Cook Engineering Design Center (CEDC)

Sample Project Proposals

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Automation and Industrial Design

Bottom Bots 2.0: Robot Refinement and Algorithm Development

Overview

This project seeks to build on past 89/90 work, as well as recent developments the sponsors have made.

The growth of algae, barnacles, and bio-matter on boat hulls is a common problem that affects all types of boats left in water for long periods of time. Current methods to solve this problem include toxic hull paints, which slow the rate of growth, divers, who scrape boat hulls after bio-matter has grown, and complete boat removal/cleaning at a marina.

State and federal laws are changing to disallow diving on boat hulls because it causes the removal of toxic hull paints as well, and releases them into the environment. Additionally, marinas must now construct costly waste water collection facilities, which capture hull-cleaning residue on "pulled" boats and store it nearby until it can be properly disposed of.

Bottom bots seeks to minimize the need for hull paints, and eliminate diver cleaning and out-of-water cleaning by replacing them with an affordable, in-water robotic system that can clean boat hulls as effectively as a diver. This project will focus on the refinement of the sponsor's design changes since the previous 89/90 group, and the development of control methods/algorithms for the robot itself.

Goals

- We would like to see the following come out of this project:
- Functional prototype
- Ability to be manually operated while under seawater
- Smooth/non-glitch operation while under manual control
- Development of an intelligent user interface to facilitate manual control
- On-board sensors and data acquisition
- Some advancement toward automated tasks/capability
- Sponsors intend to work closely with the team so good communication about all facets of the project is essential.

Deliverables

- Functional prototype, able to clean a ~30 ft keelboat in seawater
- "On-shore Control Box" with:
- Intelligent user interface that can feed data from on-board sensors to user
- Practical power supply, either sourced or developed, that can be interfaced into system
- Control algorithms
- Build in safeguards to robot
- Algae and toxic paint filtration: TBD
- Report detailing project advancements, including:
- Commented code of control algorithm(s)
- High-level and sub-level flow charts/documentation on all inputs/outputs of robots, as well as user interactions necessary for control, error recovery, etc. (Like a graphical plan of the code and inputs from user.)

Required Facilities
- Access to either a swimming pool or large tank of water would be extremely helpful. Sponsors will also work to provide a testing tank, but this should not be expected.
- Extensive use of FDM and other types of 3D printing.

Knowledge Areas Needed for Project
- Control Systems
- Digital Electronics
- Engineering Graphics (CAD/CAM)
- Fluid Mechanics and Gas Dynamics
- Solid Mechanics
- Software Engineering

Proprietary Information and Confidentiality Requirements
- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Innovative Technical Knowledge Database/GUI

Overview

The industry leader in high performance industrial digital printing hardware, we maintain a core R&D engineering group in Lebanon, NH. This group manages multiple concurrent product development and technology exploration projects. The proposed project would create the architecture and process for an integrated, graphically organized technical knowledge database and manage the pilot implementation of this system. Utilizing Web 2.0 tools, it must combine database multi-user flexibility and search abilities with an intuitive graphical interface.

Goals

The overall goal is to migrate technical information from static repositories to a dynamic environment where test plans, project activities, scientific problem solving and product planning ideas are shared and manipulated in a real time network environment. Engineers, managers and technicians would use this environment for all daily technical interaction sharing varying levels of read/write access. If designed and implemented properly, the technical knowledge base would organically grow as a densely linked, topically comprehensible entity.

A crucial addition to any available commercial package, even if one does exist that meets most specifications, will be the design of an architecture that facilitates technical communication and physics based problem solving to match the personality of this dynamic R&D group.

Deliverables
- Work with potential users to define scope, specifications and desired features.
- Review existing mind mapping and database interface software packages, evaluate capabilities and present the options, along with customization possibilities, to key decision makers.
- Innovate the knowledge base software architecture in conversation with beta users.
- Implement, in conjunction with the IT department, customizing a commercial product and/or creating new graphical input and output algorithms and database designs.
- Train, interact with pilot users, specify, debug, and make recommendations for next phase.

Knowledge Areas Needed for Project
- Software engineering
- Product design
- Project management
- Modeling and optimization

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Manufacturing and Business Process Optimization

Overview

The sponsor produces precision castings and its ZA-12 zinc alloy castings offer an excellent combination of mechanical properties, surface finish, and low cost. ZA-12's strength, hardness, and wear properties are better than any other general-purpose nonferrous casting alloy. The castings have such high precision that they require little finishing machining and therefore can be a very cost-effective solution for many applications.

