collaboration among team members created barriers to completing prototypes and other course deliverables. Our students found creative and resourceful ways to overcome these barriers and meet course requirements.

In our Biomedical Engineering Department, students may enhance their design experience and preparation for careers in the engineering profession through work experience. At the Les Aspin Center for Government Studies, students can work as interns for the US Food and Drug Administration and learn first-hand how the FDA functions and what is required to market a regulated medical device. Students participating in our highly popular and nationally recognized Cooperative Education Program gain work experience at medical device companies prior to graduation.

As you read through this report and learn of the benefits of industry sponsorship of senior design projects, please consider becoming a sponsor. We recognize the value to our students and program of strong ties to industry, and we are interested in working with additional companies to help us prepare our students for careers in biomedical engineering.

Respectfully,

Jay R. Goldberg, Ph.D., P.E.
Professor of Practice in Biomedical Engineering
Senior Design Course Instructor

Frank Pintar, Ph.D.
Professor and Chair
Department of Biomedical Engineering

industry sponsorship

Senior Design Course Sequence:

At Marquette University, all senior biomedical engineering students are required to successfully complete a set of project-based capstone design courses (BIEN 4920, Principles of Design, and BIEN 4998, Senior Design). At the end of these courses, students will demonstrate:

- The ability to connect and apply the knowledge and skills developed in previous engineering (and other) courses towards a design solution (to a specific problem) that creates value for a customer
- The ability to plan and produce a product or service that will meet customer needs
- The ability to work effectively in teams
- Written technical and oral communication skills

Senior Design Project:

The major component of the course is a design project that is managed by a multidisciplinary team of three to five students for an entire academic year. During the year, project teams identify customer needs, develop potential designs, construct and test prototypes, and deliver a design and/or working prototype to their industry sponsors. Project teams develop project schedules, maintain project notebooks, conduct economic and risk analyses of their design solutions, and develop and present written and oral project proposals and final reports.

Many of the projects are industry sponsored and provide students with an opportunity to learn about the needs of the medical device market and the operations of a company. Experience gained from industry sponsored projects helps prepare students for careers in the medical device industry. Teams are advised by a biomedical engineering faculty member and a representative from the sponsoring company.

Benefits of Sponsorship:

Benefits to companies sponsoring design projects include:

- Additional resources at little cost to company

Three to five senior engineering students will be dedicated to each project for two semesters. The sponsoring company can specify the composition of the project team (biomedical, electrical, computer, and mechanical engineering students). This can be very beneficial to companies with limited engineering resources and can allow companies to focus efforts on higher-priority projects.

- Involvement and participation in the training of new engineers and potential employees

- On-campus advertisement of the sponsoring company

Involvement in the senior design project will provide the company access to and a higher profile among graduating engineers.

Benefits to students of industry-sponsored projects:

- Opportunity to work on real-world problems important to industry
- Exposure to the medical device industry and market
- Experience with project management and product development
- Familiarity with requirements and constraints of medical device design

Requirements for Industry Sponsorship:

Personnel: Sponsoring companies must identify at least one company representative to act as an industry advisor to the project team. The industry advisor would be the company contact for the project team, advise students on issues involving customer needs, provide technical expertise and advice, and approve design concepts and prototypes. Faculty advisors will be responsible for administrative issues (grading, monitoring progress of teams, dealing with team personnel issues, etc.) and providing guidance to the team.

Time: At a minimum, industry advisors must be available to discuss project requirements, customer needs, and potential designs. Communications can be in-person or by phone, e-mail or video conference. The advisor determines the frequency of communications.

Travel: The sponsoring company determines the need for travel.

Funding: Depending upon the needs and expectations of the sponsor, a fund of $1000–$1500 may be necessary to pay for prototypes and testing.

Other: Students have access to Marquette University's computer network, libraries, Discovery Learning Laboratory (machine shop, collaboration space, 3D printers, prototyping resources), faculty expertise, and engineering laboratories. Sponsors may want to provide additional resources (prototyping facilities and/or personnel, laboratories, etc.) to their project teams if desired.

Types of Projects Appropriate for a Senior Design Project:

- Lower priority projects for which the company lacks resources
- Projects that can be completed in nine months or less
- New products (hardware or software)
- Product improvements (new features, packaging, materials, etc.)
- Process improvements
- Development of test procedures and/or test equipment

Protection of Proprietary Information:
Sponsors can request that members of their project teams sign non-disclosure agreements to protect confidential and trade secret information.

To Sponsor a Biomedical Engineering Senior Design Project:

If you have any questions about our senior design program or if you are interested in sponsoring a senior design project please contact Dr. Jay Goldberg at (414) 288-6059 or jay.goldberg@marquette.edu.

We look forward to working with you.

industry sponsors

2019–2020

SeaSpine, Carlsbad, CA
Medtronic USA Inc., Minneapolis, MN
GE Healthcare, Waukesha, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia
FreedomTrax, Waukegan, IL

2018–2019

GE Healthcare, Waukesha, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia
Resolution Medical, LLC, Minneapolis, Minnesota

2017–2018

Mortara Instruments, Milwaukee, WI
3M, Minneapolis, MN
GE Healthcare, Waukesha, WI

2016–2017

Siemens Medical Solutions USA Inc., Hoffman Estates, IL
Safe Place Bedding, LLC, Conesville, OH
9 Degrees of Human, Milwaukee, WI

2015–2016

Medtronic USA Inc., Minneapolis, MN
Trek Bicycle Corporation, Waterloo, WI
Cardiac Profiles Inc., Franklin, TN
Zimmer Biomet, Warsaw, IN

2014–2015

GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN
Rowheels, Fitchburg, WI

2013–2014

Cytophil, Inc., East Troy, WI
DesignWise Medical, Loretto, MN
GE Healthcare, Waukesha, WI
Siemens Healthcare, Hoffman Estates, IL
Medtronic USA Inc., Minneapolis, MN

2012–2103

NeoCoil, LLC, Pewaukee, WI
Gauthier Biomedical, Grafton, WI
3M, Minneapolis, MN

2011–2012

GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN
Innovator of Disability Equipment and Adaptations, LLC, Pewaukee, WI

2010–2011

Cardiac Science Corporation, Deerfield, WI
DePuy Orthopedics, Inc. Warsaw, IN
GE Healthcare, Waukesha, WI
Medtronic USA Inc., Minneapolis, MN

2009–2010

DePuy Orthopedics, Inc. Warsaw, IN
GE Healthcare, Waukesha, WI
3M, St. Paul, MN

2008–2009

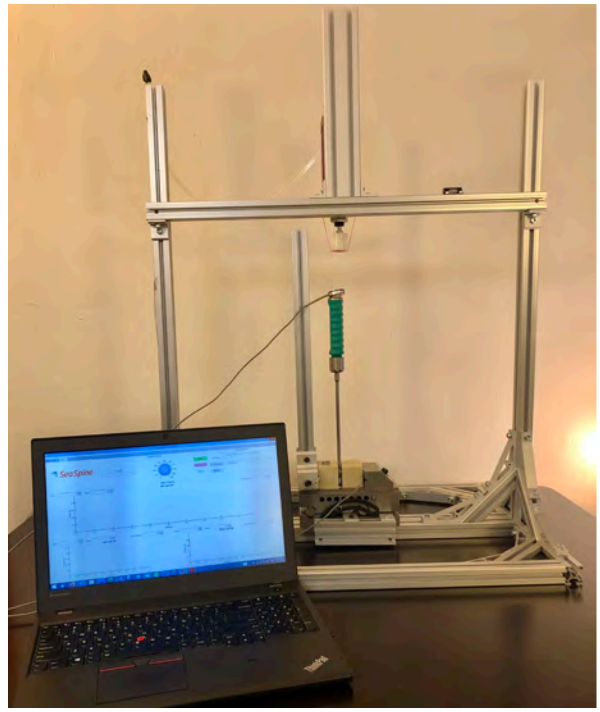
DePuy Orthopedics, Inc., Warsaw, IN
Siemens Medical Solutions, Hoffman Estates, IL
GE Healthcare, Waukesha, WI
ACTRA Rehabilitation Associates, Brookfield, WI
Gauthier Biomedical Inc., Grafton, WI
Stevenson Industries, Simi Valley, CA

SPINAL IMPLANT IMPACT TEST DEVICE

Project Team: Nicole deGuzman
Edward Dold
Jake Horder
Maggie Weglarz
Chaimaa Maghfour

Faculty Advisor: Dr. Brian Stemper

Sponsor: Zac Dooley
SeaSpine, Inc.



