DEPARTMENT OF
BIOMEDICAL
ENGINEERING

MARQUETTE
UNIVERSITY

MEDICAL
COLLEGE
OF WISCONSIN

SENIOR DESIGN PROJECTS 2022

On the cover: A team of students tests a prototype of a digital otoscope for use during telemedicine visits with pediatricians. Details can be found on page 13.

SENIOR DESIGN PROJECTS 2022

TO OUR INDUSTRY PARTNERS

We are pleased to present the Biomedical Engineering Senior Design Projects completed during the 2021-2022 academic year with the joint department between Marquette University and the Medical College of Wisconsin.

The Department of Biomedical Engineering at Marquette University and the Medical College of Wisconsin 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 sixth year of our new joint Department of Biomedical Engineering between Marquette University (MU) and the Medical College of Wisconsin (MCW). Department faculty from MU and MCW served as advisors to project teams. This year we continued our 17-year collaboration with the Milwaukee Institute of Art and Design (MIAD). Six of our project teams collaborated with industrial design students from MIAD during the spring semester. This was the eleventh 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.

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 industry advisor determines the frequency of communications.

Travel: The industry advisor 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 proprietary 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

2021-2022
GE Healthcare, Waukesha, WI
eClusion, Milwaukee, WI
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia

2020–2021
SeaSpine, Carlsbad, CA
Spectroscopy and Data Consultants, Pty. Ltd., Brisbane, Australia

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

Development of a Smart Insect Sampling Unit (NIRSID Smart Field Unit)

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Sponsors:
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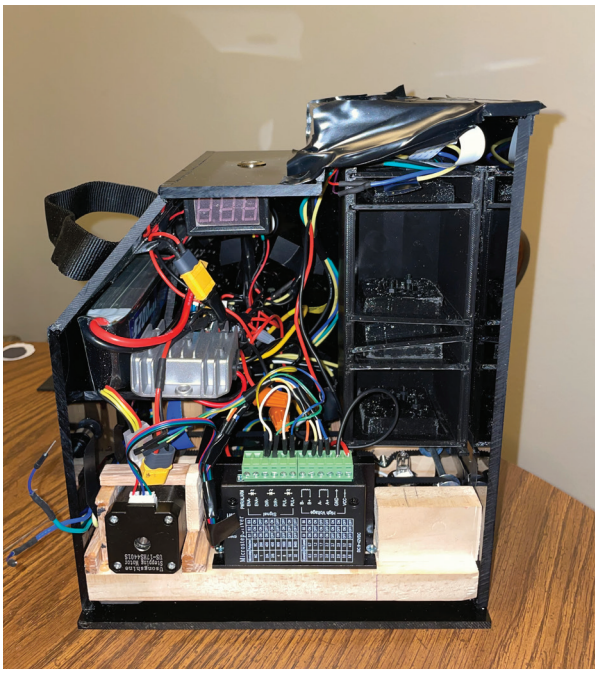
Spectroscopy and
Data Consultants
PTY LTD, Australia

Mosquitoes are the deadliest animals in the world to humans. They are carriers of fatal diseases including Malaria, Zika, and Dengue. Currently, disease control programs lay traps for mosquitoes and send out personnel in the following days to collect the mosquitoes. The collected mosquitoes are then transported to labs to be tested, usually via molecular techniques or dissections, and the results are analyzed to determine if the mosquitos are infected. If the mosquitoes are found to be infected, personnel will return to the site of collection to implement their disease control plan to eliminate the mosquitoes. However, this approach is costly and time-consuming. A new approach is needed to quickly and cost-effectively determine if mosquitoes in the tested area are infected so that control plans can be executed to eliminate the infected mosquitos and reduce spread of diseases.



Using near-infrared (NIR) spectroscopy, our industry sponsors designed a machine-learning algorithm to determine if mosquitoes carry disease. This approach requires less training than traditional methods, however the unit is costly and is constrained to the lab due to its size, weight, and battery requirements. Likewise, the fiber optic cable on the spectroscopy unit is fragile and would be prone to breaking during field use.