The sponsor has worked with Thayer School in the past to optimize their casting and machining operations. These efforts were very fruitful and the sponsor continues to benefit from the implemented process improvements.

As a result of these successes, the sponsor is interested in further optimization of business practices and manufacturing processes.

Goals

- Analyze the sponsor's business and manufacturing processes from order entry to shipment and identify production inefficiency.
- Perform process mapping, the 7 mudas (wastes), 5 S and other lean analysis techniques to improve manufacturing processes.
- Develop an algorithm to measure the potential cost savings of improvements. Use Throughput Accounting methods to identify throughput-related cost reductions.

Deliverables

Process maps of the improved process and estimated cost savings.

Required Facilities

Students will be encouraged to visit and observe the sponsor's manufacturing processes.

Knowledge Areas Needed for Project

- Factory Layout and Scheduling
- Manufacturing Systems
- Modeling and Optimization
- Organizational Design
- Quality Control and Reliability

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Engineering for Energy and Environment

Design/Build Small Hydroelectric Turbine—Energy Reclamation

Overview

We have been manufacturing small hydroelectric reaction type turbines for over 10 years. In this project, you will utilize existing hydraulic designs and through miniaturization apply these designs to energy reclamation opportunities that exist in small water companies around the US. In many cases, such water companies waste excess pressure to downstream systems with pressure reducing valves. Currently, the only technology available to reclaim this energy is PAT (pumps as turbines) technology. A true turbine design, which can accommodate varying head pressures and flow through the day and night, will improve energy production in a given application by a minimum of 50%. The PAT technology does not yield the same effect and for this reason does not have widespread application.

Turbine technology can offset many tons of carbon emissions across the country annually. In general, this type of small hydroelectric turbine is considered to have no negative environmental impact because it goes into existing facilities. Additionally, the economics of even small projects are excellent due to this utilization of existing civil works and pipelines. Another key economic factor is the streamlining of the federal licensing process, which allows for a closed conduit exemption instead of a full federal license.

Goals

It is the goal of this project to design, build and install a miniature reaction Francis turbine in a water company in southern Vermont, to be tested and commissioned by February 2008.

The plan is to use the CAD/CAM and rapid prototyping facilities of the engineering labs to reduce costs and production time on these small turbines.

Deliverables

Utilize CAD techniques to create a complete set of digital production drawings for use in CAD/CAM applications. These drawings and designs will include hydraulics, case design, gate and other components. Due to the homologous nature of turbine design these scalable data will allow the manufacturer of this style turbine in various sizes to be applied in numerous water companies with predictable results.

Production of tooling components using machine shop resources utilizing rapid prototyping and CAM technologies to fabricate precision casting wax injection molds for very complex 3D turbine parts.

Test designs in FLUENT or other program to predict results for various scales in production.

Strength, wear and other mechanical testing for various components within assembly (FMEA – Failure Modes and Effect Analysis).

Unit built in collaboration with our company and installed at southern VT water company.

Test production unit against FLUENT predictions.

Required Facilities

- CAD lab
- Digitization facilities, CMM
- Potential machine time to fulfill tooling requirements (CNC milling)

- FLUENT – fluid analysis
- Students will be given the opportunity to visit our facility and participate in the device installation at the southern VT water company in February 2008.

Knowledge Areas Needed for Project

- Fluid mechanics
- Solid mechanics
- Product design
- Engineering graphics (CAD/CAM)
- Project management

Proprietary Information and Confidentiality Requirements

Confidentiality required for sponsor-provided information
Intellectual property ownership rights retained by sponsor
Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Genetic Tools Development

Overview

In the current economic and political climate, there has been enormous attention focused on the need to develop sustainable and renewable sources of liquid fuel. Ethanol has a significant and growing role in this development, providing a cleaner, domestically-produced, renewable energy solution.

Ethanol in the U.S., however, is currently produced almost exclusively from corn, relying on an expensive and limited material. Processing ethanol from cellulosic biomass—wood, straws, fuel energy crops, paper pulp and agricultural waste products—significantly reduces the feedstock cost for fuel ethanol production. This in turn provides the opportunity to produce cellulosic ethanol far more cost-effectively than corn-derived ethanol.

In nature no organism is capable of quickly reducing and fermenting biomass sugars without significant formation of by-products. Our research laboratories are now developing a new generation of enzymes, microbes and processes for economical conversion of cellulosic feedstocks into ethanol. With this conversion will come a complete rethinking of the ways in which we fuel our economy.

Goals

To develop a novel mutagenesis tool compatible with high temperatures.

