American Society for Engineering Education
2005 Illinois-Indiana Sectional Conference

Friday and Saturday, April 1 – 2, 2005

NORTHERN ILLINOIS UNIVERSITY

Student Poster Session Abstracts

ROSE-HULMAN INSTITUTE OF TECHNOLOGY: HAWTHORN PARK ENHANCEMENT PROJECT

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OVERVIEW

This project involves designing several enhancements for Hawthorn Park, located in Terre Haute, Indiana. The enhancements include a dam hazard classification assessment, slope stability analysis, and a bike trail connection. The project was submitted by the Vigo County Park and Recreation Department. The project is based within a fictitious company, "Three Point Consulting", to provide a real world experience before graduation. Within the framework of this company, project requirements are provided and schedules developed.

The structure of the team consists of members with varying areas of interest. The project encompasses several areas of civil engineering which include the disciplines of water resources, geotechnical, and transportation engineering. The project consists of many challenges, including the constraints of state regulations and the interaction of group members.

HAZARD CLASSIFICATION ASSESSMENT

The purpose of the hazard classification assessment is to examine the conditions surrounding Burns Lake and the dam that contains it. Burns Lake dam is currently classified as a high hazard dam and thus must be inspected every two years by a licensed civil engineer at the expense of the owner. The Vigo County Park and Recreation Department would like the hazard classification investigated to determine if a lower classification is appropriate. The primary focus of the hazard classification assessment is ensuring the safety of the public. The secondary focus is the determination of the affected areas in the event of a dam failure.

SLOPE STABILITY ANALYSIS

The purpose of the slope stability analysis is to investigate the stability of the dam under different conditions. The analysis consists of performing a subsurface soil investigation and then performing a stability analysis using a computer model. The stability analysis is performed using the XSTABL computer program. The analysis is performed under two separate conditions, at normal (constant) lake level conditions and during rapid drawdown. Data taken from the subsurface investigation is input into XSTABL and a model of the dam is created. The computer model then calculates the critical slip plane and then calculates a factor of safety. The stability of the dam can be ascertained from the level of the factor of safety.

TRAIL CONNECTION

The purpose of the trail design is to connect an existing bike trail, which runs along the south side of Hawthorn Park, to Tupelo Shelter within Hawthorn Park. The trail connection will make restroom facilities available which are currently absent along the trail. There are several considerations when designing the trail connection including alignment, slope, impact to the surrounding environment, and safety of trail users. Other considerations include following the guidelines set forth by the American Association of State Highway Transportation Officials for developing bicycle facilities.

TEAM STRUCTURE

The fictitious company, "Three Point Consulting", consists of four senior civil engineering students from Rose-Hulman Institute of Technology. A list of potential design projects was presented to the senior civil engineering students at the beginning of the year. The students were asked to rank the projects according to their preferences. The projects were then divided up among seven teams of four members. Andy Bolyard is heading up the water resources portion of the design, Dan Conley is focusing on the hazard classification system, Eric Diehl is designing the trail connection, and Jon Keim is performing the slope stability analysis.

Fuzzy Logic Control of a Magnetic Suspension System using xPC Target

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Controls is a large area of electrical engineering research with applications ranging from temperature regulation systems with response times measured in minutes to high-precision high speed applications requiring minute corrections every microsecond. However, some problems defy conventional control approaches. Systems with high degrees of nonlinearity require linear approximations which are not valid outside of a small operating region. Unstable systems prove difficult to evaluate and model. Parameter changes in a given system often render a controller less effective or even cause the system to become unstable. Advanced control techniques are required to effectively control these difficult systems. Fuzzy logic is one such technique. The magnetic suspension system is an example of an unstable, nonlinear, and time-varying plant. The goals of this project are to design a fuzzy logic controller and implement it using Simulink and the xPC Target Box to suspend a 21g hollow steel ball at a desired equilibrium position and track reference position signals.

