DEPARTMENT OF
BIOMEDICAL
ENGINEERING

MARQUETTE
UNIVERSITY

MEDICAL
COLLEGE
OF WISCONSIN

SENIOR DESIGN PROJECTS 2021

ON THE COVER: An assistive device developed to increase independence for a client with Spinal Muscular Atrophy is demonstrated by a student team member. Details of this project can be found on page 17.

to our industry partners

We are pleased to present the Biomedical Engineering Senior Design Projects completed during the 2020-2021 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 fifth 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 16-year collaboration with the Milwaukee Institute of Art and Design (MIAD). Five of our project teams collaborated with industrial design students from MIAD during the spring semester. This was the tenth 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 other sources of support including the Thomas M. Aaberg Retina Research Fund, Medical College of Wisconsin Neuroscience Research Center, and the Medical College of Wisconsin Department of Anesthesiology.

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

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

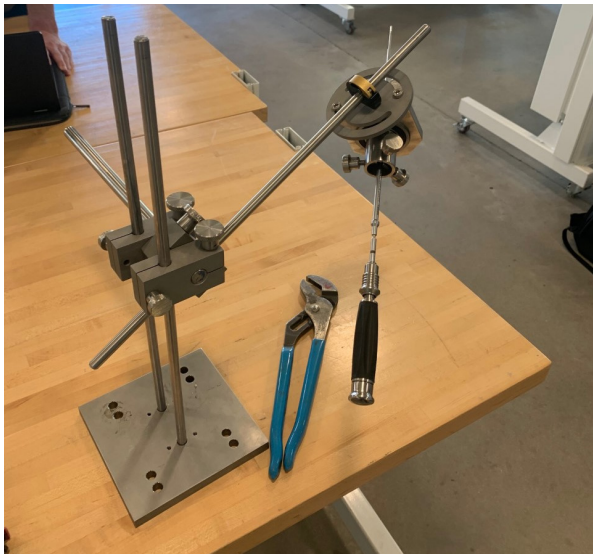
2008–2009
DePuy Orthopedics, Inc., Warsaw, IN
Siemens Medical Solutions, Hoffman Estates, IL
GE Healthcare, Waukesha, WI
ACTRA Rehabilitation Associates, Brookfield, WI
Gauthier Biomedical Inc., Grafton, WI
Stevenson Industries, Simi Valley, CA

SPINAL INSTRUMENT TEST FIXTURE

Project Team: David Boss
Nick Bruns
Nick Georgiou
Claudia Melendez
Jake Schweizer

Faculty Advisor: Dr. Brian Stemper

Sponsor: Zachary Dooley
SeaSpine, Inc.



Spinal instrumentation requires clearance from the FDA and other regulatory agencies before surgical use on patients. Evaluations required for this clearance are composed of simulated surgical procedures on cadavers and laboratory testing for physical performance characteristics. In these evaluation settings, the instrument must be held rigidly at set angles and often must be adjusted to different positions. However, there are no current cost-effective tools to stabilize instruments during evaluation. Currently at SeaSpine's testing facilities, these stabilization techniques are limited to holding the instruments by hand. This method is often unreliable because it adds external forces, rendering results unclear as the forces from the instrument and external forces cannot be differentiated.

As a solution, a stabilization device was developed that can be used by engineers and surgeons to stabilize the instrument inserter. This was accomplished by creating a base, a junction, and an instrument holder. They were held in place by three rods; two were positioned in a vertical position, and one was positioned in a horizontal position. The instrument holder is adjusted to fit different instruments with several screws, and is adjustable through a horizontal disk with two channels and the clamp that secures it in place. The junction allows movement of the horizontal bar at different angles. The device accommodates instruments of various sizes. Not only does it hold this instrument rigidly, but it can be adjusted to different angles in any direction. The device can rotate around the axis parallel to its length while maintaining this constant angle. Additionally, the device is easy to operate and set up, as it is not heavy or complex. It will aid in the data collection in the evaluation of SeaSpine's inserter instruments and spinal cages. Testing performed on an MTS machine showed that the device reduced fluctuations in x-axis moments by 50% and fluctuations in y-axis moments by 25% compared to when the tests were conducted without the device. This indicates that the device meets its main goal of reducing unwanted moments caused by hand movements during spinal instrument testing.