Deliverables

- Reports per normal coursework requirements
- Establishing temperature effects on function
- Proof-of-concept at elevated temperatures

Required Facilities

- Specialized materials, consumables and work space will be provided at the R+D facilities.

Knowledge Areas Needed for Project

- Biochemical engineering
- Proprietary Information and Confidentiality Requirements

Confidentiality required for sponsor-provided information

- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

High R-Value Energy Curtain for Solar Greenhouse

Overview

We are in the middle of constructing a solar-retrofitted greenhouse at the farm site. This project was designed and supported by a previous ENGS 190 course in the fall of 2006. This building design project was an attempt to greatly increase the growing season provided by an enclosed space (greenhouse) while minimizing fossil fuel inputs. This greenhouse is currently under construction and is expected to be enclosed by the end of fall, 2007.

One of the most significant systems called for in the 190 design for the solar retrofit of the existing greenhouse structure was the design, creation and installation of a high-R energy curtain to conserve and retain the heat stored in the thermal mass and growing soils during cold nights. It is the combination of the thermal mass and the energy-conservation systems that will allow this solar heated greenhouse to provide a functional growing space for up to 10 months of the year, without the addition of any fossil-fuel heat. Thus, the creation and installation of a functional and durable energy curtain with a high R-value will be essential for a successful building retrofit.

Goals

The aim of this project is to design and install a movable insulation system that will allow the solar greenhouse to have soil temperatures remain above 32 degrees F for at least 10 months of the year, in Hanover, New Hampshire. This task can be achieved by successfully fulfilling two main goals. First, extensive research will need to be done into the current commercial offerings for movable insulation. This will provide important background for the current state of the industry and identify any possible system or systems that might be of use. A complete evaluation of the current need, including structural and space limitations, environmental challenges inherent in greenhouse spaces and a review of the previous 190 design that established a minimum R value for the energy curtain will all be necessary to effectively evaluate the design parameters. Second, appropriate materials and installation systems will be required to solve the problem once it has been described. This will likely entail significant work with insulating materials, protective covers, infrared reflective materials and various support and storage techniques that may be of use in the final design.

Deliverables

It is expected that this design process will supply a complete design, including cost estimates, an installation plan and thorough parts list. It is also expected that a working iteration of this movable insulation system will be installed in the greenhouse by the end of the winter term of 2008.

Required Facilities

- Access to the solar greenhouse is available at the farm, just 3 miles north of campus.

Knowledge Areas Needed for Project

- Heat transfer and thermodynamics
- Fluid mechanics
- Machine design
- Materials science
- Environmental engineering
- Engineering graphics (CAD/CAM)
- Modeling and optimization

Proprietary Information and Confidentiality Requirements

- None

Engineering for Humanitarian Needs

Arsenic-Free Water Filter

Overview

The problem of arsenic poisoning from well water is immense, well documented, and mind boggling — tens of millions of people from the foothills of the Himalayas to the Ganges delta are afflicted by a continuing natural disaster that cripples their mental and physical capabilities. Our previous filtration designs demonstrated a simple, inexpensive, and reliable way to remove arsenic from contaminated water using electrolysis. We now desire to turn this concept into a manufacturable product.

System Overview: Affordable solar home power systems now make electrochemistry practical. The appliance will have three stacked containers. Water (~ 20 L) is poured into the top unit. A little electricity from a re-chargeable battery injects a measured dose of iron from an electrode into this water, where it coagulates with the arsenic. The batch flows through the center unit where the arsenic is removed by a sand filter. The clean water collects in the bottom unit, which users access via a faucet. Electricity permits "batch" treatment instead of "continuous flow," with excellent dosing, mixing, and low-arsenic results. Cheap iron plates and sand are the only consumables. Gas bubbles collected from the second electrode indicate that the system is working. The volume of collected gas indicates when the treatment is complete. Further design parameters are available.

Our company has sponsored ENGS 89/90 projects for 7 years. In 2009, a Thayer team demonstrated an effective electrocoagulation arsenic removal system. The invention won first place at the national Collegiate Inventors Competition. The team members are available to consult with this project.

Goals

The goals of this project are to design, field test, and prepare for manufacturing a rugged, effective, and reliable household arsenic-removal appliance, based on Dartmouth's award-winning 2009 project, for use in arsenic-afflicted areas.

If the project is successful, the product will be field tested in Bangladesh, India, and Nepal in 2014 and may be trialed in other developing countries. There will be opportunities for travel internships to assist with field trials and scaling. Our company may file for patents based on the project, citing student inventors.