Fuzzy logic is a system of logic that works with non-absolute values. Conventional logic only uses zero and one, fuzzy logic uses all values in between. Inputs to the fuzzy logic system are 'fuzzified' through membership functions. These membership functions are each assigned a linguistic definition. For instance, there are two inputs to the fuzzy logic controller for the magnetic suspension system: error and change in error. The linguistic definitions 'large' could be applied to the error input if it lies within a certain range. The membership functions output the level of certainty that the linguistic definition applies to that input. The next step is to use rules to determine an output. Rules follow the form "If *input 1* is *linguistic definition 1* and *input 2* is *linguistic definition 2*, then *output* is *linguistic definition 3*". The rules assign a certainty value to an output membership function, which is associated with the third linguistic definition. The output membership function represents an output value. The final output of the system will be the sum of the product of the output membership function values and their certainties.

The xPC Target is a 200MHz PC outfitted with A/D and D/A converters. A model of the fuzzy logic controller is created in Simulink, and is compiled to C code for use on the xPC. The position error signal from the magnetic suspension system is taken through the A/D converter and the change in error is computed on the xPC for use by the fuzzy logic controller. The fuzzy logic controller takes these input values, and determines the correction needed, which is converted through the D/A, and applied to the plant.

Several techniques exist for creating fuzzy logic controllers. The simplest methods attempt to mimic the behavior of human operators, whether by interviewing them to get the information, or by collecting data of inputs versus operator commands. In the case of the magnetic suspension plant, however, such information is not immediately available due to the fact that no human operator can hope to stabilize and control the plant given the reaction times involved. Through observation of the system and behavior of previous controllers implemented for this system, several iterations of fuzzy logic controllers were created to attempt to stabilize the system. The current fuzzy logic controller uses seven input membership functions for the error input, five for change in error, and five output membership functions, with a total of thirty-five rules. When this controller was tested on the magnetic suspension system using a 0.5Hz, 0.5V peak to peak square wave as a reference position input signal, the steel ball tracked the reference position square wave signal with an average steady state error of 50mV, overshoot of 18%, and settling time of approximately 60ms. By comparison, using the previous conventional classical digital controller, the steel ball tracked the same reference position waveform with zero steady state error, 32% overshoot, and settling time of 550ms. The fuzzy logic controller is capable of tracking 0.5V peak to peak square waves with maximum frequency of 1Hz. When the input frequency is limited to 0.5Hz, the steel ball can track a 0.8V peak to peak square wave. In the future, an integrator will be added to the fuzzy logic controller to reduce the steady state error to zero, and the overshoot, settling time and will be minimized by further tuning of the fuzzy logic controller rules.

REVERSE ENGINEERING: SOLID MODEL OF A TWO-CYCLE GAS WEED TRIMMER

Brandon Harville and Nick Metzger
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OVERVIEW

This project deals with using the concept of Reverse engineering on a two-cycle gas weed trimmer in the context of developing an effective teaching tool for engineering design education. The methodology has been implemented as a hands-on project in Indiana University Purdue University Indianapolis' (IUPUI) freshman course ENGR 196, "Introduction to Engineering".

The purpose of this approach is to provide students with: (1) real life hands-on projects as introduction to Engineering; (2) motivation to pursue Engineering; (3) tools to effectively function in team settings; (3) immediate application of Computer Aided Design (CAD) software; (4) opportunity to interact with student mentors.

The significance of the project is: (1) using Reverse engineering as a systematic approach for engineering design education and application; (2) using Reverse engineering to introduce students to the notion of "evolutionary product design" based on the reuse of existing design information. Many companies practice this design process as a cost- and time-effective way of introducing new products to the market.

This project is designed to impact retention efforts in three ways, namely, interest in engineering and "community building" through team interactions. Involving students in hands-on projects is known to create interest and excitement for the field of engineering. Encouraging students to work in teams will lead them to build "design" communities that they can also participate in outside the class. Involving student mentors in the project will provide the freshman students with additional role models besides faculty.

Engineering concepts introduced to students in the project are, reverse engineering, solid modeling, generation of fabrication drawings and team work.