CONDUCTING BALANCE AND CONCUSSION EVALUATIONS ON PARA-ICE HOCKEY ATHLETES

Project Team: Cal Smeets
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MIAD Partners: Connor Sannito
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Faculty Advisor: Dr. Brian Schmit

Sponsor: Dr. Mike Uihlein

Concussions are one of the most common sports injuries, with an estimated 3.8 million occurring per year. Concussions in sports are typically caused by large magnitude impacts to the athlete's head and are highly prevalent in sports such as football, hockey, rugby, soccer, and basketball. Some common symptoms that come with concussions and impacts to the head are headaches, dizziness, photophobia, phonophobia, amnesia, loss of consciousness, loss of coordination, slowed reaction time, irritability, and a decrease in the athlete's overall performance.

Currently, the BESS testing system is one of the most common tests used to rapidly assess an athlete's state of balance. The test requires one to stand in different postures with their eyes closed to determine whether a possible concussion has occurred. Paraplegic ice hockey players cannot perform these standing positions, which creates a need for a device that will aid the project sponsor, who works with the US Paraplegic Men's Ice Hockey Team, in evaluating concussions in these athletes.

The purpose of this project was to design a device that would allow the sponsor to effectively assess balance of these paraplegic ice-hockey players and evaluate them for a concussion. The device needed to allow the athlete to remain in his sled while performing the evaluation, allow different sled and blade arrangements to be compatible with the device, be used with an error scoring system, and present the appropriate amount of challenge when balancing to effectively assess concussions. The device contains three components; the primary load support balance board system, the interconnecting sled frame system, and the secondary support balance board system. These components work together to allow a para-ice hockey player in his sled to be placed and strapped onto the device and have his balance tested. The balance boards provide a means for an athlete's balance to be challenged and the sled frame allows for different length adjustments that fit the needs of an athlete and his sled.

Verification of the design indicated that the device provided a way to keep the athlete in his sled during testing, was easy and quick to use, was effective in showing a difference in results between a non-altered state of balance vs. an altered state, was compatible with different sled arrangements, and was compatible with an error scoring system.

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

DETECTING HEART SOUNDS DURING TELEMEDICINE VISITS

Project Team: Lorraine Ambray
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Teodora Vukosavljevic

MIAD Partners: Bart Kamyk
Szymon Salamon

Faculty Advisor: Dr. Gui Garcia

Telemedicine, also known as telehealth, is a means for patients and healthcare providers to meet through video or phone. This emulates a standard in-person visit to a clinic with the convenience of meeting from anywhere. While telemedicine provides great convenience and better access to healthcare for patients in rural communities, a drawback is that clinicians are unable to perform a physical exam. This means that clinicians must rely on the patient's symptoms and self-report during telehealth visits. A vital part of a standard doctor's visit is the physical exam, during which doctors listen to heart and lungs sounds. This allows detection of an irregular heartbeat, murmurs, or other possible heart conditions. Likewise, doctors listen to crackles, decreased breath sounds, or wheezing that can indicate possible lung diseases. While there is an increasing trend for routine check-ups through telemedicine, clinicians are still unable to provide standard physical exams during telemedicine visits.

This project involved developing a device to detect heart and lung sounds for telemedicine. The device can be

used by the patient to record heart and lung sounds and then transmit those sounds to the clinician for assessment. The device is comprised of three parts. The first part is the mechanical enclosure, which is also referred to as the housing or digital hand grip. This is the exterior portion that the patient will be holding. It has a button on the exterior that the patient or caregiver will press to start and end the recording. The second part of the device consists of the electrical components housed inside the mechanical enclosure that allow for processing of the heart and lung sounds. It includes a microphone that transduces the sound waves into an electrical signal, a button that when depressed begins the recording, a network of resistors and capacitors for signal filtering, and a microcontroller that converts the analog electrical signal into a digital signal for the computer to process. The third component of this system is the software. Code was developed to collect data during recording and convert the signal into a sound file that can be played on any computer, tablet, or smart phone. This sound file can then be sent from the patient to the clinician to listen and evaluate the patient's heart and lung sounds.