Deliverables

A manufacturable design of a household appliance that will remove arsenic from well-water using the electrocoagulation of arsenic removal technology.

Verify and document the operation and effectiveness in the categories of robustness, longevity, simplicity, and affordability.

Documentation for manufacturing and CAD files.

A final report covering design considerations, discoveries, and recommendations for manufacturing and deployment. A language-neutral pictogram-based user manual is desired.

Facilities Required

- Machine shop
- Chemistry lab

- Project lab

Knowledge Areas Needed for Project

- Chemical Engineering
- Engineering Graphics (CAD/CAM)
- Environmental Engineering
- Machine Design
- Modeling and Optimization
- Product Design
- Project Management

Proprietary Information and Confidentiality Requirements

- Confidentiality is not required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Low Cost Solar Collector Performance Modeling and Design

Overview

Our non-profit organization is committed to improving the quality of life for communities all over the world through the implementation of appropriate technologies that are socially conscious, environmentally aware, and fully sustainable.

Many Central Asian countries would benefit from solar thermal collectors for water and space heating. High quality manufactured collectors, such as in the United States, are not available or appropriate there. Basic materials such as wood, horsehair, sheet metal, glass, and black paint are. An optimized solar collector that utilizes local materials and incorporates traditional methods has potential to greatly reduce the dependence on non-renewable and valuable energy sources for heating.

If the project is successful there is the possibility of a sponsored implementation trip to the region in the summer.

Goals

The object of this project is to catalogue the traditional solar collector methods in different parts of Central Asia, perform CFD and thermal simulations on various traditional and high-end methods to determine collector effectiveness, and design an optimized collector that is appropriate, utilizes local materials, is sustainable, and socially and economically feasible.

Deliverables

- Catalogue of traditional collector designs in different areas.
- CFD and thermal models on various traditional methods.
- Prototype and performance data of optimized design.

Knowledge Areas Needed for Project

- Heat transfer and thermodynamics
- Fluid mechanics
- Environmental engineering
- Product design
- Modeling and optimization

Proprietary Information and Confidentiality Requirements

- None

Engineering in Medicine

After-the-Fact Dosimetry Device—Unplanned Radiation Exposure

Overview

Electron paramagnetic resonance (EPR) has been used for more than 40 years for measurements of exposure to radiation, including dating applications in fields like geology and archeology. Most importantly, dosimetry has been used retrospectively to assess the exposure to radiation of the victims and survivors of the atomic bombs in Japan and, more recently, the Chernobyl accident. The use of EPR is based on its unique capabilities to measure free radicals.

Teeth have traditionally been used for this type of test because this matrix material (especially that of the enamel) stabilizes the free radicals created during exposure to radiation. The amount of free radicals present in the matrix is therefore proportional to the dose of radiation received. Traditionally, tests have been conducted by making measurements on teeth that have been shed due to natural causes or treatment, and then concentrating the enamel material to make the measurements using conventional EPR spectrometers. However, with the advent of new EPR techniques that permit the measurements to be made in living subjects, dosimetry measurements can be conducted in vivo, without removal of the teeth. With this advancement, such technology can be used to help deal with the medical consequences of a nuclear catastrophe when a population of people is exposed to an unknown amount of radiation. In such an event, it is important to be able quickly and reliably to triage people into three categories:

Group 1: Low radiation exposure and low risk of becoming sick. It is important to define this group (the largest) to help keep the system clear for those actually in need of medical attention (<~2 Gy).

Group 2: Moderate radiation exposure that carries significant risk but can be treated (~2<~7 Gy).

Group 3: Those who have received a dose of radiation that is probably too high to respond satisfactorily to medical intervention (>~7Gy).

We have been developing a prototype and a set of clinical trials using this technology over the past 15 years. The need for such a capability is indicated by the fact that this development is being supported by grants from NIH and the Department of Defense. The overall orientation of the research is to develop a device that is transportable and readily operated in the field with sufficient speed and accuracy that large numbers of people can be screened by first responders. The current device focuses on making the measurements in the molar teeth (the large teeth in the back of the mouth). Recent developments have indicated that there may be some significant advantages in making the measurements on the back of the incisors (the front teeth).

We are looking for help to develop the technical aspects of this new approach. The current process takes ~15 minutes, uses the molar teeth for analysis, and is largely comprised of setup time. It also is limited by the fact that many people have extensive fillings in their molar teeth, making it difficult to find sites where the enamel can be measured. The time required for the measurements could be drastically reduced and allow for a more rapid triage system in the event of an emergency if there existed a method to create and position the resonator loop on the teeth in the front of the mouth (the incisors). The general feasibility of this approach has been demonstrated, but an effective and practical device to make the measurements needs to be developed. The requirements are both in the development of the hardware to position the loop and also in modeling to determine the optimum configuration of the sensing end of the detector.