Since 2000, the FDA has recorded more than 1,000 reportable incidents dealing with spinal implants in surgical settings. The pre-existing compressive preload that acts on the disc space creates a challenge for surgeons during surgical procedures involving insertion of a spinal implant. The magnitude of the impact force from the surgeon swinging a hammer on the spinal implant is usually increased to insert the implant into the disc space. As a result, the implant may fracture during insertion. Before surgery, spinal implants are subjected to multiple tests to demonstrate safety and reliability based on ASTM standards F1717, F2077, and F2267. Unfortunately, the standardized mechanical testing of spinal implants is limited to the traditional impact testing machines that are used in industrial settings, which do not accurately model stresses induced during surgery.

SeaSpine, Inc. requested a comprehensive impact test device that increases the clinical accuracy by including greater impact directional flexibility than the standard tests required by the FDA to characterize the fracture patterns of the spinal cages. The device was designed to replicate the magnitude and direction of impacts seen in surgical settings. Therefore, the project involved designing and building an impact test device that allows the client to test various types of implants with their respective inserters. The device can test a spinal cage and inserter at various angles and impact forces.

The prototype underwent experimental verification during the final week of the project. Due to the COVID-19 outbreak, the team was unable to fabricate all components that were a part of the design, but as many components as possible were tested. With this delay in the schedule, there was no time to reassess and improve the design. However, the tests that were completed showed that the impact test device could operate as intended with additional adjustments and components that were unable to be fabricated. Implementation of these design changes would create a test fixture that is durable, repeatable, and able to replicate a spinal cage being inserted during surgery.

FREEDOM TRAX ALL-TERRAIN WHEELCHAIR

Project Team: Mia Cabela, Veronica Davalos, Zarina DeCastro, Emma Baker, Kyle Harty

Faculty Advisor: Dr. Jay Goldberg

Sponsor: Dan Livingston, Freedom Trax

Currently, Freedom Trax has two product lines: FT1 and FT2. The FT1 model can be used by rolling the customer's standard wheelchair onto the track. The FT2 model comes equipped with a chair supplied by a third-party vendor and can be removed from the track when the chair is not in use. Both models are based on the Freedom Trax special all terrain track that is designed to help those who have difficulty traversing rough terrain, such as sand, mud, and snow. Both models can run for roughly 7 miles on a single charge and are controlled by a joystick, which allows for quick and easy turning. Due to the construction of the track, the chair is capable of making very quick and tight turns without the track breaking or skipping, making the track very durable on different terrains.

The market for the FT2 model consists of people who have mobility issues but do not need a standard wheelchair on a daily basis. Older customers whose mobility has become limited due to age related health issues but do not wish to use a wheelchair regularly will benefit greatly from the FT2 model, which will help customers live an active lifestyle by helping them get around rough terrain encountered at a beach, on a mountain hike, or while hunting.

The problem that the team focused on involved the FT2 chair. Currently, it is anchored to the track with two pins that attach the bottom of the front two chair legs to the track. This requires the user to get low on the ground to secure or remove the pins. Many customers do not bother removing the chair from the track unless it is absolutely necessary.

The team created a design for a chair that would allow the user to fold it onto the track when it is not in use. The chair height can be easily adjusted to 13, 15, or 17 inches, to allow the user to customize the chair to their activities. The chair backrest angle can be adjusted from 90 to 130 degrees with 10 degree increments to provide the user with the proper amount of comfort and support. The chair is made of lightweight aluminum tubes to allow for easy assembly for the user and the manufacturer. The seat of the chair is made of waterproof polyester and a waterproof memory foam cushion to allow the chair to be comfortable and easy to clean as the chair is used for different types of outdoor activities.

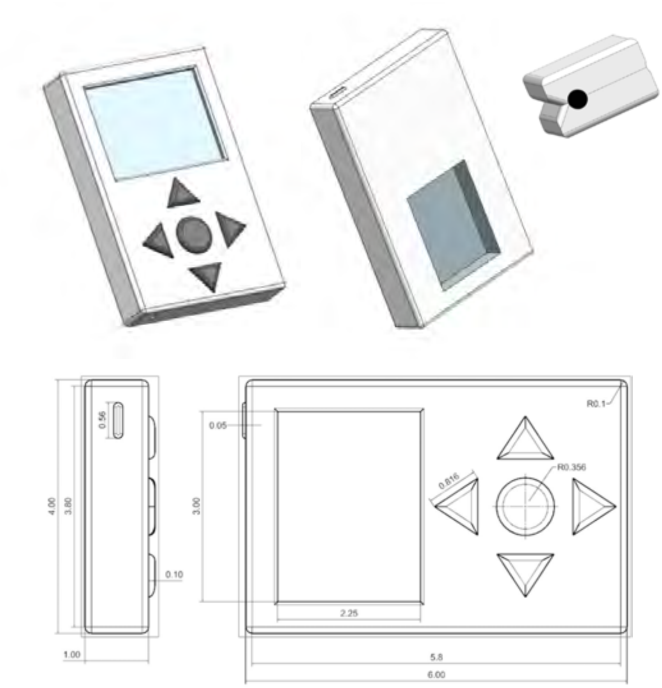
The physical prototype was not tested, but the team was able to verify the design of the chair legs, seat, and backrest by calculating the forces required to permanently deform the chair. The FT2 Track is safe for users weighing 300 pounds or less. Since the chair is capable of being folded when it is not in use and is calculated to safely hold a user weighing ≤ 300 pounds, the team successfully created a design that can be used on the FT2 track for daily activities.

LOW-COST, PORTABLE, NON-INVASIVE IRON MONITORING DEVICE

Project Team: Jake Beery
Samantha Lammers
Morgan Armoneit
Paul Gagne
Sydney Eger

Faculty Advisor: Dr. Bing Yu

Sponsor: M. Sikulu-Lord, M.D., Spectroscopy and Data Consultants Pty Ltd.



A low-cost, portable, non-invasive iron monitoring device to ensure safe and efficient measurement of iron levels in people living in developing nations is in serious demand. Currently, most devices that measure iron levels are invasive or require travel to a clinic. This causes those in remote parts of the world to deal with longer travel times to clinics and high medical costs for testing. They are also at greater risk for iron deficiency because they often do not have consistent access to nutritional foods and are living in unhealthy conditions.

According to the World Health Organization, iron deficiency is the most common nutritional disorder in the world affecting one in four people. When iron deficiency goes unmonitored, it can cause serious complications.

The team designed a device that enables patients to monitor iron levels more easily, more efficiently, and at a lower cost. The device uses a clamp, which compresses the customer's finger and is connected to the main device using a cable. The finger clamp consists of a photodiode which measures the light emitted from three LEDs and converts this value into a measured voltage. The device then converts this voltage into a measured iron level using an Arduino microcontroller and relays this information to the customer. The main device consists of four triangular selecting keys, one "enter" key, and one power on/off button. It is also battery-powered to increase portability and make it easier to use for those in remote areas of the world where electrical wall outlets are not always accessible. With this system in place, the device is able to efficiently measure hemoglobin concentrations to monitor iron levels in patients.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

WEARABLE EMG-BIOFEEDBACK UNIT TO MONITOR REAL-TIME MUSCLE ACTIVATION

Project Team: Francisco Fuentes
Jose Bodewig
Christy Dolick
Luke Dowell
Molly Ballanger

Faculty Advisor: Dr. Scott Beardsley

Sponsor: Dr. Donald Neumann
Marquette University
Physical Therapy

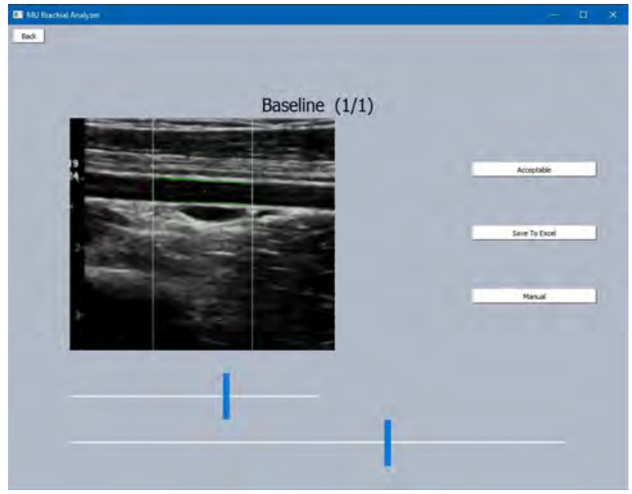
Understanding the way in which a human body moves can be difficult when learning about it for the first time. For physical therapy students, seeing the muscles associated with a movement can be particularly difficult to visualize. Seemingly simple movements of the body can employ multiple muscle groups. Since the physical contraction of the muscles occurs under the skin, a biofeedback device indicating which muscles are active (and when they are active) would aid student learning of the biomechanics of human movement.