REVERSE ENGINEERING

The purpose of the freshman reverse engineering project is to provide future engineers with hands-on experience on how machines work by systematically taking them apart. They also learn valuable teamwork skills and get to meet people they might otherwise not get to talk to, while exploring the Pro/Engineer Computer Aided Design software. Students apply what is learnt in ENGR 196, to a real machine. The main sections of project were, (1) Preparation for teardown, (2) Disassembly & Measurements, (3) Documentation, (4) Reassembly, (5) Project report & CAD drawing generation.

PRO/ENGINEER SOLID MODELING

Pro/Engineer was used to create a working solid model of the weed trimmer including as much detail as possible. Modeling considerations included not only the main structure of the weed trimmer but also numerous subassemblies such as the engine, cutting head, boom, handle and throttle. The model was limited to parts that could be accessed without destroying the trimmer. The model of the cutting head and engine include all the major parts of the trimmer e.g. head, cylinder, rockers, sparkplug, spool, and drive shaft. Examples of things that could not be accessed included the bearings, embedded electrical components, and the parts inside the carburetor.

TEAM STRUCTURE

When this project began the team consisted of Nick Metzger, Brandon Harville, Josh Hawley, John Storer, and Imran Ahmed from Freshman Engineering Course ENGR 196. The tasks of the group were divided as follows: Nick, Brandon headed the design and modeling. Imran and Josh handled the disassembly, and documentation. John created the power point presentation as well as any visual aids. At the end of the course Brandon Harville and Nick Metzger picked up where the group had left off and developed the final Pro/Engineer solid models.

ENGINEERING COURAGE: FROM "NOT MY BUSINESS" TO POSITIVE RESPONSIBILITY

Golnaz Hashemian

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How does a course on engineering ethics affect an undergraduate student's feelings of responsibility and decisions about ethical problems? In this study, we interviewed six students who had taken a course on engineering ethics and six who had not. An equal number of male and female students were interviewed, all with a variety of technical experience levels. General questions about the qualities and characteristics of a professional engineer gave us a better understanding of a student's values and expectations from a career in engineering.

We asked the students what they would do as participants in two short scenarios that posed ethical problems. The first scenario involved a miscalculation of salaries; the second scenario involved a potential safety hazard. For each scenario, we successively increased the level of seriousness and asked how each change altered the students' decisions.

Students who had taken the ethics course were more comfortable with the scenarios, and they considered more options before making a decision. They were also more likely to maintain consistency in their responses regardless of the changes in the scenarios. For both scenarios, even when they were not directly involved, they were more likely to feel responsible and take corrective action.

Students who were less successful in the ethics course gave answers similar to students who had not taken the course. This latter group of students seemed to have weaker feelings of responsibility: they would say that a problem was "not my business."

It appears that instruction in ethics increases awareness of responsibility, knowledge about how to handle a difficult situation, and confidence in taking action.

DEVELOPMENT OF A COMBUSTION CHEMISTRY SIMULATOR USING EXCEL AND MATLAB

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OVERVIEW

Detailed combustion chemistry models have been formulated in recent years to assist in the development of new technologies for engines, power plants, fuels, and related technologies. These models have been of limited value, however, due to the complexities of numerically integrating the chemical kinetic equations. While some commercial software packages have emerged to address this computational issue, combustion chemistry models have not achieved the status of an engineering tool because of this problem.

THE MODEL

An engineering simulation tool has been developed for the analysis of detailed combustion chemistry. The framework of the simulator consists of an Excel/Visual Basic for Applications (VBA) interface that dispatches the problem specifications to Matlab where the coupled species and energy balance equations are solved. Excel also serves as the database for kinetic and thermochemical properties. The graphical post-processing of the simulation results is facilitated by the incorporation of a third party ActiveX control called Flipper Graph that is integrated directly into the VBA code.