Our project involved the design of a low-cost insect sampling unit that can be used by our industry sponsors) to collect spectroscopy data in the field. This is achieved through a securely housed optical unit that diffracts light containing wavelengths in the NIR range and focuses it on a camera that does not filter out NIR light. The intensity of the light at each wavelength is then captured and saved to a microSD card as well as emailed to a remote user to analyze the results. A motor and tray are used to load the mosquito samples and place them, one at a time, in the optical imaging unit. Thus, multiple samples can easily be collected by the device. Data collected from the samples can be used for analysis to determine if the mosquitoes are infected and can aid disease control personnel in efficient decision-making regarding control plans for elimination of mosquitoes.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

2021–2022

Biocompatible Gaming Mouthpiece*

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Rheanna Quandt

Faculty Advisor:
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Sponsor:
Chris Hege, eClusion, Milwaukee, WI

MIAD Partners:
Olivia Wilas
Olivia Roth

The Quadstick mouthpiece provides a way for quadriplegic individuals to control and use a PC by blowing into tubes that are part of the mouthpiece. However, the current mouthpiece is made from low density polylactic acid (PLA) which can leach into the individual's mouth during use. This leaching causes both irritation of the user's gums and dryness in their mouth. Currently, there are no commercially available solutions on the market to prevent the degradation of the PLA.

The purpose of this project was to provide a solution that slows/prevents the degradation of the PLA into the user's mouth and reduces the resulting discomfort. Our solution is a redesigned mouthpiece configuration with a 4 mm coating of silicone on each of the nubs (tubes) that make contact with the user's lips and mouth. Food-grade silicone does not break down when interacting with saliva and provides a barrier between the user and the PLA mouthpiece.

Testing was completed to verify that the silicone coating reduced leaching of the PLA. A spectrophotometer was used to confirm that the addition of silicone significantly reduced the presence of PLA in a saliva solution. Contact of the mouthpiece with saliva was simulated via an artificial saliva solution. Separate containers of saliva were exposed to a sample of PLA (control) and another sample which was coated in silicone.

The spectrophotometer then measured the difference in light absorption between the two samples. While the spectrophotometer used for this experiment could not measure the maximum absorbance wavelength of PLA, results indicated that the design reduced absorbance compared to the control. This implied that less leaching occurred with the silicone coated device.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Device to Clean Teeth and Remove Plaque*

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Clinical Advisor:
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Marquette University
School of Dentistry

Proper dental health is an important factor that contributes to a person's overall health. With poor dental hygiene, cavities and gum disease may occur which can result in heart disease, diabetes, cancer, and other diseases. As people age, increased motor deficits and diminished motor skills make it difficult to maintain proper oral hygiene. Often, those with diminished motor skills need assistance cleaning their teeth and gums. There is a need for a device that enables those with motor deficits to clean their teeth independently, efficiently, and comfortably.

Collaborating with the dental school, the team developed a way for users to clean their teeth in a comfortable and independent manner. Using the base model Oral-B Pro 1000 electric toothbrush, the team designed a handle and a 5-sided head attachment to help those with motor deficits maintain sufficient dental hygiene. The handle case, developed in collaboration with the Milwaukee Institute of Art and Design (MIAD), provides a more ergonomic and comfortable way to hold the toothbrush. The 5-sided head attachment allows for the user to reach all areas of the teeth with minimal movement of the wrist. Similar to a roller coaster on a track, the toothbrush head follows the teeth and rotates as needed to brush all tooth surfaces.

Additionally, the head oscillates the bristles to allow for more efficient tooth cleaning. This converts the linear oscillations produced by the Oral-B Pro 1000 to rotational oscillations that move the bristles. The device allows for an independent way for patients to clean their teeth comfortably and efficiently.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

2021–2022

Adaptive Technology Mounting System for Independent Use by Individuals with Spinal Cord Injuries*

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Sponsor:
Chris Hege, eClusion, Milwaukee, WI

Spinal Cord Injury (SCI) refers to damage to any part of the spinal cord or the nerves at the end of the spinal canal. Such an injury typically results in loss of strength, sensation, and function below the area of injury. With limited movement and mobility, people with SCI often encounter challenges with their social and professional lives. In the case of our primary client, he has no lower extremity mobility and limited arm movement with minimal grasping ability. Due to these restrictions, he, like many other people with SCI, was not able to play video games without depending on another person to help him enter, set up, and refine his gaming system.

The purpose of this project was to provide our client with a custom gaming system that incorporates all his current components in an optimal layout for him to play video games comfortably. The system must support him so that he can play video games independently, while socially engaging with his friends and being a part of an online gaming community. The system was required to fit the dimensions of his wheelchair and anthropometric measurements. The designed system contains two independent bases connected by a mesh that contains all the wires and power cables. Each base houses the motor for the linear actuators while maintaining safe wire management. This elegant, aesthetic setup accommodates all of the client's components supporting independent, comfortable gaming without risk of wire entanglement or dislodgement.