The project sponsor (a professor of kinesiology) wanted to make a complicated concept more engaging by integrating the concept of biofeedback into his lectures. Previously, he developed a series of surface electromyography (EMG) sensors wired to a central hub that provided analog light feedback of muscle activity during movement. Not only did the multiple wires used in this device complicate the visualization of muscle activation, it also made the setup for the device tedious and time consuming.

The team expanded on the original design and used input from students, other physical therapists, and physical therapy patients to create a wireless device that provides visual biofeedback of muscle activation without the use of wired connections between sensors and hub. The system used rechargeable surface EMG sensors placed on muscles of interest to continuously measure the electrical activity of the muscle. An LED was embedded into the top of each sensor case to provide continuous visual feedback of overall muscle activity. The sensors were connected wirelessly to a central Bluetooth hub that interfaced with a tablet application developed to allow the user to control the gain of the biofeedback.

Although the COVID-19 pandemic impacted the scope of the project, the resulting system provided the sponsor with a digital and wireless device that could be quickly setup to provide visual biofeedback of muscle activity for use during lectures. The individual (and programmable) gain adjustment feature built into each sensor allows them to be used across a wide variety of muscles to demonstrate the relationships between muscle activity and biomechanics during complex movements of the human body.

BRACHIAL ARTERY FLOW MEDIATED DILATION ANALYSIS SOFTWARE



Project Team: Allison Goetz, Haley Kleinhans, Emma Moravec, Daniel Pederson, Daniel Whipple

Faculty Advisor: Dr. Brian Hoffmann

Sponsor: Dr. Mike Widlansky, Medical College of Wisconsin

Brachial Flow-Mediated Dilation (FMD) is a measurement of how blood vessels respond to a change in shear stress on the vessel wall. In the research setting, this change in shear stress is created by inflating a blood pressure cuff for five minutes, then releasing the cuff to allow for a large amount of blood flow. This large increase in flow increases the shear stress and prompts the endothelial cells to respond by dilating the vessel. A low % dilation value of the artery for this test could indicate poor blood vessel health. Currently, Brachial FMD is measured using ultrasound and image analysis software to detect changes in artery diameter and flow. This requires a technician to manually identify vessel edges and outline flow integrals. The long process wastes valuable time that could be spent analyzing the data, and this process could be automated using image processing techniques to trace artery diameter values and calculate the percent dilation.

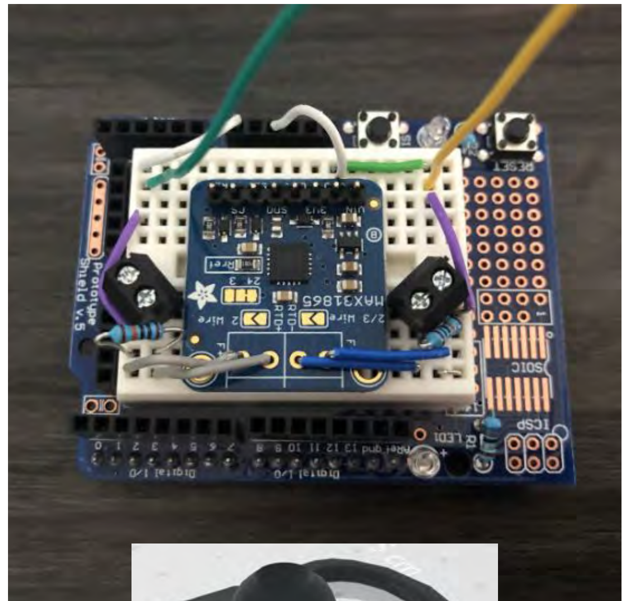
The objective of this project was to develop a software program to automatically collect and process FMD measurements from recorded ultrasound clips, drastically reducing time of analysis.

Testing and verifying the program's functionality included comparing program outputs to outputs from current analysis techniques, testing the consistency of the program in producing the artery diameter of images contained in a single video file multiple times, and comparing user-interface and ease-of-use ratings relative to other analysis software. Tests indicated that the program was not accurate relative to outputs from current analysis techniques but was consistent in output artery diameter for any given ultrasound video. The program was very simple to use relative to other analysis software.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

NON-INVASIVE TEMPERATURE SENSOR FOR STUDYING CIRCADIAN RHYTHM

Project Team:	Thomas Fellers Jarrett Burgess Mike Thayer Robert Guzek Raj Patel
Faculty Advisor:	Dr. Guilherme Garcia
Sponsor:	Dr. B. Tucker Woodson Medical College of Wisconsin



The circadian rhythm is an important mechanism that regulates the body's sleep-wake cycle and is closely linked to core body temperature. This link implies that core body temperature can be used to track the circadian rhythm. Misalignment of the circadian rhythm with the actual sleep cycle can result in sleep disorders, thus a device that tracks the circadian rhythm would be useful for research studies and possibly diagnosis and treatment of sleep disorders. Currently, devices used to measure core body temperature include oral and rectal thermometers. However, these devices are invasive and so it is impractical to use them to track the circadian rhythm because the measurements must be taken frequently over an extended period of time.

This project aimed to create a device to measure core body temperature for the study of the circadian rhythm. The device was required to be noninvasive and to be capable of taking and storing temperature measurements over a two-week period. The device consists of an Arduino microcontroller, infrared thermometer, and 3D printed Arduino housing and earpiece. The infrared thermometer is located inside of the earpiece and focused on the tympanic membrane. The sensor sends the output to the Arduino via a wire, where the data are stored.

Testing was limited due to the circumstances surrounding the COVID-19 pandemic, but early tests indicated that the infrared sensor was functioning, and that the Arduino was storing data properly to the SD card. Future testing would be needed to validate the final design.

HEART RATE VARIABILITY AND BAROREFLEX GAIN MONITOR

Project Team: Ashiya Thomas
Brendan Shaughnessy
David Fraley
Douglas Peters

Faculty Advisor: Dr. Brandon Tefft

Sponsor: Dr. Thomas Ebert
Medical College of Wisconsin

It is of critical importance to achieve an appropriate depth of anesthesia (DOA) during a surgical procedure. Anesthesiologists do not currently possess a real-time and direct measurement of DOA so they instead rely upon their experience and clinical judgement. Various physiological measures such as heart rate variability (HRV) and baroreflex gain (BRG) can be used to provide indirect assessments for patient DOA. Heart rate variability shows changes in heart rate over time and can be used to assess the ability of the heart to respond to physiological changes. Similarly, baroreflex gain is a measure of autonomic nervous system control of the cardiovascular system in response to physiological changes. Both measures assess the body's control of the cardiovascular system over time. Using a real-time version of these measures can therefore be used to indirectly assess patient DOA. No commercial technology exists that provides real-time HRV or BRG measurements.

The primary goal of this project was to design a real-time HRV and BRG monitor that can measure and display those values as well as the power spectrum of HRV. A further goal was to provide selectable trend analysis for several time intervals of these measurements. A prototype was designed and constructed to successfully achieve these goals. Filter circuitry was designed to preprocess input electrocardiogram (ECG) and blood pressure (BP) waveforms. These are then read into an Arduino and further processed digitally.

They then undergo a peak detection scheme to identify the QRS complex and systolic magnitude for the ECG and BP waveforms, respectively. This is then serially communicated to a Graphical User Interface (GUI) running on a Raspberry Pi that facilitates user interaction with the data. The GUI has various capabilities such as external data download, flagging and comment on specific data points, and trend analysis for the input HRV and BRG data.

Verification testing demonstrated that the prototype met roughly half of the target specifications. Primary issues with the prototype stem from development delays due to COVID-19. The team faced serious delays in hardware base construction as well as analog processing. As the analog processing disrupted the input signals, the Arduino and Raspberry Pi consequently had erroneous data to handle. The software was tested for a range of inputs and assuming a maximized voltage input, can appropriately output HRV and BRG real-time analysis. Because the preprocessing stages corrupted the data flow, true HRV and BRG real-time analysis was not possible. Proposed design changes include updated data filtering and base enclosure designs to increase veracity of the signal and safety, respectively. Overall, the prototyped HRV and BRG real-time monitor was successful. It represents a significant step forward in technology for real-time analysis of HRV and BRG, and assessment of patient DOA.