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

DESIGN OF A NOVEL DENTAL INSTRUMENT FOR ROOT CANAL PROCEDURES

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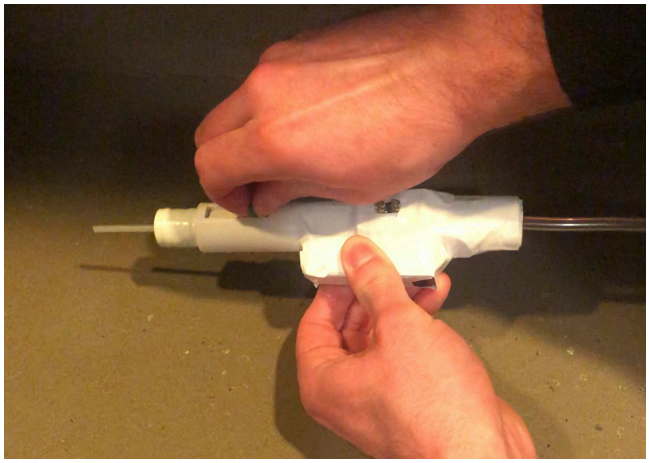
Siham Samara
Rafael Garcia

Faculty Advisor: Dr. Bo Wang

Clinical Advisor: Dr. Louis Boryc
Marquette University School of Dentistry



Root canal procedures are necessary when the pulp (soft tissue between the white enamel and dentin layer) becomes inflamed or infected. If left untreated it may cause pain or lead to an abscess. During this procedure the infected pulp is removed, and the inside of the tooth cleaned and disinfected. Then it is filled with gutta-percha, and the tooth restored with a crown or filling. Dentists cannot always accurately determine if there is any remaining organic material or fluid before adding the filling to the canal. Consequently, if any material remains and the filling is added it may lead to patient discomfort, new infection, and another procedure.

The purpose of this project was to design a prototype of a device that will be able to facilitate the removal and detection of fluid and organic material during a root canal procedure. The device was required to improve the efficiency of the root canal procedure while keeping the area sterilized and unobstructed, and the patients safe. Additionally, it had to be made of durable and non-corrosive material that can withstand the biological environment of the mouth and be lightweight and easy to handle and maneuver. The prototype of this dental instrument contains electrical and mechanical components: The mechanical component includes the suction tip which goes inside the canal, an attachment to the pressure system of the dental clinic, and the thumb-adjustable stick which allows for the movement of the suction tip for different lengths depending on the depth of the canal. This allows for the suction and removal of fluid and organic material out of the canal. The electrical component includes the sensor, battery, and light feedback system, which provides an indication to the user of any remaining material inside the canal as well as the necessary power for the lighting of the bulbs.

Testing to verify the design, target specifications, and customer needs demonstrated the ability of the device to connect to the pressure system of the dental office, suction material out of a 3 mm diameter opening, and confirm when fluid was flowing through the instrument. The device is lightweight but relatively bulky for the user to hold as a pencil. Additional small, detailed changes to the design of the prototype would be needed prior to clinical use.

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

IMPROVEMENTS IN LAPAROSCOPIC CAMERA VISIBILITY

Project Team: Meghan Wanta
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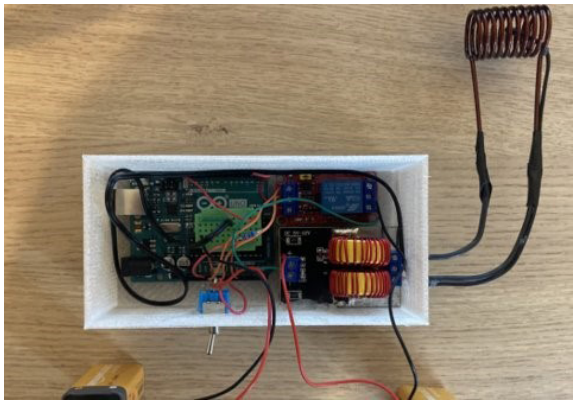
Faculty Advisor: Dr. Jay Goldberg

Clinical Advisor: Dr. Rana Higgins
Medical College of Wisconsin

Laparoscopic surgeries are minimally invasive procedures that allow surgeons to view the internal organs of patients to diagnose and treat a variety of medical conditions. Annually, approximately 15 million laparoscopic surgeries are performed around the world. The specific technology used for each procedure varies, but all use a laparoscope, which is a thin, metal tube that consists of a light source and a camera that allows surgeons to view the internal organs seen on a monitor.