Several mechanical and electrical tests were conducted to ensure that the system performed as necessary. Mechanically, tests verified that the height and width of the side bases could be adjusted to the client's preferences, with minimal tipping risk. Tests indicated that there was little risk of the electrical components overheating or drawing excessive power. The client was able to enter the system, adjust the height of the side bases and gaming surfaces, and game comfortably without requiring any assistance, thereby meeting the project objectives.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Project Team:
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Thomas Kaser

Faculty Advisor and Sponsor:
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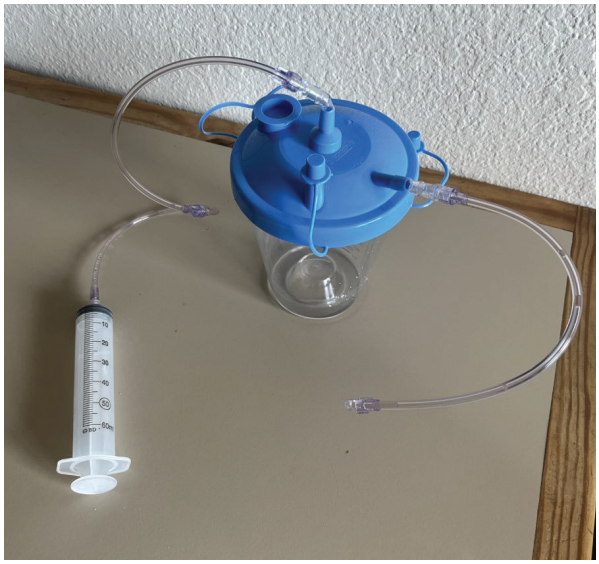
Low-cost Pressure Regulator*

The primary way to address lower respiratory infections (LRI) is to perform a lung suction procedure. To do this, the use of a wall suction pump is needed – a piece of equipment found above every hospital bed in a first world country. Wall suction pumps are not easily accessible or portable so procedures such as deep lung suctioning are not possible or practical in areas where there is limited or no access to wall suction pumps. This is a contributing factor to high mortality rates associated with LRIs. Doctors in low-income countries are only able to treat the symptoms of LRIs but cannot directly treat the infection itself due to the lack of accessible or affordable wall suction pumps.



The purpose of this project was to develop a low-cost pressure regulator that allows for a successful lung suction procedure. By doing so, this would allow lung suction procedures to be affordable and accessible for medical staff to treat LRIs rather than only the symptoms of LRIs.

The final prototype design is a passive pressure regulator that uses a syringe to draw in volume, a fluid trap to collect the drawn volume, and catheters with luer adapters to reliably and easily suction fluid. The first prototype was used to establish and confirm the relationship between the volume ratios of the syringe and fluid trap to generate a desired and limited output suction pressure. The second prototype was optimized to suction fluid and can be modified to generate a desired output suction pressure.

The development and testing of a successful prototype has shown that there is a relationship between the pressure of the syringe and the fluid trap to obtain a desired output suction pressure. The prototype successfully suctions fluid and can be modified to a desired output pressure by changing either the volume of the suction syringe or the fluid trap. Pressure is regulated by the initial conditions of syringe and fluid trap volumes. The ratio between the two determines the output suction pressure for the system which can be modified and applied in future systems.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Oxygen Saturation Monitor for Telemedicine*

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Faculty Advisor:
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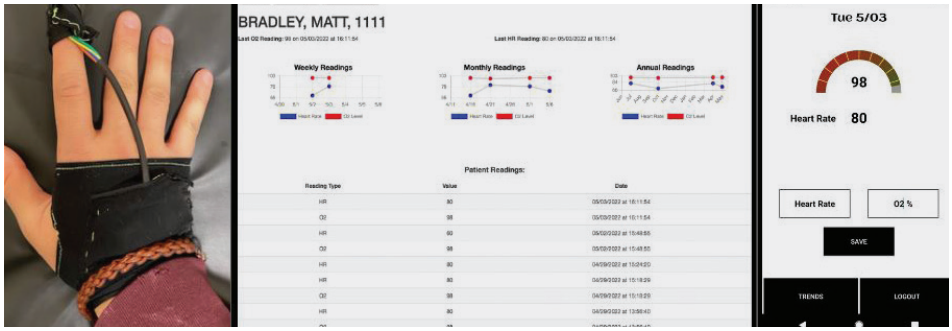
Clinical Advisor:
Anne Costello, Marquette University College of Nursing