This project was supported by a Marquette University Strategic Innovation Fund grant.

LOW-COST BATTERY POWERED VENTILATOR

Project Team: Alexa Batson, Brianna Dolan, Riley Dowdle, Louis Finney, Cindy Son

MIAD Partners: Skylar Abell, Russell Bergeron

Sponsor and Faculty Advisor: Dr. Lars Olson

The leading cause of death in children under the age of five is respiratory illness, in part because there is a lack of ventilators in developing countries. Currently, the solution to not having access to ventilators is to have patient family members and medical staff take shifts manually ventilating the patient with an ambulatory bag throughout the night. Unfortunately, there are many stories where these people fall asleep and ultimately the patient passes away. The purpose of this project was to design and develop a low-cost battery powered ventilator meant for pediatric use in developing countries. The hope is that this device will provide a solution to meet the demand for pediatric ventilators, and a means of decreasing the number of respiratory illness related deaths.

The final design of the ventilator consisted of an electro-mechanical air flow mechanism, where the pump is always on and there is a solenoid valve that allows the air to flow to the patient as they inhale and stops the flow of air to the patient as they passively exhale. The device was designed to be powered from a wall outlet but has a battery backup to provide power during power outages and patient transport. The outer housing and user interface were designed in collaboration with students from Milwaukee Institute of Art and Design to ensure the final design was intuitive and comfortable for medical personnel to use. The housing is able to stand at two different angles to allow the screen angle to be adjusted. The LCD screen clearly shows all patient statistics numerically and graphically so medical personnel have all pertinent patient information readily available. Additionally, the buttons are color coordinated with the user interface function they control.

The final design included a mechanical safety release valve, auditory alarm, and pressure, temperature, CO2 and flow sensors. To bridge the language barrier a look-up table programmed to have language options for English and Spanish was included.

Due to circumstances surrounding the COVID-19 pandemic no aspects of the final design were able to be implemented into the prototype. A proof-of-concept prototype was created instead, using the pump and solenoid valve to show it was possible to inflate and deflate a balloon with the electro-mechanical air flow design.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

ORAL pH SENSING RETAINER

Project Team: Morgan Ford
Jules Horning
Bridget Kocer
Zachary Novak
Eric Van Hare

Faculty Advisor: Dr. Bo Wang

Sponsor: Dr. Christopher Okunseri
Marquette University
School of Dentistry

Tooth decay is a prevalent issue that affects roughly 96% of the world population. Of them, 26% are untreated. Tooth decay is caused by built-up levels of plaque in the mouth associated with poor brushing and oral care. While improved oral care would decrease the level of plaque, it does not target the source of the issue. Plaque levels rise in response to highly acidic foods and beverages, such as coffee and soda. As the oral pH increases, it significantly increases the development of plaque and tooth decay. Untreated tooth decay is irreversible and can cause significant pain that impedes a person's daily routine.

The objective of this project was to design and create a proof-of-concept prototype of a minimally invasive device, intended to measure and communicate pH in the oral cavity to prevent enamel decay and improve oral health. The proposed design relies on a pH sensitive hydrogel embedded within a classically shaped, acrylic, upper jaw retainer. Hydrogel is a 3D matrix of polymer that absorbs or expels water depending upon specific chemical conditions. The hydrogel used swells in response to higher pH values and expels water at lower pH values. The proposed design uses the embedded hydrogel in conjunction with a force sensing resistor (FSR) to measure the volume change of the hydrogel. The volume change is correlated with a change in oral pH which is read by an Arduino Uno.

The proof-of-concept prototype was intended to measure a change in pH, and alert the user to dangerous acidic levels in the mouth to prevent enamel decay. Restrictions due to the COVID-19 pandemic prevented a functional proof-of-concept prototype from being completed.

This project was supported by a Marquette University Strategic Innovation Fund grant.

BACK TO BIRDIES: ASSISTIVE GOLF DEVICE

Project Team: Connor Alba
Kennedy Coplen
Drek Dumond
James Kubik

Faculty Advisor: Dr. Jay Goldberg

Sponsor: Kathleen Beauchamp

Scleroderma includes a group of rare diseases that lead to the hardening and tightening of the skin and connective tissues, resulting in decreased motion of the joints and extremities. Depending on the severity of the disease, scleroderma can also affect the blood vessels, internal organs and GI tract, and cause musculoskeletal aches and pains. The hardening and tightening of the skin are a result of an overabundant production of collagen in the body. The cause of this abnormal amount of collagen is unknown but studies show that the body's immune system does not recognize the abundant production of collagen. Common symptoms of scleroderma are Raynaud's disease and arthritis. Raynaud's disease affects the blood vessels in the fingers and toes causing them to contract in cold temperatures and results in pain or numbness. Approximately 100,000 people are diagnosed with scleroderma each year in the United States. Currently, there is no cure, but there are a variety of treatments available for individuals with this disease including anti-inflammatory medications and immuno-repressive, occupational, and physical therapies.

Our client developed scleroderma two years ago while she was on a trip to Europe to golf at several international golf courses. Due to the reduced mobility in her hands from the condition, enjoying her passion for golf has become more difficult. The purpose of this project was to increase our client's control of her golf club by providing her with more hand surface area contact on the club. Our device aims to improve golf club control, speed, comfort, and ease use for individuals with limited hand or wrist strength and/or mobility.

The Assistive Golf Device is a single device comprised of three components. The base layer of the device was designed to match the same tapered dimensions of her golf grips. This piece was 3D printed with ABS plastic and designed to encompass the remaining layers. The middle layer was composed of memory foam to provide a comfortable grip and give our client a greater surface area of contact between her hand and the club. To sustain the integrity of the device, a neoprene rubber was used as the external layer so that it could be easily cleaned and withstand continuous wear.

Preliminary verification testing was performed on campus with our client at the Athletic and Human Performance Research Center. We utilized the Marquette Golf Team's Trackman launch simulator to analyze ball speed, carry, and total distance the ball traveled using the Assistive Golf Device. Final verification testing was completed using a Flight Scope system at our client's Pro Golf Club. Our data for total distance showed a 16.09% increase with a driver and a 40.3% increase with a pitching wedge when using the Assistive Golf Device. Time trials confirmed that attaching the device to the club was not time-consuming or cumbersome.

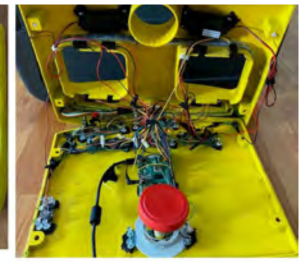
This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

MATTHEW'S MOZART: CUSTOMIZABLE LEARNING TOOL TO INCREASE ENGAGEMENT

Project Team:	Gavin Heller Lizz Radtke Tara Wasson Ryan Martin Patrick O'Brien
MIAD Partners:	Dasha Florov Josh Horth
Faculty Advisor:	Dr. Scott Beardsley
Sponsor:	Mary Houser, Assistive Technology Coordinator, Menomonee Falls School District

Our primary customer was a 5-year-old boy, Matthew, with a rare chromosomal disorder that resulted in multiple cognitive and motor challenges. To improve Matthew's cognitive and motor abilities, his therapy team used multiple tools, toys, and objects throughout a typical therapy session. The tools, which were cumbersome to manipulate, offer limited functions and could not accommodate variable lesson plans. While significant strides have been made using current therapy methods, no solution exists which offers both the therapy team and Matthew a means of streamlining and optimizing his learning sessions.

The purpose of this project was to create a device that would increase Matthew's engagement during therapy sessions through a variety of customizable learning tasks. The device needed to be interactive with easily seen options to develop Matthew's object association skills and his understanding of cause and effect. The device also needed to be stable and easily manipulated to limit the



support required from the therapist. Matthew's family also desired the device to be small and lightweight for easy transportation and storage.

While the COVID-19 pandemic impacted the scope of the project, the final prototype was able to meet a subset of the customer needs. It was strategically colored to improve memory retention and featured several interactive components that provided different auditory and visual feedback stimuli. Feedback was controlled by a Raspberry Pi 4, powered by a micro-USB cord that plugs into a wall outlet. The two compartments on the device were equipped with break beam infrared sensors that detected when an object such as a toy was placed within. Upon detection, the compartment was lit by LEDs placed around the inside wall. A red button near the front of the device could be pressed to play audio files stored on the Raspberry Pi, such as Mozart's "Eine Kleine Nachtmusik" (Matthew's favorite artist). A separate green slider at the top rear of the device used magnet sensors to trigger LEDs along the track as the slider was moved during learning tasks. Finally, the back panel of the device contained separate control buttons for speaker volume and powering down the device.