Although a minimally invasive approach is often preferred over traditional open surgical procedures, problems exist with current laparoscopes. The lens at the end of the laparoscope tends to become foggy and obstructs visibility on the monitor. To remove the condensation on the lens, the surgeon removes the laparoscope, cleans it, and reinserts it into the patient. The fog on the lens is hypothesized to be caused by the temperature difference between the colder operating room environment and warm, humid environment inside the body. Insufflated CO_2 gas used during surgeries can also create a temperature difference. The team focused on eliminating or decreasing this



temperature gradient to reduce fogging of the lens. The purpose of this project was to develop a solution that would reduce the fogging of the lens without the need for the surgeon to remove, clean, and reinsert the scope. The device could not increase the diameter of the scope, and had to be as lightweight as possible and maintain a temperature range that would not pose a risk to the patient.

The design solution contains a DC powered, zero-voltage switching induction heater, and an Arduino to effectively program and control the heating mechanism. All components are encased in a 3D-printed capsule to protect the components from hazardous materials in the operating room. A coil outside of the case will contact the scope to increase the temperature of the scope. The act of heating the scope would eliminate the temperature gradient resulting from insertion of the scope during surgery. Ultimately, this would reduce the fogging effect and improve the image quality available to the surgeon, improving accuracy of diagnosis or treatment.

Verification testing of the prototype indicated that the team's design solution successfully eliminated fogging of the lens when placed in a simulated internal physiological environment. The device was able to heat the scope within a few seconds and effectively remove any fogging.

This project was supported by the Thomas M. Aaberg Retina Research Fund.

POCKET OPTIC

Project Team: Austin Bielek
Anna Santilli
Jacob Harnois
Natania Vega

MIAD Partners: Amanda Evans
Lexi Wettengel
Jay Jackson

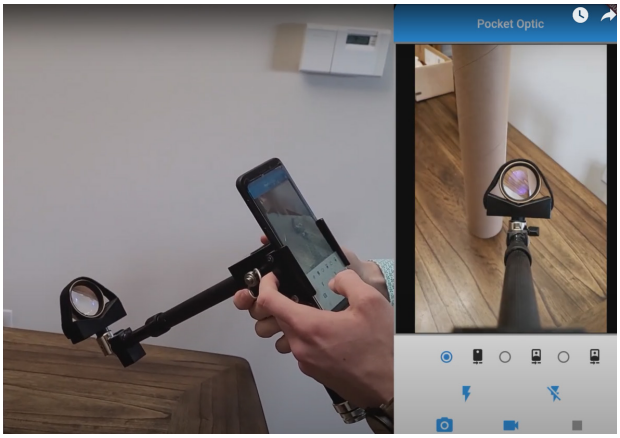
Faculty Advisor: Dr. Robert Cooper

Clinical Advisor: Dr. Baseer Ahmad
Medical College of Wisconsin

Smartphones have been increasingly used in the practice of medicine, as tech-savvy medical students around the country use their camera function to send pictures of potential pathologies to their mentors for a second opinion. At the Froedtert and Medical College of Wisconsin Eye Institute (and other medical institutions), it is currently common practice to take a picture of the patient's retina with a phone camera through a diopter lens, in a process known as fundus photography.

This project was created to address the difficulty associated with obtaining high quality fundus images with a cell phone. Currently, obtaining a fundus image requires aligning the patient's retina, diopter lens, and phone, and inverting the image. The proposed solution for making this process easier consisted of two parts: a fixture to securely hold the phone and diopter lens in alignment, and a camera application for a phone that can invert the image in real time.

For the fixture, there were multiple design iterations due to limited manufacturability options due to the COVID-19 pandemic, in addition to minor adjustments to



functionality. The final prototype consisted of telescoping tubing to obtain the correct focus and focal points for different diopter lenses, a fully rotatable lens mount to aid in removing flash reflections, a bike mount phone holder to securely hold the user's phone in place to take a picture, and a handle to hold the fixture.

A phone application was developed for both Apple and Android devices with the ability to use the flash independent of the camera. To accommodate newer phones with multiple back facing cameras, a radio button requires the user to select which camera to use before beginning the exam. The app allows the user to take a still photo or record video, as well as zoom in as needed.

There were additional features requested for the app such as being able to invert the image in real time and perform image editing and cropping from the application itself. However, these features were unable to be implemented in the available time frame. Overall, with the combination of the app and fixture, the process of fundus photography has been made easier so that anyone, with or without training, would be able to create a clear image of a patient's retina accurately and reproducibly.