MIAD Partners:
Payton Hartis
Benjamin Cole



Pulse oximetry, or oxygen saturation monitoring, is used to measure the amount of oxygen in a patient's blood. The level of oxygen carried by red blood cells (hemoglobin) is referred to as oxygen saturation. Tissues depend on the blood to deliver oxygen for survival. Therefore, it is important to make sure that patients are getting enough oxygen to vital organs through oxygen saturation monitoring. A pulse oximeter is typically used to monitor the oxygen content of patients suffering from conditions or diseases that affect blood oxygen levels. Currently there are a few existing solutions that utilize a wireless pulse oximeter that interfaces with a mobile app.

The purpose of this project was to develop an innovative oxygen saturation monitor connected to a mobile application for telemedicine applications. The device is required to accurately measure oxygen saturation and heart rate and display these readings in an application that both the user and physician can view. The Oxygen Saturation Monitor for Telemedicine has three components: a wearable oxygen saturation monitor, a mobile application for patients, and a web application for physicians. The mobile application serves as the interface where the patients can input their data to monitor their oxygen saturation levels. The web application serves as an interface where the physician can view the patient's data. This data is stored in a table and graphed to analyze trends for specific durations of time.

Testing to verify the design showed the Oxygen Saturation Monitor for Telemedicine can accurately read a user's oxygen saturation and heart rate, while establishing a user-friendly interface and communication with the physician. Testing also improved the design's ability to be comfortable to wear and unencumbering for the user. Patient and physician studies have not yet been conducted but will be required for commercialization of the device and application.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Otoscope for Telemedicine Application*

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Faculty Advisor:
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Clinical Advisor:
Anne Costello, Marquette University College of Nursing

Ear infections are one of the leading causes for doctor visits among pediatric patients, with approximately 30 million visits per year. While ear infection severity may vary from patient to patient, it results in discomfort with symptoms including irritability, pain inside the ear, and muffled hearing. If left untreated, ear infections can spread to nearby tissue in or around the ear, leading to more serious problems. Doctor visits help mitigate the risk of ear infections causing more serious problems.

During a visit to the doctor, otoscopes are the primary tool for identifying ear infections and making other observations regarding ear health. With the COVID pandemic that began in early 2020, many things came to a halt including in-person doctor appointments for minor health concerns. For many pediatric patients, in-person appointments became less frequent since children were at higher risk for a COVID infection and the severity of the infection was unknown. An inexpensive digital otoscope would mitigate these risks and facilitate remote visits with the doctor. A digital otoscope would allow the patient to remain at home during an online appointment while capturing images of the ear for a physician to view. However, the quality and cost of digital otoscopes varies widely; inexpensive digital otoscopes may not always yield images with sufficient quality to make a diagnosis, and many do not allow for the transfer of images in real time.

The purpose of this project was to create a digital otoscope that was affordable for families, provided good image quality for the physician analyzing the images, and could display images to the physician in real time during a virtual appointment. The final design of the digital otoscope incorporated three major internal components: an Arduino nano, an LED ring, and an Arducam, in a custom designed external casing made of polylactic acid (PLA) that could be used with disposable clinical specula. The combination of components resulted in an affordable digital otoscope that can display an image of the ear in real time for use during a virtual appointment. Validation testing of the prototype demonstrated that the system could image the ear canal and display the image on a computer screen in real time using a freely available software package.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Hearing Protection for Dentists*

Project Team:
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Francisca Klebba
Kathryn Kennedy
Mitchell Pisinger

Faculty Advisor:
Dr. Said Audi

Clinical Advisor:
Dr. Jamie Mandigo,
Marquette University
School of Dentistry

Dentists are constantly exposed to high frequency and high intensity noises from dental drills. Because of this, they have a 2.5 times greater chance of developing hearing loss compared to the average population. In addition to the hearing loss, patient-staff interface suffers greatly, as the dentist is not able to hear nor converse as precisely as needed to ensure patient safety and comfort. Feedback from a survey completed by Marquette Dental School professional dentists and dental students indicated that currently a small percentage of dentists wear some form of hearing protection device, and that for those who do, their main choice is the classic foam ear plug. Unfortunately, foam ear plugs are not comfortable to wear for long periods of time, do not actively filter out damaging frequencies, and negatively impact doctor-patient communication.