The device allows Matthew's caretakers and his therapy team to interact with him and can be used to increase Matthew's engagement outside of therapy sessions. The device design keeps long term use and versatility in mind, enabling it to be used as a substitute for multiple tools used by Matthew's caretakers and the therapy team. This saves space for the caretakers and eliminates the need to purchase more tools as Matthew develops.

This project was supported by a Marquette University Strategic Innovation Fund grant.

ASSISTIVE CAMERA CONTROL

Project Team: Blake Van Niel
Nicholas Claxton
Michael Makdah
Nathan Sutka
William Youman

MIAD Partners: Brendan Sanna
David Gabriel

Faculty Advisor: Dr. Frank Pintar

Sponsor: Katie Schultz, DPT
Milwaukee VA Hospital

The term quadriplegic is used to describe a person who is affected by a neurological deficit in all four limbs, preventing them from performing what others would perceive as simple and mundane tasks. The goal of this project was to design a new assistive device for a quadriplegic male with a hobby that normally requires the use of his hands. The client is a Vietnam war veteran with a passion for photography and a complete C5 spinal cord injury. The previous solution to camera operation involved a bite switch, made for skydiving, that could be modified for use with a camera. Due to wear over time the device broke leaving our client without a way of pursuing his favorite hobby. As a result, our project sponsor requested a team of students to develop a new and improved assistive camera device for her client.

The main goal of the project was to not only replace the device our client was using before but to improve it as much as possible. The device had to not only allow him to take photos as conveniently and comfortably as possible, but also be designed to last much longer than any previous bite switch he had used. After interviewing both our client and sponsor, we developed target specifications based on our client's needs. Our device replaced the bite switch with a blow switch that would be more durable and less strenuous to use. The switch interfaces with the camera and triggers the shutter with a small burst of air, representing a significant improvement compared to the bite switch. Using a blow switch allows for long term use and increased comfort for our client.

The team had a stretch goal to include an option that would allow our client to independently control the lens zoom feature on his camera. The design for the zoom control involved mounting a small servo motor on top of the camera with a lever arm that would directly rotate the zoom knob of the camera. The servo motor is controlled by a joystick that our client can move left or right by rotating his shoulders to move his arms. Both the joystick and the servo motor are interfaced through an Arduino Uno microcontroller which has been programmed to control the motor when moving the joystick. Due to restrictions caused by the COVID-19 pandemic, our team was unable to fully complete zoom control implementation and testing. However, the team successfully developed two different versions of a prototype to allow our client to independently take photographs using his camera.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

HEART KART

Project Team: Sarah Gorzek
Tom Adam
Ellie Debelak
Alison McGrew
Madeleine Purdue

Faculty Advisor: Dr. Tanya Onushko

Sponsor: Casey Vogel, DPT
Ann and Robert H. Lurie
Children's Hospital,
Chicago, IL

Approximately 400 heart transplants are performed on pediatric patients each year, according to the International Society for Heart and Lung Transplantation. When a heart transplant is required, pediatric patients rely on a Ventricular Assist Device (VAD) for short term care. The VAD is used as a bridge-to-transplantation by keeping the patient's heart pumping until there is a transplant available. Patients often use a Berlin Heart EXCOR, which is an air driven blood pump that is attached internally to the patient's heart with cannulas and hangs outside of the patient's chest, reaching down towards the knees. Patients may be attached to the Berlin Heart for three months to one year. During this time, they may have difficulty walking on their own due to the VAD limiting movement and their sense of independence. Improving cardiovascular function improves the overall health of the heart and other body systems allowing the heart to rest and grow stronger prior to receiving a heart transplant. Therefore, the focus of the Heart Kart project was to create a device for pediatric patients who are connected to a VAD to be able to move around the hospital in a safe, comfortable, and productive manner to improve their cardiovascular health.

Through meetings with the project sponsor and observations of a pediatric patient who was implanted with the Berlin EXCOR, we were inspired to create a device similar to a child's scooter that could improve the patient's quality of life while awaiting a new, healthy heart. We created a scooter-like device that the patient can use to propel herself using her feet while standing or walking slowly. The Heart Kart was designed specifically to be adaptable for pediatric patients aged 2 through 6 years. It has adjustable components for handlebar height and seat height and distance, and is lightweight. The Heart Kart also incorporates several safety features, such as a lap belt and hooks to secure the wires and tubing connected through the patient from the VAD. It was designed to allow hospital staff to easily make adjustments for different age patients and can be easily sanitized.

This project was supported by a Marquette University Strategic Innovation Fund grant.

PROJECTS • 2019–2020

ALL-TERRAIN WALKER

Project Team: Sofia Flores
Vanessa Pescatore
Katerina Revelis
Thomas Lang
Kate Chamberlain

Faculty Advisors: Dr. Jessica Fritz
Dr. Gerald Harris

Sponsor: Sarah Neilson

There are many nervous system-related disabilities that impact people's quality of life throughout the world. Every year in the United States around 1,000 babies are born with spina bifida, which is one of the most common neural tube defects. This condition is a result of a hole in the spine leaving the spinal cord exposed which leads to a range of physical and mental disabilities. Children who grow up with spina bifida and other mobility disorders are constantly challenged by their assistive devices as they grow and play. After research and conversations with the sponsor family and physical therapist of our two-year-old client with spina bifida, it was evident just how limiting pediatric walkers can be.

The desire of this active family was to receive an all-terrain walker with added recreational features that still provides the necessary mobility assistance for the client both indoors and outdoors. They wanted the walker to function through rough, bumpy terrains and snow while remaining light and maneuverable enough for their daughter to use independently. They also expressed their desire for added recreational features that would help them and their child with everyday challenges. These requirements would allow this cognitively and socially developed child to move, play, and continue to grow with her peers.

The design uses the same walker frame and back wheels as the client's current Nimbo walker with the addition of redesigned, more robust front wheels. It remains lightweight and collapsible like the Nimbo, so it is easy for the client to push and easy for the family to transport. It includes the same height adjustability so it can be used for years to come during her current stage of fast growth and development. The redesign of the wheels includes a larger diameter, wider contact area with the ground, added treads, and uses a firm yet naturally shock absorbent latex free material. The wheel housing was redesigned to compensate for the added height of the wheel diameter. These changes were based on preliminary wheel testing data and research. To add snow functionality, a ski attachment was designed to easily snap onto the front two legs.

Various recreational features were added to the final design. These included a cup holder, a toy holder, a foldable seat, an umbrella holder, carrying straps for the parents, and an improved back wheel ratchet system. The attachments that were purchased and tested were tweaked for optimal functionality. Those that were not tested were validated through research. The proposed design and partially finished final product have a sound foundation of preliminary testing, hands-on brainstorming, and research. The final prototype will successfully provide mobility and functionality in areas that would otherwise be inaccessible to the client.

This project was supported by a Marquette University Strategic Innovation Fund grant.

PORTABLE OXYGEN TANK FOR USE DURING SPORTING EVENTS

Project Team:	Lucas Barbosa Caolan Lyons Steven Zapart Myles Roeske Alex Pletcher
MIAD Partners:	Olivia Paul Samantha Shappell
Faculty Advisor:	Dr. Jay Goldberg
Sponsors:	Amy Morgan-Tautges, Dr. Christine Schindler, Children's Wisconsin

The client for this project is a high school freshman who suffers from respiratory issues due to the removal of a damaged lung. Although our client has difficulty performing physical activities due to these respiratory issues, she still manages to participate in her high school volleyball and softball teams. Currently, she requires a large oxygen tank, but cannot use this source of oxygen during game play. Thus, the goal of our project was to provide her with a portable, lightweight, and safe source of oxygen that she can easily use during her sporting events in order to prolong her playing time. Our product focuses on providing her with a reliable mobile source of oxygen while participating in sporting events.

The team's final product considers and addresses all of our client's medical conditions. In addition to having only one lung, she has scoliosis, hand tremors, a port above her hip, an ingestion tube, and bad scarring from surgeries. The key features of the prototype include a protective casing for the oxygen tank to ensure her safety, an accessible zipper that is more reliable due to her poor grip strength, Velcro patches to allow her to add her jersey number, and different types of

selected polyester to ensure breathability, flexibility, and comfort. After having to create an alternate design due to the pandemic, these were important features we managed to incorporate.

This product will allow our client to play softball and volleyball for much longer stretches of time than she previously could. Although, COVID-19 created many challenges for our team, we made necessary adjustments to keep the project on track and accomplish as much of our goal as possible.