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

PROPRIOSENSE: GAIT BIOFEEDBACK DEVICE

Project Team: Joseph Cava
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Michelle Kaczmarczyk
Katelyn Moore
Devon Plata

Faculty Advisor: Dr. Scott Beardsley

Clinical Advisor: Dr. Melissa Dygulski
Marquette Neurorecovery Clinic

Athalamic stroke can leave patients with full motor ability in their legs but without any sensation. Proprioception is the ability to know where one's body is in space. Without proprioception, patients often struggle to walk correctly or independently. Patients experiencing a loss of proprioception rely on direct visual feedback of their leg to confirm if the leg is resting on the ground, above the ground, behind their body, or in front of their body. Looking directly down toward the leg to obtain this visual feedback is bad for posture and can lead to balance instability during walking. During physical therapy, the therapist can provide feedback about gait, so the patient does not need to look down, however that is not a long-term solution. In an effort to provide alternative sources of feedback, the Marquette Neurorecovery Clinic has added a squeaker to the bottom of the patient's shoe to let them know when their foot hits the ground, however, it does not provide information about the rest of the gait cycle. As a result, this solution is limited in its ability to help the user become independent by learning where their leg is as they walk.

The purpose of this project was to create a feedback device to help stroke patients know where their foot is during the gait cycle. The goal was to help the patient relearn to walk and gain the muscle memory and confidence to walk independently of a physical therapist without looking directly at their leg. The solution that was developed (ProprioSense) has two components; a physical component that the patient wears and an iOS application implemented on an iPhone or iPad. The physical component consists of two force sensing resistors mounted on plastic discs that are placed on the ball and heel of the foot. There is also a hardware module containing an Arduino with accelerometer and the circuitry for the force sensing resistors. The components are secured to the user with adjustable Velcro straps to provide an individualized fit. A gait detection algorithm is implemented on the Arduino that combines measurements from the accelerometer and force sensing resistors for wireless transmission to the iOS application via Bluetooth. The iOS application then presents visual and audio cues to the user to indicate what phase of gait they are in. The application is designed to be downloaded onto an iPad attached to the front of a walker or placed on the therapy treadmill in the Neurorecovery Clinic.

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

NEXT-GEN NEURO: NEUROMUSCULAR RE-EDUCATION DEVICE

Project Team: Kristin Burke
Jacqui Heim
Holly Meyer
Tania Salinas
Marisa Strobel

Faculty Advisor: Dr. Brandon Tefft

Clinical Advisor: Ms. Nicole Hoover
Zablocki VA Medical Center

Thumb instability leads to pinch posture deformities, which are common in older patient populations. This is typically caused by osteoarthritis, which can occur at the basal and carpometacarpal joints at the base of the thumb. Current methods of treatment include object-centric exercises such as holding a pencil and running the thumb along it or reaching into a canister and pinching a small object to remove it. Neuromuscular re-education (NMRE) is a new method that can be used to re-train the muscles, brain, and nerves to communicate with each other better and improve overall movement, strength, and function of the joint.

The purpose of the Next-Gen Neuro device was to provide tangible feedback to patients so they could have a starting benchmark, and a goal to work towards. The benefit of NMRE is that it uses real-time patient data (such as an EMG signal from a contracting muscle) to provide a tailored experience and result for each user. The device was designed to use electrodes to measure the user's EMG signal. Based on the strength of muscle contraction and corresponding intensity of the EMG signal, the device would trigger different lights. When the patient is contracting the incorrect muscle or otherwise not contracting the target muscle, no LEDs would light. A minor contraction would trigger the red LED, a moderate contraction would trigger the yellow LED, and a full correct contraction would trigger the green LED. The main device components include a compressive glove, electrodes, LEDs, pre-processing circuit (to read, amplify, and reduce signal noise), microcontroller (to queue the LEDs), and post-processing circuit (the LEDs).

Testing was conducted to verify the intended results of the Next-Gen Neuro device and ensure that the design specifications and customer needs were being met. The device had a calculated accuracy of 97.62% with 1 false positive and 0 false negatives from the input EMG signal and output LED changes. The completed device was lightweight (<0.5 lb), portable, and easy to use. Further testing needs to be completed prior to market introduction and product commercialization.

This project was supported by the Medical College of Wisconsin Department of Anesthesiology.