The purpose of this project was to develop an affordable hearing protection device for dentists that is comfortable to wear for long periods of time, can cancel out high frequency drill noises, and allow for clear communication between patient and dentist. The device that was developed consists of two main components: Decibullz ear plugs and a small lightweight box that connects to the ear plugs via headphone wires. This box houses the electrical components that amplify the safe frequencies and filter out the damaging frequencies.

Feedback from limited testing of our device on volunteers from the Marquette Dental School along with analysis of the bandwidth of the device's input and output signals suggest that our device successfully filters out damaging frequencies, allows for clear conversation between patient and dentist, and is comfortable to wear for extended periods of time.

Remotely Evaluating Development of Pediatric Motor Functions

Project Team:
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Sarah Ernst
Ellie Lammers
Kate Piper
Shahd Sawalhi

Faculty Advisor:
Dr. Tanya Onushko

Sponsor:
Dr. Samuel Nemanich, Marquette University Department of Occupational Therapy

Evaluating pediatric motor function during in – person appointments can result in many challenges. Pediatric patients are easily distracted and therefore it can be difficult to get them to focus during the time of the evaluation. Additionally, traveling to tests can be burdensome and expensive for the patients and their families. By conducting motor development research remotely, many of these drawbacks can be eliminated. Parents can perform the motor development tests with their child at a time when the child is willing to participate. Additionally, when evaluations are done remotely, an increased number of patients can be included because travel is eliminated.

The purpose of this project was to create an iOS-based application that can be used to gather video and audio data of pediatric patients as they move through a series of gross motor and balance tests shown in a test video. This test video shows an avatar performing various motor and balance skills such as standing on one leg, standing on toes, jumping forward and backward, and jumping side to side. As the avatar performs these tasks, the child follows along, and the video recording of them performing the tasks is saved to the "Photos" application. Additionally, the application includes instructions for the parent of the child to help them setup the test and upload the recorded video to a Box server.

Testing verified that the created application is easy to use, engaging to a child user, and able to collect video and audio data of the child performing the gross motor and balance tasks. The data acquired from this application will be able to be analyzed by the sponsor and his lab to characterize the development of a pediatric patient's gross motor and balance abilities. Further development of this technology will include merging with an existing app that tests fine motor coordination.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Wearable Pulse Oximeter*

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Arsenii Pavlenko
Tori Radermacher
Anna Valente

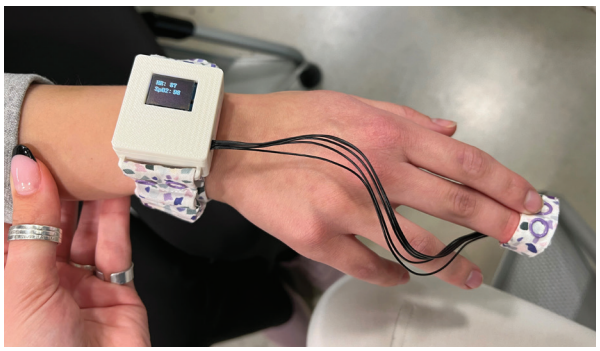
Faculty Advisor:
Dana Cook

Clinical Advisors:
Dr. Christine Schindler and Amy Morgan-Tautges, Children's Wisconsin

Pulse oximeters are a commonly used device that measures blood oxygen saturation. Many pulse oximeter devices are currently available, but they do not often combine accuracy with patient mobility. Current hospital grade devices (± 2% accuracy) are often required to be plugged in constantly. These devices typically have cords that are 3 feet long, which restricts patients from being able to move freely. Additionally, many pulse oximeters are not discrete and do not allow patients to freely use their hands and fingers, as the sensor is commonly placed on a finger.

The goal of this project was to create a wireless device that accurately measures a 13 year-old patient's blood oxygen saturation. The main focus was to design something that would maximize the mobility of the client, ensure that it would be comfortable for her to wear continuously, and have the hospital grade accuracy of existing medical devices. As a result, a wireless wearable pulse oximeter was designed, with a detachable sensor and straps, allowing the client to wear the device on her wrist and ankle, to obtain measurements from the finger and toe, respectively. This flexibility in measurement location increases the ability for the patient to use her fingers freely, as well as obtain accurate readings when her Raynaud's syndrome may be interfering with obtaining measurements in one specific location on her body.