The combustion chemistry model is applicable to mechanisms involving elementary gas phase reactions where the gas is assumed to be ideal. The computational methodology is conceptually based on the industry standard CHEMKIN format. The model accepts input in the form of a stoichiometric matrix, associated kinetic parameters for the forward reactions, and thermochemical properties. Reverse rate constants are determined using the supplied forward rate constants and computed reaction equilibrium constants.

COMPARISON TO EXPERIMENTAL DATA

The usefulness of the simulation tools has been demonstrated using a recently published reduced mechanism for the combustion of methane in fuel-lean gas mixtures. This is a type mechanism that includes the minimum number of steps to describe the basic characteristics of the combustion system. Preliminary results have shown the predicted auto-ignition delay times to be within the margin of error for experimental values from shock tube experiments.

THE DESIGN OF A FIRE TRAINING TOWER AND PUMP TEST PIT FOR THE GREENCASTLE, INDIANA FIRE DEPARTMENT

Jason Lange, Jeffery Poole, Todd Wallace and Michelle Woodward

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Overview

This project involves the design of new training and testing facilities for the Greencastle Fire Department, located 30 miles west of Indianapolis. The Department would like a two-story training tower that firefighters could use during the year to practice fire extinguishing drills and rescue situations. Included in this tower would be a burn room, capable of housing contained fires, a basement rescue apparatus consisting of a hole in the floor between stories and a second floor room with walls that can be moved to create additional obstacles for training. This tower would be marketable to other fire departments in the area and would result in increased competence of the area's firefighters.

The Department would also like to have an underground water storage pit on the same site as the fire training tower. Currently, in order to test the capacity of their truck's water nozzles, they have to pump water from ponds and quarries. A water storage pit would allow the Department, and other nearby stations, to test nozzles and hoses on site.

Team Structure

The team consists of four civil engineering students from the Rose-Hulman Institute of Technology. At the beginning of the academic year, the senior civil engineering students were given a list of potential projects and were asked to rank them according to order of interest. Based on these rankings, faculty created seven teams of four members. Jason Lange and Michelle Woodward focused on the structural design and member selection for the fire training tower. Jeffery Poole is the primary designer for the tower's foundation. Todd Wallace's concentration in the project is design of the underground pump test pit.

Preliminary Site Investigation

Preliminary site investigations included a site survey, building envelope and geotechnical investigation. The geotechnical investigation of the site revealed that the water table is high, the soil is compactable and the bearing capacity is 3500 psf (pounds per square foot). There were no restrictions to the use of the site other those created by the burn room. According to the Indiana Administrative Code, the fire in the burn room is considered an open burn and this would affect the placement of the tower on the site.

Fire Training Tower

Based on the design requirements given by the Greencastle Fire Department, a complete design layout of the steel fire training tower was completed. Steel was chosen for its reusability, ability to withstand a certain level of heat and ease of construction. The layout includes a burn room, a storage room, an interior staircase to the second floor, and the inclusion of several training drills. The burn required research of commercially available insulating panels that can withstand flames and high temperatures. Using the layout, a bracing plan was developed taking into consideration the placement of doors, windows and other obstacles. A structural analysis of the tower resulted in forces and moments on all members and the adequacy of the design for the tower. Finally, steel member sizes were chosen using these forces.

Pump Test Pit

The pump test pit is designed to consider the heating of the water due to the pump, the speed of water exiting the nozzles, the removal of debris from the water and the ability to remove any air entrained in the pump. The pit is an underground storage chamber made of cast-in-place concrete. It has been designed to limit turbulence of water entering the intake hose. The aspect of the pump test pit that most governed the sizing of the pit was the amount of water needed to control the temperature of the pump. This was larger than expected and resulted in a much larger pump test pit. The turbulence from the returning water will have very little effect on the pump as long as all the air that is possibly entrained can be removed prior to the intake. Also, because the buoyancy of the groundwater could cause the pit to "float", extra precautions, such as widening the floor of the pit beyond the walls, were taken to prevent this from happening.