PREVENTION OF MEDICATION ERRORS IN THE OPERATING ROOM

Project Team: Anna Wilczynski
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Grace Grad
Irah Comia
Zoe Relias

Faculty Advisor: Dr. John LaDisa

Sponsor: Dr. Kathryn Lauer
Medical College of Wisconsin

In the operating room, anesthesiologists are responsible for administering the correct drug and dose to a patient at the correct time for the duration of the patient's surgery. To increase efficiency, nurse anesthetists may draw medications from various similar looking vials prior to the operation that are then handed off to the resident physician or anesthesiologist at the time of administration. Due to these factors, an Adverse Drug Event (ADE), which is an injury to the patient from an error, reaction, or overdose, can easily occur. According to an evaluation of the adapted National Coordinating Council Medication Error Reporting and Prevention (NCC MERP) index, ADE's occur in 3.7% to 30% of hospital admissions, of which 28% are preventable. Currently, anesthesiologists and CRNAs utilize best practices and proper labeling to ensure medication errors are prevented. Another solution is the Codonics Safe Labeling System; however, its estimated cost of implementation is approximately one million dollars.

The purpose of this project was to provide a device to aid anesthesiologists in maintaining best practices such as reading each syringe label prior to administration, simplifying the medication hand-off procedure, and providing a physical organizational process to the workflow. The Organizational Box allows for labelled, drawn-up syringes to be categorized by their drug class in specific drawers to reduce confusion and simplify hand-offs. The mechanical design of the drawers, and visual and auditory feedback emitted from the device helps ensure that best practices are followed. The improvement of containing and organizing the drawn-up medications in the workflow allows for less reliance on memory and decreases the potential for the medications to be moved out of sequence or misplaced by another operating room team member.

Verification and validation testing indicated that the Organizational Box emitted the proper visual and auditory feedback on cue, and that its syringes remained fixed in place and secured. The device was also able to be disinfected for the operating room environment. With some size adjustments, the Organizational Box fit in and improved the workflow of the anesthesiologists. Future work will involve the incorporation of a scanner for reading of barcodes on drug labels, and work to reduce the overall size of the device to better fit in the operating room.

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

HEART KART II

Project Team: Kari Knopp
Ally Rising
Gaby Serrano
Clare Dyra
Zoe Marmitt

Faculty Advisor: Dr. Tanya Onushko

Clinical Advisor: Dr. Casey Vogel
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Children's Hospital of Chicago

Many children who are awaiting heart transplants require a mechanical circulatory support device, known as a ventricular assistive device (VAD), and must remain in the hospital with an average wait-time of 6 months. These devices operate outside the body and greatly inhibit the patient's mobility. To provide children with exercise while waiting for a donor heart, the Heart Kart was created as part of a senior design project in May 2020. Currently, the Heart Kart is being used by pediatric patients every day at Lurie Children's Hospital for lower extremity exercise. The Heart Kart prepares the patient's body for transplant to be as strong as possible, as well as providing the children with mobility, independence, and a sense of normalcy. This year's project provided design improvements to the original version. The Heart Kart I successfully provided a way to allow children awaiting heart transplants to exercise; however, the design and usability required improvement.

This team successfully improved upon the original design including better gliding functionality, the addition of a fulcrum for better control and steering, and several design modifications to improve the safety and aesthetics. The Heart Kart II is composed mainly of PVC tubing which allows for modifications and additions to be made using basic tools

such as drills, sanders, and saws. It has both an adjustable handlebar and seat, with increased adjustability. The handlebar can move up and down and the seat can move both up and down and frontwards and backwards. The seat, which is larger than the previous version, is bolted in place, instead of glued, making it sturdier and safer. The Heart Kart II has four caster wheels, two swivel stem wheels in the front and two fixed flanged wheels in the back which vastly improves the gliding capability. Lastly, the Heart Kart II has a fulcrum on the back made of light-weight aluminum tubes to allow a healthcare provider to push, pull, turn, and steer the cart.

Testing demonstrated that the Heart Kart II would not tip over during normal use. The Heart Kart II was also stable enough to seat a person up to 55 pounds during testing, which meets the specifications for use with children. The adjustability features were deemed easy to use by novice users and the range of adjustability met the needs of the patients. The Heart Kart II is painted in bright yellow, and a basket was added to it to further enhance the patient experience.