Goals

- Create device to position the measuring/holding detector (resonator) on the back of the incisor teeth in a way that is rapid, reproducible, and comfortable for the subject.
- Create a program that uses finite element analysis to evaluate different configurations of the sensing resonator loop that provides maximum sensitivity and ease of placement.
- Deliverables
- Design and then carry out finite element analysis to determine the loop shape(s) that gives maximum sensitivity. The potential variables involve the size and shape of the sensing loop, the location of the enamel in the teeth, and the distribution of the electromagnetic field in the loop.
- Design and then fabricate a device for reliably positioning the resonator on the back of the incisors.
- Define procedures for operation of the device by non-technical, non-trained staff.
- Recommend portability related enhancements.

Required Facilities

Our laboratory is considered to be the leading site in the world for the development of in vivo EPR and for in vivo EPR dosimetry. The instruments used for the measurements are made in the laboratory. Several very skilled and experienced engineers and EPR spectroscopists are involved in the overall project. The idea of using the incisors is a new and promising approach, but because of other aspects that are already underway in the research, it is difficult to allocate sufficient time for these developments to be carried out by the existing staff. They will, however, be fully available to provide advice and feedback to the students undertaking this project. Most or all of the measuring devices are in place as well as facilities for testing the developments in vitro and then in volunteers. If the project is successful the students will be making an important contribution towards meeting a significant national need. They would be authors or co-authors in the papers resulting from these developments. There would be the potential for continuing involvement beyond the time of the 190 project for the continuing development of the technique through the grants that support it and/or a small company that is involved in the commercialization of the technique.

On the other hand this would be a challenging task. While an extensive supporting structure is in place, the students would be expected to provide much of the initiative and hard work to make the actual hardware and to develop the software. The project is of central importance to the overall research so there will be a demand and expectation of high quality and diligent work on the project. There would be an ongoing need for the students to become familiar with the principles and practice of the research and to be involved in the discussions of the overall progress and plans of the overall research. That is, they would be expected to be real members of the team!

Knowledge Areas Needed for Project

- Fluid mechanics
- Solid mechanics
- Machine design
- Control systems
- Electromagnetics
- Materials science
- Biomedical engineering
- Statics and dynamics

- Product design
- Engineering graphics (CAD/CAM)

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
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Analysis of Artificial Knee Performance Using Medical Imaging

Overview

It is estimated that over 500,000 artificial knee joints are implanted each year in the United States, with an international market of an even larger magnitude. The knee implants available today are highly engineered devices and are the results of many years and many millions of dollars of research in materials science, mechanics, and bioengineering. As such, most of the major problems associated with early models of knee implants, such as fixation and material biocompatibility, have been solved. The biggest problem now affecting the performance of these devices is related to the wear behavior of the polymer component. At present, there are limited methods of evaluating the wear behavior of an implant in vivo; the best wear analyses are based on measurements taken after the implant has been removed from the patient.

The objective of this project is to investigate possible methods of analyzing the wear behavior of a knee implant in vivo using medical imaging technology. The students involved will gain knowledge in materials science, mechanics, bioengineering, software design, medical imaging, and orthopedics. Students will also have the experience of working closely with radiologists and orthopedic surgeons, and with engineering researchers in both academia and industry.

Goals

Students will design and build a phantom knee joint that can accommodate several different models of knee implants. Students will then work with radiologists to obtain medical imaging data of the implants, possibly using various techniques including CT, MR, x-ray, and/or ultrasound. Students will work with us to utilize and/or develop software tools to analyze the imaging data and to qualitatively evaluate the wear behavior of the implants.

Deliverables

A phantom knee joint designed to accept several different implants. The phantom must be able to bend like a real knee joint and display similar imaging properties. A mounting device must also be constructed to hold the phantom knee at various bending angles when imaged.

Imaging data sets (electronic files) obtained from scans of the phantom knee joint with several different implants, and possibly from various imaging modalities (CT, MR, etc.).

A clear, detailed, and well-written guide explaining the techniques used to analyze the imaging data for evaluation of implant wear.

A comparative study of the implant wear properties measured using the imaging analysis tools versus traditional ex vivo techniques.

Required Facilities

Imaging equipment, imaging analysis software and tools will be made available.