Per customer needs, we were able to design a product that meets all the client's physical requirements to her complete satisfaction. After meeting with the client, we knew that the most important requirements to her involved mobility, safety, and weight. Choosing materials that were flexible, lightweight and strong, we are confident that the design can perform beyond her current expectations. However, given the many problems COVID-19 has caused, we came up with a cost-efficient design that we are confident our client can use to improve her quality of life. The backpack is designed to have an oxygen tank and canister case fit inside the pouch and attach to a hook and loop strap. The backpack can close entirely providing the security and safety our client needs while playing sports. The cannula tube runs through a slot in the strap that leads to her nose to avoid getting tangled on her body. We are confident our client has a product that will directly increase her playing time and improve her overall gameplay.

This project was supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

DEVICE TO MEASURE FORCES ON SLED HOCKEY STICKS

Project Team: Andres Flores Martinez, Shawn Turner, Matthew Ramos, Brian Lee, Mike Lehner

Faculty Advisor: Dr. Brian Schmit

Sponsor: Dr. Michael Uihlein

Sled hockey is an adaptive sport that is enjoyed by both people with disabilities and able-bodied individuals alike. In this sport, players are seated on sleds outfitted with blades on the underside and use a pair of sticks with ice picks to dig into the ice and propel themselves. Over the course of a career, an athlete will perform the same motion many times to move on the ice, repeatedly placing a large amount of stress throughout the shoulder musculature. Injuries to the shoulder can be extremely detrimental to athletes who depend on their arms for mobility both on and off the ice and can leave them unable to move around or care for themselves. By analyzing both the kinetics and kinematics of the motion of propulsion and observing how varying hockey stick lengths affect the forces at the shoulder, the ideal stick length can be calculated for sled hockey athletes.

The initial objective of this project was to reduce shoulder injures in sled hockey players by optimizing the length of the stick, and was to be facilitated by building an instrumented sled hockey stick capable of measuring forces at the shoulder. By observing the Milwaukee Admirals sled hockey team and interviewing the project sponsor, a list of customer needs and target specifications were created. The original model was to be a sled hockey stick outfitted with a strain gauge rosette connected to a "player pack," which housed many of the large electronic components such as the microcontroller and power source. With the limited resources available due to the COVID-19 pandemic, the scope of the project shifted to include a MATLAB program that can calculate the forces at the shoulder when given user-inputted anthropometric data and a lightly calibrated instrumented stick capable of reading force inputs.

This project was supported by a Marquette University Strategic Innovation Fund grant.

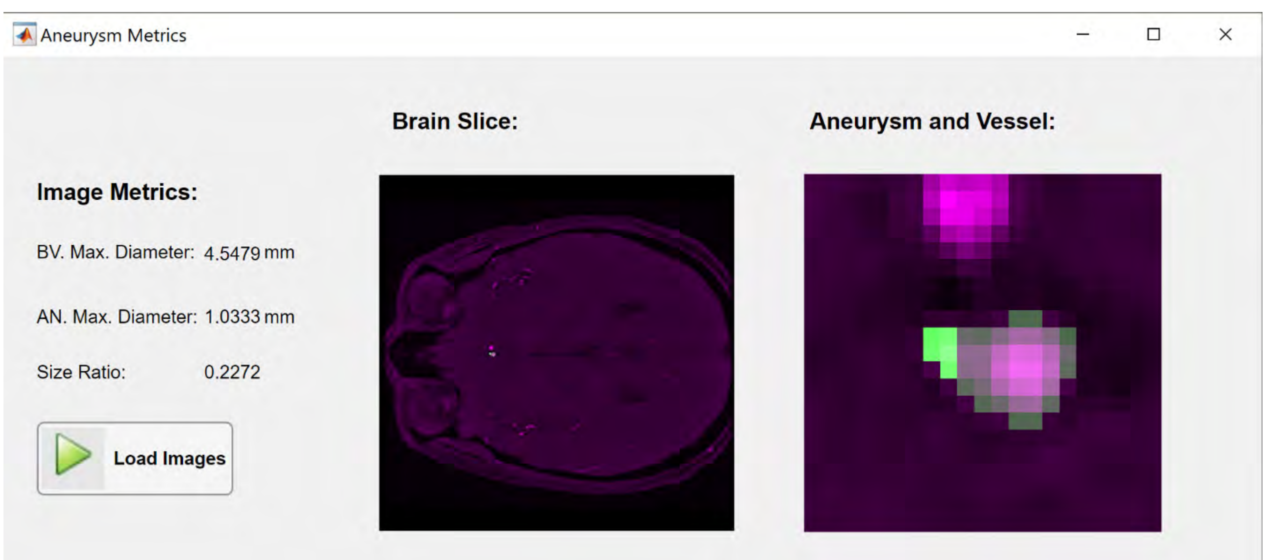
SOFTWARE FOR MODELING OF ANEURYSMS

Project Team: Grayson Johnson, Allie Adali, Anna Kratzke, Micaela Young, Jenna Grieshop

Faculty Advisor: Dr. Said Audi

Sponsor: Dr. Kevin Koch, Medical College of Wisconsin

There is a clinical need for a method for rapid and accurate measurement of the size and shape of an intracranial aneurysm (IA) to assess its severity and stability. Retaining these metrics and images for future comparison is also important for examining the progression of the aneurysm. Radiologists currently have no reliable or consistent way to observe changes in the size and shape of a patient's IA. Currently, IA measurements are acquired from images using a tool resembling a caliper, and treatment is decided based on such measurements taken by the radiologist. This adds inconsistency and unreliability to the IA measurements and introduces human error. For this project, we developed MATLAB code with a user friendly Graphical User Interface that imports image sets of the brain, segments the blood vessel and aneurysm, and calculates metric data about the size of the aneurysm. These metrics include blood vessel diameter, IA diameter, and vessel to IA diameter ratio. To validate the MATLAB code and assess the accuracy of the IA measurements, we created 3-D phantoms of blood vessels with different size IAs. Simulation results show relatively small errors in estimated diameter of an IA or change in the diameter of an IA calculated using the MATLAB code.



PROJECTS • 2019–2020

IMPROVED DESIGN OF A TABLE EXTENDER FOR GE CT SYSTEMS

Project Team:	Alex Clark Emanuel Wasson Monique Hing Wesley Gilmore Eduardo De Leon
Faculty Advisor:	Dana Cook
Sponsor:	Adam Cohen GE Healthcare

CT scans expose patients to low levels of radiation that are impacted by the scanner, the desired image, and the table on which the patient is lying. While these levels of radiation are typically low, they can still negatively affect the patient's health. Thus, it is in the best interest of all healthcare providers to try and lower the radiation patients are exposed to.

The current table extender used at GE Healthcare, which is used for taller patients as well as infants in some cases, poses a risk to pediatric patients in particular as a result of not having an optimized geometry for X-ray attenuation. The sponsor presented the need for a multi-functional, cross-compatible table extender that would reduce radiation dosages while maintaining its structural integrity.

X-ray attenuation during CT scans is associated with the type of material being used, as well the thickness and the geometry of the surfaces. The amount of material being utilized and overall thickness of the device is positively correlated with higher radiation dosages. A material such as carbon fiber, therefore, is desirable due to its high specific strength. This would require less material in order to maintain its mechanical strength, which would reduce radiation dosages compared to weaker materials. The geometry of the table extender must be considered because it affects the image quality of CT scans. In particular, any sharp edges would present image artifacts during scanning. This requirement dictated a design that must contain smooth edges.

Material selection as well as removing as much material as possible were primary areas researched during conception of the table extender prototype. Optimizing the geometry was necessary for maintaining the structural integrity of the table extender when large portions of material were removed. Stress and strain test simulations were performed to measure the factor of safety of the design and to ensure that the strength was appropriate for standardized loads. While image testing of the prototype was not possible due to the restriction resulting from the COVID-19 pandemic, X-ray attenuation calculators were utilized with thickness and material used as inputs. The simulation tests and simulated X-ray attenuation results indicated low radiation exposure and high structural strength for the new table extender design.

This project was supported by a Marquette University Strategic Innovation Fund grant.