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SEATING SUPPORT SYSTEM FOR INCREASED INDEPENDENCE

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Spinal Muscular Atrophy (SMA) is a genetic disorder that affects the muscles and nerves causing weakness that worsens with age. Type II SMA patients are not able to stand or walk on their own and often need support when sitting. These individuals tend to experience tremors in their fingers, and have scoliosis and respiratory muscle weakness. Our client has limited motion and strength in his arms and fingers, requiring assistance with everyday tasks. The client's current solution is to have someone lift his arms for him, however, this does not give him much independence.

The purpose of this project was to create a device to increase our client's independence when using his arms. The device was required to fully support the weight of his arms and make it easier to raise his arms vertically. Additionally, it had to accommodate his existing range of motion, and be adjustable for growth and light enough for his caretakers to attach and detach it from his wheelchair. The assistive device has three main components: the clamp and shaft, the upper arm support, and the lower arm support. The clamp and shaft connects the assistive device to the client's wheelchair. The upper and lower arm supports have tension springs which remove the weight of gravity from the client's arms, allowing for more independence.

Testing verified all of our initial target specifications, but the device needs additional improvements. While it does keep the client's arms at a comfortable resting height, it needs to allow the client to move his arms up and down. Further design changes will be needed to give the client the desired level of independence.

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

ASSISTIVE FISHING DEVICE

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Cerebral palsy is a neurological disorder caused by brain development issues or damage in the areas involving muscle movement control. This disorder limits one's limb mobility and can even affect the ability to stand. Spastic quadriplegia is the most severe form of spastic cerebral palsy, resulting in loss of use of the whole body. This loss of control includes limb, torso, neck, and face muscle stiffness. Our client suffers from spastic quadriplegia and requires assistance with all tasks of daily living. This burden greatly reduces his independence during any portion of the day.

The objective of this project was to provide a functional assistive fishing device that will allow our client, a local teenager, to reel in a Wisconsin pond fish. Our client has never been able to personally take part in fishing, which is his family's favorite hobby. He has been wheelchair bound his entire life, and his caretakers have been looking for any way to involve him in this activity. The assistive fishing device is a solution that provides our client with a sense of self-sufficiency and joy. Due to the strength of the device motor and the variable speed controller, he will be able to reel in almost any pond fish that he encounters, while fishing in his home state of Wisconsin.

This reeling ability is achieved by fixing the device to our client's wheelchair and making it compatible with his permanent wheelchair control button. This specialized momentary control button requires a very low activation force, resulting in easy device control. By mounting the button to an adjustable modular hose, he has the ability to control the device with any of his four limbs, depending on his ability to do so on a given day. Through the use of aluminum brackets, a variable speed controller, and a powerful rotational gear motor, he can easily reel in any pond fish he could encounter. The custom-made casing and electrical components, coated with a silicone conformal coating, are IPX4 water resistant. This ensures there is no possibility of electrical failure or shock due to the damp environment in which the device will be used. When our client wishes to "reel" in the fish, he is tasked with holding the momentary switch through the entire reeling process. Due to the mobility and light activation force of the button, there is no concern for his ability to control the device. With the assistive fishing device, our client will finally be involved, first-hand, in one of his favorite hobbies.

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

ASSISTIVE DEVICE FOR HANDCYCLES AND RECUMBENT TRICYCLES

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Adaptive sports programs at the VA help veterans find activities to maintain health and improve functional abilities. One of these activities is the coordinated recumbent and handcycle group ride offered by the Milwaukee VA Spinal Cord Injury Unit. These volunteer-assisted rides provide veterans with an opportunity to participate in a challenging excursion using various routes on and around the campus. However, differences in a veteran's skill, age, and vehicle type make route selection challenging as the volunteers try to strike a balance between demanding and achievable rides for the group as a whole. Currently, disparities between veterans' skill levels result in the group separating during rides, necessitating more volunteers.

The objective of this project was to create an assistive device that could be used intermittently during lengthy group rides to aid less skilled patients as they face issues with difficult topography and limited endurance. The device had to be easily swapped between vehicles, controllable by users with limited dexterity, and allow for assistance when desired so that users could still be challenged during their rides, but not to the point of exhaustion. This would help minimize skill gaps among riders, allowing the entire group to go on longer and more challenging rides with fewer support volunteers.