NEW OFFICE STUDIO AND SITE DEVOLOPEMNT FOR BAKER ARCHITECTS

Darrin Lowe, Andy Mullis, Eric Munchel and Scott Tourville

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OVERVIEW

This project involves designing a new office studio for Harold Baker III, a Terre Haute Architect. A four member team was created for the site analysis, site design and building design. A fictitious company, "ARCHINEERING", was created to help provide real world experience with the project. The team members acted as company employees and created scheduled, divided tasks, and meet with faculty mentors to complete the design.

The four seniors functioned as a multi-disciplinary team. Some members focused primarily on architectural work and modeling, while others focused on site and structural designs. This project presented many challenges, such as working with a real client, following design codes and meeting deadlines.

SITE DESIGN

The site design presents several interesting challenges. Mr. Baker's residence is on the site, and he has requested that the new building work well with the existing house. He has also requested that the new building span a ravine on the site, with guest parking on the south side of the ravine, a pedestrian bridge crossing approximately 80' over the 17' deep ravine, to the front entrance at the north of the building. The site also contains an employee drive, parking lot and entrance into the building.

The site was analyzed for flood concerns and soil type. The site was found to have no flooding issues, and the soil will not present any additional design challenges. To utilize the site, a retaining wall was designed, and a survey was performed so that as many trees as possible could be saved. The site has been utilized to meet all of the client's requests.

STRUCTURAL/ARCHITECTURAL DESIGN

The client has specified a truss/roof support system that he wishes to use, based on his architectural ideas. The client specified shape and materials for the truss, and the team was able to analyze the truss and size the members, connections and support system. The client requested that the truss/roof system have an attached cable-stayed system to create desired architectural effects. He has requested that the cables also have a outdoor cloth draped over them to cover the parking lot, and that vehicles be able to drive/park under the cables.

The pedestrian bridge was also designed as a cable-stayed system, and will blend in with the building. The architectural design process was assisted by the client, and began with the creation of a site model. Multiple building models, small and to scale were created to see how they matched the site and residence. After several options were considered, a multi-curved building was selected by the client.

TEAM STRUCTURE

The team consists of four senior civil engineering majors. Andy Mullis and Scott Tourville were responsible for all of the structural analysis, and were assisted by Eric Munchel and Darrin Lowe. Darrin was in charge of site design, and was assisted by Scott and Eric. Eric was in charge of architectural design and modeling, and was assisted by Andy. Scott served as the client liaison, throughout the project, while also taking time as project manager and editor. Andy served as editor, then manager, while Eric and Darrin teamed up to be manager and editor for the last academic term. Members rotated roles for academic purposes.

Returning a Karr Column to Student Use

Jennifer R. Lowe and Scott D. Noblitt

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A Karr reciprocating-plate column can be used for liquid-liquid extraction experiments; however, the Rose-Hulman Institute of Technology Karr column has been unused for many years because of a lack of a suitable ternary system. Our goal was to bring the Karr column project back into regular use to enhance the variety of projects available in the undergraduate chemical engineering laboratory. Previous work was done, and a system of 1-octanol, ethanol, and water was selected. In order to make the Karr column a regular experiment in the unit operations laboratory, a number of elements needed to be put in place. The ternary system had to be tested in the Karr column to see if it produced an acceptable extraction. A distillation system to purify the 1-octanol from the top product had to be designed. Finally, an analysis method using gas chromatography (GC) was needed to determine the composition of the extraction and distillation products.

Two trials were performed with the Karr column under different operating conditions to determine the required time to reach steady state, the product compositions at steady state, and quality of the separation achieved. The heavy feed contained 16.2 wt% ethanol for both trials. One trial was conducted at a reciprocation rate of 75 strokes/min with an overall composition of 33.5% octanol, 10.8% ethanol, and 55.7% water. The extraction appeared to be approaching steady state at 90 min. The bottom product contained 9.4% ethanol. The second trial was performed at a reciprocation rate of 99 strokes/min with an overall composition of 44.1% octanol, 9.0% ethanol, and 46.7% water. This trial appeared to be approaching steady state at 165 min. The bottom product contained 6.9% ethanol. Thus, both trials extracted ethanol from the water, but the second was more effective at transferring ethanol to the octanol-rich phase. Both trials took significant periods of time, and the first did not definitively reach steady state.