Knowledge Areas Needed for Project

- Solid mechanics
- Biomedical engineering
- Statics and dynamics
- Engineering graphics (CAD/CAM)

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Development of a 'Smart' Deep Brain Stimulator

Overview

Deep brain stimulation (DBS) is used to treat Parkinson's Disease. Electrodes are surgically placed in the subthalamic nuclei of each patient, and continuous ~180 Hz electrical stimulation is delivered to this part of the brain. Symptoms of Parkinson's Disease are often dramatically improved (less tremor, stiffness and difficulty initiating movements). But no one knows how the therapy works. We believe that the stimulation releases neurotransmitters, glutamate within the subthalamic nucleus and dopamine at more distant sites in the motor control circuit. A self-sufficient brain machine interface that could sense changes in the neural environment (i.e. neurotransmitter levels) in its vicinity and accordingly direct electrical pulses of the correct amplitude and frequency through microelectrodes to a specific location in the subthalamic nucleus would create closed loop control of the stimulator and improve Parkinson's disease treatment and reduce DBS side effects. However, it is not clear which neurotransmitter is best to use as the feedback signal in a smart DBS system.

We believe that DBS causes glutamate release in the subthalamic nucleus and probably in the substantia nigra (where dopaminergic neurons reside), and that glutamate release, in turn, triggers the production of more dopamine, 'resetting' the motor control structures in the brain. To design DBS control algorithms, an understanding of glutamate and dopamine release as a function of DBS is necessary. We have already used a pseudo-random sequence of stimulation of the subthalamic nucleus (STN) in rats and the tools of system identification to determine a transfer function between the DBS input and the glutamate concentration (the output) and tested its accuracy and ability to predict experimental results. Now we are interested in determining the link between dopamine and glutamate.

Goals

Develop a LabVIEW-based experimental interface to control stimulation and assess neurotransmitter release.

Develop an interface for control of fast cycle voltammetry to measure dopamine levels moment by moment.

Develop adaptive mechanics for dynamic control of glutamate or dopamine release.

Use the tools of system identification to measure the transfer function between electrical stimulation and glutamate and dopamine in a rodent model of Parkinson's Disease.

Determine whether the transfer functions for glutamate and dopamine are correlated, and determine how this correlation is related to the loss of dopaminergic neurons in a rodent model of Parkinson's Disease.

Deliverables

An analysis of the limitations of the current technology available - what needs to happen in order to use smart DBS in humans?

A report comparing the benefits of smart DBS based on dopamine or glutamate - which neurotransmitter is the better target for any commercially viable 'smart' DBS system?

A fully functional algorithm-based experimental control model of a healthy motor control system written in LabVIEW.

A 'smart' DBS system prototype:

- The prototype will be based on glutamate or dopamine as demonstrated by targeted control of these neurotransmitter levels in the brains of individual rodents.
- The prototype will be adapted so that when it is used in a rodent with induced Parkinson's, it will maintain the level of the target neurotransmitter within a certain window.

Required Facilities

- Must be proficient with MATLAB programming
- Must have an interest in neuroscience
- LabVIEW experience helpful, but not necessary
- System identification knowledge helpful, but not necessary

Knowledge Areas Needed for Project

- Control systems
- Analog electronics
- Digital electronics
- Signal processing
- Software engineering
- Materials science
- Biomedical engineering
- Product design
- Statistical analysis
- Modeling and optimization

Proprietary Information and Confidentiality Requirements

Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Method and System for Tracking Ultrasound Imagery

Overview

Anesthesiologists use a device to stabilize an ultrasound image during regional blocking procedures. In addition to enabling a steady image, the device provides the opportunity to perform ultrasound guided blocks to private practice clinicians for whom the cost of hiring additional staff to use ultrasound technology is prohibitive.

The first iteration of this device which has recently gone to market is manually controlled and relies on friction in ball and socket joints to maintain a "locked" configuration when the target image is acquired. Even when locked, the device is able to accommodate tiny "tilt" and "rotate" motions, which are crucial in ultrasound image optimization. With this implementation, it is easy to ensure that the device holds a fixed position in space and can capture meaningful imagery. However, it may be more desirable for some medical procedures to fix the ultrasound transducer to acquire an image of a moving target, such as a catheter tip, or a hard lesion, as it is manipulated through less dense tissue. This would require a truly "hands-free" solution, wherein the device and its corresponding transducer can track a target image over the course of a procedure.

A plurality of robotic arms exist for medical purposes, however, at the time of writing this proposal, none have been specifically designed to assist regional blocking procedures.