Verification testing indicated that our design met the needs of the veterans who are our sponsor's clients, and exceeded many of our ideal target specifications. Specifically, the device was able to move a rider weighing up to 370 pounds, climb a grade as steep as 11%, and move a heavy user more than 5 miles with battery power only. The device was also able to be transferred to a new vehicle in less than 7 minutes using only tools found in a standard bicycle repair kit.

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

DEVICE TO PREVENT INJURIES DUE TO VISUAL IMPAIRMENT

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Those with visual and cognitive impairments are at a much higher risk of harming themselves or others while using conventional assistive devices. These solutions typically only address a single variable such as mobility but not aspects such as visual or cognitive impairments, developmental delays, or seizure disorders. The patient for which this project is aiming to help suffers from all of the previously mentioned conditions, and these conditions limit his overall mobility. Also, his inability to communicate verbally further complicates his condition since he cannot provide explicit feedback. Due to his complex set of medical conditions, he struggles to navigate his surroundings safely and comfortably. Coupled with this concern is the constant stress placed on his caregivers to continually bend over and guide him with their hands on his arms or walker. Despite his set of complex medical conditions, his nurse describes him as a happy and energetic 4-year-old child. Therefore, a solution that improves his mobility while considering the effects of his complex condition is crucial to his freedom and quality of life.

This project involved the design of an assistive walking device to help him to navigate his surroundings safely, comfortably, and independently, reducing the risk of injury from collisions with various obstacles. This was achieved by designing a variety of attachments to his current gait trainer to aid him in detecting and avoiding obstacles while navigating outdoors. By utilizing a Light Detection and Ranging (LiDAR) sensor in conjunction with a mechanical buzzer, the final design both detects obstacles up to a range of 18 feet and notifies him in the form of an audio alert. Additionally, as a failsafe, the gait trainer was equipped with linear actuators on the back wheels to deploy in the event that he approaches an obstacle too closely. The actuators act as brakes to safely and slowly stop the gait trainer from colliding with an obstacle. After a 10-second period, the actuators retract to allow him to alter his direction. The solution also includes a vibration component on the handlebar that is remote-controlled by a caregiver and can provide positive reinforcement for him as he uses the gait trainer. The entire system utilizes two Arduino microcontrollers (1 Arduino Mega 2560 and 1 Arduino Uno), and the system is powered by a 12V drill battery for easy set-up and charging. Testing was performed to verify the sensitivity and specificity of the overall system. Based on the device's performance, the final design should allow him to confidently navigate his environment and explore the world as a curious, energetic 4-year-old.

This project was supported by the Medical College of Wisconsin Neuroscience Research Center.

PRECISE TESTING OF SMELL LOSS IN COVID-19 PATIENTS

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COVID-19 is an infectious respiratory illness caused by the SARS-CoV-2 coronavirus strain. This disease was declared a pandemic in 2020 and shares a lot of symptoms with the common flu. These can include fever or chills, cough, sore throat, and body aches but a key symptom that distinguishes itself from the flu is the new loss of taste or smell and the shortness of breath/difficulty breathing. Some people may feel completely fine with no symptoms and still carry the virus. However, they may experience loss of smell and not be aware of it. People test positive through saliva tests or nasal swabs. While it may not be deadly to those with no pre-existing conditions, it can be for those with weaker immune systems.

The inspiration for this project came from a goal to study the long-term effects that COVID-19 has on the olfactory abilities of someone who had the virus. This project involves the design of a test device to decrease the amount of time it takes to detect the virus in people so the spread of the virus can be mitigated. This was tested through a simple experiment to test how well a subject could distinguish particular odors from another. A 60-gallon aquarium air pump provides constant air flow

through an air filter that leads into a 12-way splitter that allows the tester to easily switch between odorants during the experiment. The odorants tested were different drops of essential oil scents on a small piece of paper in vials. Using plastic tubing, the vials have a hole drilled into the cap big enough to fit the tubes that connect to the splitter. The splitter then has one tube connecting to a CPAP mask worn by the test subject. Finally, a flush line is connected to flush out any potential leftover odorant to assure proper testing.

Multiple experiments were conducted to verify that the prototype device performed as required. The desired length of an experiment was set to run between 30-60 minutes and after testing, the best test ran for just under 37 minutes. Additionally, the experiment was run on a member of the project team and in 10 trials (one trial representing the detection of one odor), he was able to correctly identify 8 of the 10 smells, verifying the functionality of the device.

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