Two bench-top distillation apparatuses were used to separate the water and ethanol from octanol. Both simple and fractional distillations were tested. The fractional distillation proved to be too time-consuming, as it often took two hours to fully heat the column before any distillate was ever collected. Simple distillation proved to be acceptable, as it was able to provide 2.5L of octanol product that was more than 99% pure in a single laboratory period.

A GC method to analyze the Karr column trials was developed based upon several single-component standards. A variety of columns were considered for use, including the 10% OV-101 Chromosorb W-HP 80/100, 6' X 1/8" X 0.085" SS column and the AllTech Poropak T 80/100, 6' X 1/8" X 0.085" SS column. The Poropak T column was decided upon because it could resolve the water, ethanol, and the denaturing agents in the ethanol easily. Unfortunately, the column's maximum temperature is below the boiling point of octanol, making the elution of octanol time-consuming and requiring manual integration to determine the amount of octanol present. The GC was found to be useable, but it would be more practical if another column or system was used.

The ternary system of 1-octanol, ethanol, and water can be used in the Karr column if two 5L simple distillation apparatuses are acquired. There would still be difficulty in ascertaining the amount of octanol in solutions, and very few trials could be taken to steady state in five laboratory periods. Changing ternary systems to replace ethanol with 1-propanol would allow the Chromosorb column to be used in the GC, which would give a more short elution time for the octanol. The propanol would also be free of denaturing components, making it a true ternary system. To conclude, while the Karr column can be used again, there are still improvements to be made before the project can be implemented as an experiment in the undergraduate unit operations laboratory.

THE EFFECT OF ELEVATED TEMPERATURE ON ELASTIC AND VISCOELASTIC PROPERTIES OF HYDRATED CEMENT

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ABSTRACT

Although concrete has a well-deserved reputation for good fire resistance, it can lose 70-80% of its strength after exposure to just 500°C, such as during a fire in a reinforced concrete building. This strength loss is accompanied by a measurable decrease in the Young's modulus. This loss in strength and stiffness can undermine the structural integrity as well as indirectly cause the reinforced concrete member to be over-reinforced, condition that allows the structural member to fail in a sudden, explosive manner. The primary reactive component of concrete that degrades at high temperature is the hydrated cement. The objective of this study is to develop a better understanding of the degradation in the stiffness and the change in the viscoelastic properties, two very important parameters in design, of cement paste. Samples of cement paste at various water-cement ratios and percentages of mineral admixtures were prepared and cut into plates. These samples were tested in oscillatory bending using a dynamic mechanical analyzer to measure the Young's modulus for the change in stiffness and tan δ for the change in viscoelastic behavior between room temperature and 500°C. To complement these results, companion samples were tested in a thermogravimetric analyzer using the same temperature profile and gas flow rate to identify the decomposition of the various different hydrates. The results show that certain mixtures are more susceptible to high temperature degradation. The Young's modulus typically dropped by over 60% and most of the drop occurred before 200°C. Since 200°C is the lower bound temperature for the decomposition of calcium silicate hydrate as shown by the thermogravimetric analysis results, the decrease in Young's modulus must be primarily due to microcracking caused by evaporation of water from the capillary pores. The sensitivity of the loss in stiffness is dependent on the quantity of mineral additives. As for the viscoelastic properties, tan δ typically decreases to negligible values at a little over 200°C and increases again at higher temperatures. This indicates a change in the mechanism that governs creep from low temperature to high temperature. These results will allow strategic upscaling of the experimental study to apply directly to concrete.