Goals

It is our long term goal to, using existing technology, create a system that allows clinicians to indicate a target image, then track that image over the duration of a procedure, wherein the ultrasound transducer is always over the target image.

Deliverables

Identify, rank and source relevant visual image acquirement and tracking systems

Identify, rank and source potential robotic arm technology OR Design and prototype a robotic arm that has the "sweep", "tilt" and "rotate" functionality necessary to performing a regional block

Create a system for a robotic arm which can track an image generated by an ultrasound system

Knowledge Areas Needed for Project

- Machine design
- Control systems
- Signal processing
- Electromagnetics
- Software engineering
- Biomedical engineering
- Statics and dynamics
- Product design
- Engineering graphics (CAD/CAM)

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

Product Design

System to Track Athletes's Position Using Video

Overview

Trak Performance software allows a user to track where an athlete or official (hereafter will just refer to players) moves around a field/rink/court (field for short), thereby providing tactical information on how the player uses the field, and their velocity (which translates into work rate), both of great interest to coaches. The Trak Performance software assists the user in tracking players, one player at a time, by providing a diagram of the field on screen, and recording the user's mouse movements as the user follows the player's movements around the field, watching a separate video. The user can also setup hot keys to hit when various events occur, like a shot.

There are systems that track player movements, such as ProZone, but they require a major, permanent system installation at the stadium, and cost on the order of $10,000/game and require sending the video out to a processing center.

When we saw a demonstration of ProQueSys, it seemed that the technique used in the goldfish example could potentially be applied to the problem of tracking players as they moved around a field.

Goals

To determine the feasibility and, if feasible, the computational requirements to semi-automatically track entire team(s) of athletes as they move about a field using a single camera angle and the ProQueSys software system. We define 'tracking' an athlete as knowing where they are on a field at every instance of time, thereby not only knowing their location, but thereby being able to calculate their velocity, and thus determine running speed, work rate etc.

Deliverables

Familiarize with the ProQueSys (PQS) tracking platform.

Create interfacing specifications.

Develop tracking system using PQS tools—includes tracking players, tracking field boundaries as camera pans back and forth following the ball, registering players as they enter or leave the field.

Tracking strategy may depend on using one or multiple PQS tracking instances to initially track the field boundaries. This way the tracking models can reasonably accurately determine the viewing angle of the camera, and feed this information back into the tracking models. Knowing approximate field boundaries improves the accuracy of player tracking.

Second development stage will focus on producing one or more player tracking models. One model will be able to track dozens of players at once, since the ProQueSys core can apply the same model to multiple objects in the tracked environment. ProQueSys currently uses several image processing strategies, a selection of which will determine the best tracking performance, given the player models. Tracking targets include players, referee(s) and the ball.

Test models on selected test video(s). We will pick a sport on which to focus all initial development, likely candidates are soccer and field hockey.

Effectiveness evaluation will depend on human scoring of the resulting tracked players. Measures will include players missed, players mis-identified, system losing track of a player, or the system tracking a single player multiple times.

Trak Performance software, which uses a manual tracking technique, may be used to provide current standard of accuracy for comparison with PQS models created in this project.

Later in the project the focus will be on improving the human interaction with the tracking system to allow an operator to correct tracking mistakes and mix-ups.
The team will deliver the results of their feasibility study, as well as all software, user interface, PQS models, etc.

Required Facilities

All development must be on the Macintosh OS X platform as that is how we deliver all of our software.

Knowledge Areas Needed for Project

- Software engineering

Proprietary Information and Confidentiality Requirements

- Confidentiality required for sponsor-provided information
- Intellectual property ownership rights retained by sponsor
- Sponsor accepts responsibility to discuss IP ownership directly with the student project team and project advisor