Experimental verification testing resulted in a statistically significant difference between the wearable pulse oximeter and commercially



available BV Medical device for the blood oxygen saturation measurement. However, testing yielded mean values that were within 3% of the BV Medical device reading. Future tests will involve additional subjects with different skin colors and a greater number of samples to evaluate the accuracy and performance of the wearable pulse oximeter.

An additional component of the device is a mobile application that tracks data and alerts the client's parents when the oxygen saturation levels are too low. The mobile application has been designed to allow the user to set the alarm threshold value, as well as the ability to customize the volume and push notifications. The mobile application is designed to display the real time heart rate and oxygen saturation, along with stored biometrics for trends. The current mobile application has a functioning user interface, but currently does not connect via Bluetooth to the physical pulse oximeter. Future improvements will be to connect the sensor and mobile application to transmit and store data.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Activity Center for Hearing and Visually Impaired Child*

Project Team:
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Matthew Cote
Andrew Hruz
Christina Smith

MIAD Partners:
Reed Sell
Mengdian Xing

Faculty Advisor:
Dr. Frank Pintar

Sponsors:
Kelly Leffert and Mary Houser, Menominee Falls School District

The team worked with a client who has partial deletion of the 13th chromosome. Due to this condition, he has auditory, visual, and physical impairments. Currently, there are no commercially available tables or activity centers that fulfill the specific therapy needs of the client.

The objective of this project was to create an activity center for the client to use in conjunction with his various therapies. The team developed a table with an adjustable height, per the customer needs, with a removable angled surface to bring objects and information within the client's field of view. Additionally, the table has a flat-black surface to help focus the clients' eyes. The activity center withstood weight and tipping tests to verify the safety of the device. As this product was made specifically with this client in mind, commercialization of the product is not practical. However, minor modifications could be made for others looking to fulfill a similar need.

*Supported by R25 EB013070 from the National Institute of Biomedical Imaging and Bioengineering.

Design Enhancements for Power Stander to Provide Independence*

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The client, a 12-year-old with Neuromuscular Atrophy type II, has limited mobility and uses a powered wheelchair to move independently. His family purchased the Standing Dani device when the client was 2 years old, but it has been unusable for the past 1-2 years due to the client's growth in both height and weight which contributed to device instability and difficulty during loading. The client has been using a stationary stander to provide the therapeutic benefits associated with standing, but this solution does not allow the client the degree of independence that the power stander provides.

The purpose of this project was to update the design and modify the Standing Dani device so that it is safe and accessible for the client's current and future use. The loading mechanism for the device had to be modified so that a single caregiver could load the client and avoid lifting over a seat and to provide the potential use of the Dani with an in-home lift. Additionally, stabilizing features such as anterior support beams to improve the device's tipping point and a stronger, more stable base plate were incorporated into the prototype design. To ensure that future use of the Dani will be possible as the client continues to grow, the frame of the device was extended to accommodate greater heights, and the chest and knee padding were moved to appropriate anthropometric positions.

Testing to verify the design indicated that the device modifications provided safety and accessibility to the client during loading and use on several surfaces. Additionally, testing confirmed that the modifications increased the height and weight limits of the device such that it will be safe for current and future use by the client. During verification, the power system of the device, which was not included in the scope of the project, began to fail. To troubleshoot, the team attempted replacement of the battery charger and the battery itself, but further evaluation of the power system will be necessary for use of the device.

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Seating Support System for Increased Independence*

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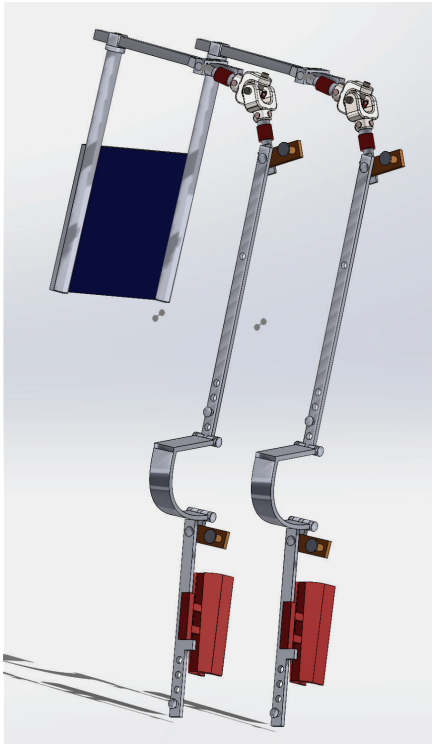
Our client has a rare neuromuscular genetic disease called SMA (Spinal Muscular Atrophy) Type II which affects his skeletal muscle growth and movement of his joints. It causes progressive atrophy of his muscles through his lifespan. SMA (Spinal Muscular Atrophy)



only affects 1 in 6,000 people and therefore is a very rare and unique disease. SMA Type II is caused by a genetic mutation in the SMN 1 gene in Chromosome 5 that causes the SMN protein, which is responsible for the neuromuscular function of most muscles in the body, to be non-functional or slightly functioning. This SM1 gene is responsible for controlling the function of motor neurons and giving proper muscle function.