PURDUE UNIVERSITY ECE 496 ASIC DESIGN PROJECT: PROGRAMMABLE FINITE IMPULSE RESPONSE (FIR) FILTER

Andrew Penner, Jeffrey Hall, Lindsey Hall, Nakul Jeirath, Omar Shaikh

Faculty Advisor: Professor Mark Johnson

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OVERVIEW

This project involves the complete design, layout, and fabrication of a packaged IC to implement a digital programmable finite impulse response (FIR) filter. The design team is challenged with the selection of the design project, development of the device architecture, VHDL source design, synthesis, placement and routing of the IC components, final design generation, and testing at each stage of the process. The chip will be manufactured by the MOSIS Service at no charge for educational purposes. The project also involves implementing an FPGA edition of the design for demonstration and testing. Completion of the final solution involves the development of a multi-layer printed circuit board (PCB), test application for the design, and demonstration of the finished working project. The major challenges presented by this project include the development of an efficient architecture subject to timing and area constraints, and modification of existing software tools to perform the various stages of the IC design flow. VHDL source code, synthesized netlists, VHDL test benches, and a MATLAB ™ simulation model are complete. Layout and physical verification are in progress.

TECHNICAL SPECIFICATIONS

The purpose of designing a programmable FIR filter is to create a chip (IC) to perform, in real-time, various digital audio and signal processing applications. The pipelined architecture is designed to allow the user to re-load coefficients to change filter characteristics without interruption in processing. Using a 0.5 micron technology, the design is predicted to execute a 64 tap filter function with 16 bit signal data at a sample of at least 500 KHz. The 16 bit inputs and outputs are received via a 16 bit ADC and a 16 bit DAC, respectively. Filter coefficients and waveform samples are externally multiplexed into the chip via a 16 bit input bus. An output control signal from the chip sets the state of the multiplexer thus signaling that the current input is either coefficients or data. The design uses an ASIC cell library developed by Johannes Grad and Prof. James Stine at the Illinois Institute of Technology, Chicago, IL.

TEAM STRUCTURE & COMPOSITION

The design team consists of five seniors majoring in Computer Engineering, all with extensive design experience. Each member of the team contributes equally to the overall completion of the design as various tasks are distributed on a weekly basis. Each week, the team meets to discuss design issues, evaluate the current progress of the design, and to distribute new tasks and duties. Andrew Penner and Nakul Jeirath are the system architects. Omar Shaikh developed much of the pipeline VHDL code. Jeffrey Hall has performed major software scripting and design efforts to streamline the design process and ensure adequate testing and development to the specifications required by the MOSIS Service. Lindsey Hall works with the implementation of the design, FPGA model development, final testing of the completed product following fabrication, and the design and development of a populated PCB to demonstrate the final working product. The team advisor is Dr. Mark C. Johnson, Manager of Digital and Systems Laboratories, School Electrical and Computer Engineering, Purdue University, West Lafayette, IN.

SENSING WITHOUT SENSORS: INFORMATION HARVESTING FROM SIGNAL STRENGTH MEASUREMENTS

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OVERVIEW

A traditional problem with wireless communications is the phenomenon of fading which is normally considered a negative trait whose impact should be minimized. This research takes the opposite standpoint. It shows that fading can be used constructively to extract meaningful information, such as motion in the environment, from regular RF signals since changes in the surrounding environment affect the level of fading. Such a method of motion detection has several advantages: (1) any wireless network can become a sensor network, (2) it is highly effective in preserving battery life in sensor networks, (3) it reduces hardware cost since actual sensors are not necessary.

The reason why any wireless network can be transformed into a sensor network is that wireless transceivers are generally capable of measuring the strength of a received signal. Motion of individuals or objects in the vicinities of these transceivers produces shadowing and multipath fading effects which alter the received signal strength and allow for detection. As an example, an 802.11-based wireless network can be used to log the signal strength variations in a particular environment. Users could simply leave their wireless network on and later refer to the signal strength log to extract motion-related information betraying a particular kind of activity. Parents coming back home after an evening out could see if their children took advantage of their absence, and burglary victims could determine when an intrusion took place.