The Super Intelligent Earplug

Overview

It goes without saying that classical music is dramatically different from all other musical styles. It may be less obvious to many people, though, that some of those differences are:
The music is almost always performed purely acoustically, without any amplification whatsoever (except when performing in outdoor venues) and
The music is often extremely flexible, and the musicians are continuously adjusting to each other (and the conductor) in order to stay together, and
The music vacillates frequently and rapidly between volume extremes and furthermore often has different instruments playing simultaneously both very loud and very soft.
In order for the classical music performer to be able to perform at their peak they need to be able to hear well both themselves and their colleagues at all times.
As the symphony orchestra has evolved over the last 200 years the number of instruments has increased dramatically, and the volume of many of those instruments has also increased. For many orchestral musicians it is now imperative that they wear ear protection if they expect to retain their hearing throughout their career. (The major symphony orchestras have experimented with sound baffles, meant to protect the more downstage musicians from the louder sounds of the more upstage players, with mixed results. There is, however, general agreement that they are unsightly to the audience.)
Unfortunately, any ear protection yet devised causes a significant loss of clarity of the ambient sounds, often making it difficult or impossible for the musicians to hear themselves. Additionally, the musicians are forced to insert and remove earplugs often during a performance, a distraction to themselves, their colleagues and the audience. The classical musician needs to be able to continue to hear clearly and well, yet have the total volume stay at manageable, non-damaging levels.
The Intelligent Earplug will enable the performing musician to hear well and clearly at all times by passing through to the ear-canal all safe sounds at a very high level of audio fidelity. For obvious reasons this needs to be accomplished without any noticeable latency. Those sounds that exceed the user-selectable threshold for loudness comfort will be reduced to the threshold level. The Intelligent Earplug will be as small, discrete and comfortable as conventional earplugs in order that its use will be transparent to the concert-going audience. It will operate with its own self-contained power source in order that it not require any wires, even if that means that it will need to be charged between uses.

Performers on some of the lower volume and lower pitched instruments (e.g. the cellos and basses) often find that they cannot monitor their own sound well at low volume, even when the overall volume of the orchestra is below the threshold for damage. In this situation one is often instinctively tempted to play slightly louder, resulting in a lack of blend within the section.
The Super-Intelligent Earplug will additionally allow the performer to mix into the ambient sound a small user-controllable amount of his/her own sound. The Super-Intelligent Earplug will add a wireless pickup, discretely mounted on the instrument, with the ability to transmit wirelessly to the Intelligent Earplug. In order that many musicians might simultaneously use this technology, it is important that the wireless transmitter and receiver be paired in a way that they can only communicate with each other.

Goals

Determine the best hardware and software configuration to maximize audio fidelity while minimizing power requirements for each of the three components.

Deliverables

- Ideally, one working prototype with ideas for future improvements.

Knowledge Areas Needed for Project

- Analog electronics
- Digital electronics

Proprietary Information and Confidentiality Requirements

- None

Transportation

Formula Racing Hybrid IC Controls and Simulation

Overview

The engine of a hybrid vehicle differs from an ordinary vehicle in that it is not directly controlled by the driver. In a series hybrid drivetrain, the driver's input directly controls the electric motor, and the engine responds to the power demands of the drivetrain. This requires the implementation of an engine controller. The engine can be run in a variety of different modes. In order to determine the best mode of operation, the performance of the car must be analyzed in simulation so that the performance of each mode of operation can be determined. In addition, the engine requires a controller that is capable of maintaining proper engine operation under various load conditions.

This will be a very challenging project, given the complexity of the system and the relatively young age of the project. The simulation must be validated through testing, requiring a final product well in advance of the mid-March due date. It is expected that the system will allow the car to run in EV-only or IC-only mode. Furthermore, the car should be able to perform quite well in either mode.

Goals

This team will work closely with the energy storage team, generator team, and data acquisition team to develop a MATLAB simulation of the car. This code will be based on code developed last year. The results of these simulations will be used to compare energy accumulators as well as the optimum mode of operation for the engine. This team will then seek to develop an engine controller that is capable of maintaining proper engine operation under various loads. This controller may be constructed from scratch or from a modification to an existing off-the-shelf generator controller. This team will additionally be responsible for the design of any addition controller modules required to manage the power flow between blocks of the car.

Deliverables

By the first progress report, we expect the team to have an initial simulation of car performance. Based on these simulations, we expect this team to have chosen an optimum mode of operation for the engine which is well supported with decision matrices and simulation. By the end of the first term, we expect the team to have built a working throttle controller which is capable of maintaining proper engine operation under varying load conditions. The second term will be used for additional controller design, system redesign, data collection, and refinement. By the end of the second term, we expect a working control system for the vehicle which is not only able to maintain proper operation, but is able to shut down the vehicle under overstress or dangerous conditions. We expect full documentation on data collection, algorithm development, and controller implementation. Construction must be robust and professional; signals need to be provided to other systems in the car.

Required Facilities

- CAD - Cadence, SIMetrix, MATLAB
- Electrical - Standard lab facilities
- Mechanical - Solder station, assembly area

Knowledge Areas Needed for Project

- Machine design
- Control systems
- Analog electronics

- Digital electronics
- Signal processing
- Computer engineering
- Product design
- Engineering graphics (CAD/CAM)
- Project management

Proprietary Information and Confidentiality Requirements

- None