Our client can sit down and maintain proper spinal posture for a short period of time. Typically, people do not live past their early adulthood with this condition, but some have been known to live longer depending on the severity of their condition. People with Type II can live longer since they still have multiple copies of the SMN2 gene that can compensate for some of the lost function of the SMN1 gene and enable some muscular functions that the SMN protein provides. This may allow patients to sit for a short while, however they will still not be able to functionally move their arms and legs within the ranges of motions with the strength of the average healthy individual.

There are three main functional components of our design that will help promote movement and assist the client's arm to move in specific directions with the proper physiological ranges of motion and proper force production. These three functional components include 1) a rotating shaft hinge connection which allows the client to rotate his arm side to side externally and internally, 2) bolted joint connections in the elbow region that allow the client to flex and extend his elbow and shoulder joint portions of his arm, and 3) a spring system in the form of rubber bands which allows the user to generate optimal force to handle the weight ranges of the objects he needs to move.

PROJECTS

2021–2022

Physiological Fluid System Modeling for a Laboratory Setting

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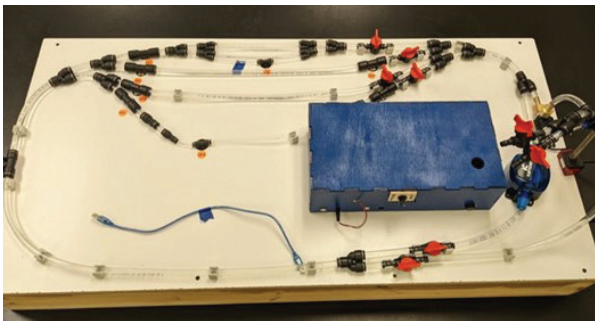
Bernoulli's principle is an important concept in fluid dynamics that relates speed and pressure of a fluid. It is especially important for understanding fluids in the body. There are multiple systems in the body in which fluids flow through the body to get nutrients and chemicals to different parts of the body. One of the most important is the cardiovascular system. The pressures and speeds of blood flow in the body are important concepts for health science students to understand, even at the most basic level. However, many introductory collegiate physics laboratories lack experiments to teach Bernoulli's principle.



At Marquette University, Bernoulli's principle is only explored with respect to height by tracking the motion of water coming out of a leaky tank. Health science students only get hands-on experience with viscosity and buoyancy force by dropping different sized balls into different liquids and measuring the velocity of the balls and measuring the differences in forces of a mass being lowered into liquid. These processes and explorations of ideas are not as applicable to their majors or what they will be doing during their careers. There is a need for a better laboratory set up and experiment to better teach fluid dynamics in a more physiologically relevant way.

The goal of this design project was to create a more physiologically relevant dynamic fluid flow laboratory model for the Marquette University Physics department that simultaneously helps demonstrate the properties of Bernoulli's principle. A better understanding of the relationship between tube diameter, fluid speed, and pressure is required for the introductory physics lab for health sciences students. The prototype designed and built by the team accomplishes this with the use of pumps and pressure transducers that measure fluid pressure at different points in a diameter reduction branch, a branched pathway, resembling the bifurcation of arteries, or a like structure, and two control branches. The speed of the pump can be increased or decreased to observe the relationship between speed and pressure and beads can be put in the system for video analysis, to calculate fluid speed. It is also built to represent the cardiovascular system to be more relevant to the health sciences students. Overall, the system allows for a more comprehensive and hands-on experience for students to study fluid dynamics in a lab setting in both a quantitative and qualitative fashion, and produces results correlating to Bernoulli's principle, to enhance students' learning experience of fluid mechanics.