MOTORIZED HANDCYCLE ATTACHMENT FOR VETERANS WITH SPINAL CORD INJURIES

Project Team: Maria Alberico
Vianey Ocampo
Zachary Clausen
Samuel Davies
Henry Zitzer

Faculty Advisor: Dr. Jay Goldberg

Sponsor: Joyce Casey
Clement Zablocki
VA Medical Center

The VA Medical Center has been investing their time and resources to help veterans affected by spinal cord injuries. Patients with this type of injury experience loss of motor function in the areas below the spinal cord. These injuries restrict the range of motion and place constraints on the exercises the veterans can perform. Part of their rehabilitation process consists of using an unassisted handcycle where most of the energy required for movement comes from the arms. Unfortunately, this form of exercise is also incredibly difficult for a recovering patient, especially when they encounter an obstacle or a large change in elevation which requires them to exert more energy. If the patient lacks the strength to summit a hill while handcycling, they are forced to turn back. This limits the amount of exercise necessary for their recovery and could dissuade them from handcycling again. Our prototype was designed to help them overcome these obstacles so they can continue handcycling which in turn will speed up their recovery process.

The objective of this project was to allow patients to overcome any change in elevation that might be too difficult for them. The current handcycles the VA offers are entirely unassisted wherby all the power input from the handcycle comes from the patients themselves. Our project focused on minimizing the amount of power input from the patients and gives them an option to have a motor assist added to their handcycles to help them overcome changes in elevation.

This added assistance to the patients comes in an attachment located behind the handcycle. When manually turned on by the patient, a battery will turn on a powerful motorized wheel that will push the patient up any hill they would otherwise need help overcoming. This attachment would give the patient roughly 30 minutes of consecutive motor usage before the battery would need an overnight charge. That would allow any patient to be able to use their handcycle more frequently, providing increased movement and exercise for a faster recovery.

department of biomedical en

Biomedical Engineering is a discipline that advances knowledge in engineering, biology and medicine to improve human health.

Students in biomedical engineering participate in cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice. Biomedical engineers develop strategies to effectively solve challenging problems in medicine and biology.

Most graduates secure employment working in the medical device/biotechnology industry. Some graduates use our "renaissance" training as a stepping stone for careers in fields such as medicine, law, healthcare management, and academics.

Distinctive Features of Biomedical Engineering at Marquette University and the Medical College of Wisconsin

Marquette University has the largest engineering school at a Jesuit University. The new joint department formalizes the long-standing relationships with the Medical College of Wisconsin and the Zablocki Veteran's Administration Medical Center. We also have strong ties to the Rehabilitation Institute of Chicago, and manage a number of Centers including the Orthopaedic Rehabilitation and Engineering Center (OREC), the Falk Neurorehabilitation Engineering Research Center and the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation.

The department has unique laboratory capabilities including CT and SPECT microfocal imaging, biotelemetry, implantable devices, telerehabilitation, and neurorehabilitation robots, in areas including neurorehabilitation, imaging systems, and cardiovascular technologies.

The joint Biomedical Engineering department offers degrees at the bachelors, masters and doctorate levels.

Co-op and Internship Program

Marquette University has developed one of the leading co-op/internship programs among Biomedical Engineering Departments in the nation. More than half of the undergraduate biomedical engineers gain co-op or internship experience before graduation. The Biomedical Engineering department has forged partnerships with many major medical device companies in the Midwest who rely on the excellent reputation established by our students as co-ops, interns and permanent employees. The Co-op and Internship Program offers students the opportunity to gain meaningful practical and professional experiences in the health care industry, in addition to their on-campus educational experiences.

Marquette University began its Engineering Co-op Program in 1919. Students usually enter the Co-op program at the end of their sophomore year and complete three to four terms of off-campus employment.

The employment experience is alternated with semesters of on-campus study, extending graduation by only one year. Internships, in comparison, are summer-only engineering experiences.

Les Aspin Center for Government (FDA Internships)

The Les Aspin Center for Government at Marquette University and the Department of Biomedical Engineering offer internships on biomedical research and regulatory issues. The Les Aspin/Biomedical Engineering Internships began in 1997 with Biomedical Engineering undergraduates participating in this innovative program in Washington, D.C. To date, more than 100 biomedical engineers have completed Les Aspin Biomedical Internships. The internships are completed at the Food and Drug Administration, Office of Science and Technology in Rockville, MD.

Undergraduate Offerings

Choose from Three Specializations

The Biomedical Engineering Department offers a strong undergraduate education. There are three tracks in the Biomedical Engineering curriculum:

- Bioelectronics
- Biomechanics
- Biocomputing

All undergraduate tracks in Biomedical Engineering are compatible with other programs offered by the Opus College of Engineering. Each track contains the requisite humanities courses, and requires 132 credit hours for graduation. Students automatically earn a minor in biology, and can earn an optional minor in areas such as mathematics, electrical, mechanical, or computer engineering. In addition, all tracks retain most of the core courses of the initial year, which allows the student flexibility to transfer to other curricula if so desired. The Biomedical Engineering curriculum is interdisciplinary in nature, incorporating courses in biology, chemistry, physics, mathematics, computer science and engineering.

We provide a solid foundation in the mathematical, physical, and life sciences necessary for the engineer to function effectively in a medically or biologically oriented problem solving environment. Social science and humanities courses prepare students to deal with contemporary ethical, cultural, and social issues.

In addition, we prepare biomedical engineers to communicate with life scientists, physicians and other health care providers to describe and model complex biological systems, collect and analyze experimental or clinical data, understand the capabilities and limitations of sophisticated instrumentation, and understand the principles of design.

Undergraduate Design Curriculum

Biomedical engineering students in our Department learn about design throughout the four year curriculum.

Freshman Year:

Students first gain experience with the design process in the freshman year during BIEN 1100 and 1110 (*Introduction to Biomedical Engineering Methods I and II*). In these courses, they participate in several team design challenges such as:

- Physiological monitoring: Design of an algorithm for analysis of ECG, blood pressure, and other waveforms
- Medical imaging: Design and testing of an imaging phantom
- Entrepreneurship: Semester-long team-based medical device design project including a business plan and elevator speech

These experiences help develop teamwork skills, and teach students about the engineering design process, including technical, legal/ethical, regulatory, and economic design constraints. Students learn to identify customer needs, develop a list of performance requirements and specifications, convert requirements into design concepts, and build and test prototypes.

During BIEN 1110, students learn about basic business concepts and entrepreneurship (as part of their design projects) culminating in a presentation of their new product ideas to students, faculty, and industry representatives at the college-wide Design Day event.

Sophomore and Junior Years:

During the sophomore and junior years of the biomedical engineering curriculum, students take courses that include individual and team-based design projects which allow them to apply what they are learning in the course to the solution of a related problem. This helps them relate theory to practice.

In the junior year, students can take BIEN 3400 *Clinical Issues in Biomedical Engineering Design*, an elective in which students observe procedures in the clinical environment and learn to identify unmet clinical needs and opportunities for new product development. Their final project proposals can serve as the basis of their senior capstone design projects.

Senior Year:

During the senior year, students are required to take BIEN 4920 *Principles of Design* and BIEN 4998 *Senior Design*. These courses require students to apply what they have learned during their previous years of the undergraduate curriculum in a multidisciplinary team-based project experience. They further develop their design, analytical, project management, communication, time management, and teamwork skills. They learn about the product development process and value creation, the medical device industry, testing for safety and efficacy, design validation, standards and regulations, risk management, project scheduling, patent issues, and a variety of design issues.

Students complete a design project from problem definition to design validation (per ISO 9001 and 13485) and gain experience in generating the same project deliverables as required in industry.

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Five Year B.S./M.S. Program

This program allows qualified students to receive a Bachelor of Science Degree and a Master of Science Degree in Biomedical Engineering in just five years. Students with qualifying grade point averages apply to the program during their Junior year. They begin their thesis research the summer between their Junior and Senior years, and continue their research during the summer between their Senior and fifth years and throughout their fifth year, culminating in the preparation of a written thesis and defense.

Research in Biomedical Engineering

Biomedical Engineering faculty and students at Marquette and the Medical College of Wisconsin are engaged in a wide range of research activities, with many opportunities available for students at both the graduate and undergraduate levels.

Research-oriented Faculty

More than 50 faculty who are active in research have primary (20), or secondary or adjunct (>30) appointments in our department, and are available for supervision or co-supervision of students.

Research Laboratories and Centers

The number of research laboratories and centers within our department has been growing dramatically, with the Biomedical Engineering Department now housing 21 research laboratories and three centers.

Most recently, the NIDRR awarded our department a **Rehabilitation Engineering Research Center on Technologies for Children with Orthopedic Disabilities (TECH4POD)**. Faculty, students, clinicians, and researchers from six area institutions are developing a national center with a focus on advancing engineering research and development based on innovative technologies addressing children with orthopedic disabilities.