Virtual Reality Treadmill Rehabilitation for Persons with Neurological Disorders

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Faculty Advisor and Sponsor:
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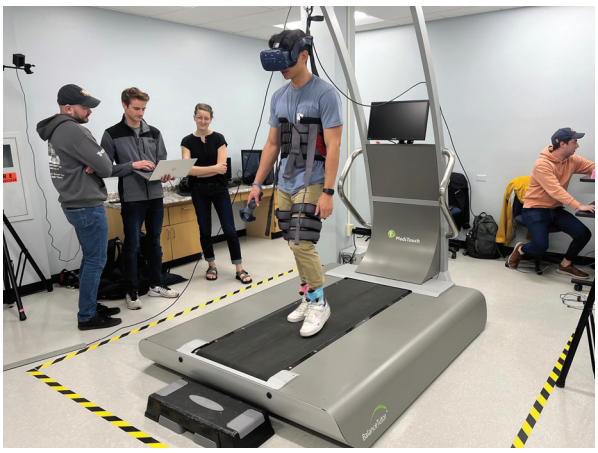
Neurological disorders such as stroke and multiple sclerosis cause damage to the central nervous system that results in balance deficits. Patients with these neurological disorders generally undergo static therapy to improve balance and regain independence. This traditional approach to rehabilitation yields low motivation in patients, meaning that there is low patient engagement during therapy and not all sessions are attended. Additionally, current metrics for balance do not provide specific biomechanical data as feedback to clinicians for quantitative analysis of patient balance. It has also been found that treadmill training with medial-lateral perturbations is effective for helping patients with neurological disorders regain balance. The BalanceTutor treadmill creates these external perturbations by abruptly shifting the entire treadmill base as the user is walking.

This project aimed to combine immersion in a virtual environment with treadmill training to improve patient rehabilitation progress and engagement in therapy sessions. The system requires the HTC Vive headset and four sensors located on the sacrum, both ankles, and held in the right hand. The virtual environment is a forest pathway that incorporates three internal perturbations that appear randomly: patients are required to catch butterflies, step over logs, and step around rocks. These perturbations help improve balance for the user at three difficulty levels that are dependent upon the frequency at which obstacles appear. Real-time feedback is given to the user in the form of a score based on the number of obstacles cleared



successfully. Clinicians also receive feedback on the user's balance in the form of a plot showing the margin of stability and as an output of time-stamped data surrounding the occurrence of internal perturbations.

The goal of this project was to prepare the system for implementation in a clinical trial to test the effects of combining treadmill training with an immersive virtual environment on the quality of patient rehabilitation. Testing verified that this product complies with HIPAA and does not cause motion sickness, increase cost of therapy, or increase clinician set-up time by more than 15 minutes.

PROJECTS

2021–2022

Resorbable Calcium-Based Cement for Filling Bone Defects

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Sponsor:
Dr. Bo Wang, MCW

Bone defects such as holes and chips that result from disease, injury, or other causes are a common problem seen in orthopedic settings. While existing solutions, such as bone cements, grafts, or other alternatives, are commonly used to replace bone mass to a defect, they require surgical intervention to ensure proper filling and repair. Few solutions exist in this space to aid the body in regenerating bone tissue, and many of them have severe limitations in their ability to restore mechanical properties or bioactivity to the original tissue. Current solutions are highly specialized for a specific type of defect, may not regenerate bone mass, require surgical intervention, and/or take several months to set properly.

The purpose of this project was to provide a universal filler for shallow and irregular bone defects most prevalently found in dentistry. The material was required to be malleable enough to fit a vast array of defect shapes and sizes, restore mechanical function to the bone over time, and resorb into the bone. The team's compound contains five components: 1) hydroxyapatite and 2) polycaprolactone, solid components that combine to provide solid structure, increase mechanical properties, and promote bioactivity, 3) dichloromethane, an evaporant used to remove excess and toxic by-products during the mixing process, 4) 2-butoxyethanol, a surfactant which increases bio-adherence, and 5) dibutyl phthalate, a plasticizer that adds softness and flexibility to the compound.

The formulation developed by the team is a resorbable, osteo-conductive paste which adheres to the bone and provides structure and mechanical function to the bone over time. Its ease of application eliminates the need for a patient to undergo a surgical procedure and its viscoelasticity lends it to easily filling of a variety of shapes and sizes of defects.

The team has designated a standard size for filling defects seen in dental applications to be a 1cc syringe fitted with a 16-gauge needle containing 0.3mL of compound available for use. However, preliminary testing has shown that a variety of syringe and needle sizes and increased product volume can be used depending on the defect size.

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DEPARTMENT OF BIOMEDICAL ENGINEERING

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