Externally Funded Research

More than $8.7 million/year in externally funded research, the largest of any department on campus, flows through the Department of Biomedical Engineering. Research and training grants are managed by Biomedical Engineering core faculty and support research projects for more than 50 graduate students.

Strong Partners

We are a member of the **Clinical and Translational Science Institute of Southeast Wisconsin.** Supported by a $20M grant from NIH, this consortium of eight Milwaukee institutions is dedicated to transforming biomedical research in southeast Wisconsin, accelerating the translation of research discoveries, and advancing patient care and education. The eight member organizations include the Medical College of Wisconsin, Marquette University, Milwaukee School of Engineering, University of Wisconsin-Milwaukee, BloodCenter of Wisconsin, Children's Hospital and Health System, Froedtert Hospital, and the Clement Zablocki VA Medical Center.

Targeted Areas of National Leadership

While our students and faculty are engaged in many areas of research, three areas of excellence stand out: Functional Imaging, Rehabilitative Bioengineering, Systems Physiology, Cardiovascular Physiology, and Biocomputing.

faculty

Pintar, Frank, Ph.D.
Professor and Chair
Biomechanics of traumatic brain and spine injury, motor vehicle crash trauma

Audi, Said H., Ph.D.
Pulmonary mass transfer, tracer kinetics, pulmonary hemodynamics

Beardsley, Scott, Ph.D.
Neuroengineering, computational modeling, perceptual learning, functional imaging

Cooper, Robert F., Ph.D.
Development of image processing and automated analysis tools, clinical imaging for studying the etiology of retinal disease

Dash, Ranjan, Ph.D.
Computational biology and bioinformatics

Garcia, Guilherme, Ph.D.
Respiratory fluid mechanics

Gilat-Schmidt, Taly, Ph.D.
Medical imaging, image processing and reconstruction, systems engineering

Goldberg, Jay R., Ph.D., P.E.
Medical device design and innovation, biomaterials

Greenberg, Adam S., Ph.D.
Cognitive neuroscience of attention, human psychophysics and computational modeling, brain network dynamics

Harris, Gerald F., Ph.D. (Emeritus)
Quantitative assessment of neuromuscular function, human motion analysis, orthopedic biomechanics, data acquisition and control, real time analysis

Jeutter, Dean C., Ph.D., P.E. (Emeritus)
Implantable transcutaneous radio frequency power transfer, biotelemetry, biomedical instrumentation, radio frequency circuit design and development

Joshi, Amit, Ph.D.
Optical imaging

LaDisa, John F., Jr., Ph.D.
Cardiovascular biomechanics, adult and congenital heart disease, stent design and development

Olson, Lars E., Ph.D.
Optical instrumentation, tissue engineering, biological transport and circulation physiology, mathematical modeling of physiological systems, biosensors

Ropella, Kristina M., Ph.D
Professor and OPUS Dean
Signal processing, cardiac and neuro-electrophysiology, functional magnetic resonance imaging

Scheidt, Robert A., Ph.D.
Human motor control, systems identification, rehabilitation engineering, embedded systems, product development

Schmit, Brian D., Ph.D.
Spinal cord injury, human neurophysiology, neurorehabilitation, instrumentation, biomechanics

Silver-Thorn, M. Barbara, Ph.D. (Emerita)
Prosthetic limbs, soft tissue mechanics, rehabilitation engineering, orthopaedic and dental biomechanics

Stemper, Brian, Ph.D.
Biomechanics of traumatic brain and spine injury, biomechanics of the cervical and lumbar spine, automotive safety

Tefft, Brandon J., Ph.D.
Cardiovascular and pulmonary physiology

Winters, Jack M., Ph.D. (Emeritus)
Neuromuscular control systems, movement and tissue biomechanics, rehabilitation engineering, telehealth, neurofuzzy computing

Wang, Bo, Ph.D.
Stem cell engineering, heart tissue engineering, 3-D bioprinting, cardiovascular tissue engineering, imaging, modeling, and simulation

Williams, Jordan J., M.D., Ph.D.
Peripheral optogenetics for motor stimulation, brain-machine interfaces and neural prosthetics, viral gene therapy for spinal cord injury and disease

Yu, Bing, Ph.D.
Optical imaging

ASSOCIATE FACULTY

Ackman, Jeffrey, M.D.
Orthopedic surgery

Ahamed, Sheikh Iqbal, Ph.D.
mHealth, pervasive/ubiquitous computing, security, privacy and trust

Ahmad, Baseer, M.D.
Ophthalmology

Bozdag, Serdar, Ph.D.
Bioinformatics/computational biology, machine learning, cancer genomics, data science

Cariapa, Vikram, Ph.D.
Rapid prototyping, process controls, neural networks, design of experiments

Carroll, Joseph, Ph.D.
Ophthalmology

Clough, Anne V., Ph.D.
Mathematical and computer modeling of biomedical systems, image processing and analysis, modeling of pulmonary hemodynamics, integral equations

Connelly, Jennifer, MD
Neurology

Fernandino, Leonardo, Ph.D.
Neural mechanisms of language processing and concept representation

Fritz, Jessica, Ph.D.
Human motion analysis, orthopedic biomechanics, computer modeling

Greene, Andrew, Ph.D.
Cardiovascular physiology

Grobe, Justin, Ph.D.
Neurogenic hypertension, obesity and obesity-associated hypertension, development of novel calorimetry methods, mathematical modeling and biostatistics

Hoffmann, Brian R., Ph.D.
Metabolism

Ibrahim, El-Sayed, Ph.D.
Cardiovascular magnetic resonance imaging (MRI)

Koch, Kevin, Ph.D.
MR imaging

Krenz, Gary S., Ph.D.
Mathematical modeling of hemodynamic properties of the lung, microangiographic measurements, pulmonary vascular morphogenesis

Kurpad, Shekar, M.D., Ph.D.
Neurosurgery

LaViolette, Peter, Ph.D.
MR imaging, cancer

Lawlor, Michael, M.D., Ph.D.
Congenital myopathy, muscular dystrophy, mitochondrial disease and gene therapy

Liebenthal, Einat, Ph.D.
Functional neuroimaging

Liu, Yu, Ph.D.
Radiology

Marklin, Richard W., Ph.D.
Ergonomics in office and industrial settings, human factors, cumulative trauma disorders

Meier, Timothy, Ph.D.
Neurosurgery

Mitchell, Aoy, Ph.D.
Cell and developmental biology, fetal concerns/prematurity diseases, genetic diseases/genomics, heart disease, solid organ transplantation

Muftuler, Tugan Lutfi, Ph.D.
MR imaging, neurosurgery

Nagurka, Mark L., Ph.D., P.E. (Emeritus)
Biomechanics, vehicle dynamics and controls, and control system design

Nencka, Andrew, Ph.D.
Radiology

Pawela, Christopher, Ph.D.
Anesthesiology

Schmainda, Kathleen, Ph.D.
MR imaging, cancer

Shah-Basak, Pryianka, Ph.D.
Aphasia, epilepsy, semantic cognition

Stowe, David, Ph.D.
Anesthesiology

Terhune, Scott, Ph.D.
Microbiology, molecular genetics

Toth, Jeffrey, Ph.D.
Biomaterials

Voglewede, Phillip A., Ph.D.
Lower limb prostheses, dynamics, kinematics

Yoganandan, Narayan, Ph.D.
Neurosurgery

Opus College Of Engineering

Since 1908, the Marquette University Opus College of Engineering has been uniquely blending professional engineering preparation with a liberal arts education to provide the world with well-balanced leaders in their profession.

OUR MISSION

The mission of the College is to excel in four critical areas:

- To prepare all students for successful careers based on a strong moral and ethical foundation
- To advance the state-of-the-art in engineering
- To serve our professional and technical communities
- To contribute to our global society

The Opus College of Engineering offers six undergraduate degrees in eleven programs/majors through four departments: Biomedical Engineering; Civil & Environmental Engineering; Electrical and Computer Engineering; and Mechanical Engineering. Marquette also offers a wide range of graduate and doctoral programs.

ACCREDITATION

All undergraduate programs offered by the Marquette University Opus College of Engineering are accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, 410-347-7700.

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Founded in 1881 in Milwaukee, Wisconsin, Marquette University has been educating people of faith to be leaders in their professional lives, their communities and in society.

Since the first graduating class of five men were awarded bachelor of arts degrees in the 1880s, Marquette has grown into a modern coed campus of more than 11,000 students who learn and grow through nationally admired undergraduate, graduate and professional programs.

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