DESIGN CONSIDERATIONS

Design considerations include discriminating between noise and interference and an actual motion event. The system should be adaptive to various topologies and must therefore calibrate a separating threshold between interference and an actual motion event in real time. Since the application is designed to be run on top of another main level program, onboard processing power is limited; the algorithm should therefore be relatively simple and consume little of the available processing power so as to effectively run in the background. The program should also be capable of relaying any detected motion to a base station which makes the information available visually with an LED as well as with a log on a PC. In addition the transmit power and rate must be set in such a way as to allow for maximum sensitivity without triggering false detections.

EXPERIMENTAL RESULTS

In our research, we successfully implemented a motion detector using signal strength variations between two nodes on a wireless sensor network. The detection information is relayed to a base station which is connected to a gateway that bridges our wireless network with a PC. The developed algorithm allows for reliable motion detection using new TinyOS modules on the Mica2 platform. The Mica2 platform is a class of Berkeley wireless network nodes on which an open source operating system called TinyOS is running. The developed algorithm only consumes a small fraction of the rather limited processing power of the mote.

One scenario used repeatedly was for a person walking through a door. In this scenario it was common to see a drop in received signal strength of at least 10dB and, in some cases involving lower transmit power (-10dBm), the fading could be so severe as to cause the signal to drop below the noise floor which is at about -105dBm. The detection of motion through a door was very reliable while the probability of detection in a more open space such as a field was slightly reduced due to less severe fading.

Future research includes extracting more information from these signal variations than just motion detection. For example, it should be possible to say something about the speed of an object, its direction of motion, as well as its size. This method could also be used to distinguish between motion of the motes themselves and motion in the surrounding environment.

Modeling Human Perception

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This research involves the analysis of how well the outcome of human auditory experiments can be predicted by modeling human perception. The overall approach of this research is to statistically compare human perception scores (estimated using computer-based models) to actual experimental data. The end goal is to quantitatively estimate human perception scores between individual speech sounds (phonemes), with the eventual clinical use of these models in refining prosthetic technology such as cochlear implants. The research team consisted of Thomas A. Werne, who volunteered his time to develop most of the software, N. Ellen Taylor, who collected data from normal-hearing subjects and statistically analyzed the data for course credit in directed research, and Dr. J. Brandon Laflen, who advised both students.

The experimental data used to analyze the modeled perceptual difference scores consists of phoneme confusion scores of normal-hearing (NH) subjects during their initial exposure to a cochlear implant (CI) simulator and CI users at 1 year post-implantation. The cochlear implant simulator attempts to model the perception of CI users by filtering an acoustic signal into different bands, modulating it with white noise, and then modulating it with sinusoids to simulate the location of the electrode array inside the cochlea because the location of stimulation in the cochlea is related to the frequency of the acoustic signal. An 8-channel CI simulator configured to mimic a 0 or 6mm shift of an implant inside the cochlea from the apex was used for this experiment. For both simulator and actual CI testing, subjects were presented with distorted phonemes in a pseudo-random order, and chose what they perceived from a list of nine possible phonemes. The data collected from NH and CI listeners is arranged in confusion matrices to compare what phoneme was perceived along the columns to what was actually presented along the rows. A high number in the non-diagonal entries in the matrix represents a high rate of confusion between the sound presented and the sound perceived by the listener, and a low number represents a low rate of confusion.

The first step in modeling the outcome of this experiment is to generate neural activation patterns (NAPs) of the original phonemes as well as the 0 and 6mm simulator sounds using the auditory nerve model of Heinz et al (ARLO, 2001). These NAPs store an estimation of the potential of neural activity in the auditory nerve as a function of time and the location along the cochlea. A difference between two NAPs represents the potential for a difference in perception between the sounds the NAPs represent.

Perceptual difference metrics (PDMs) (Laflen, 2003) in conjunction with dynamic time warping (DTW) are used to measure the differences between NAPs. PDMs quantify the difference in human perception between two NAPs. A high perceptual difference score between two NAPs should correlate with a large perceived difference between the two sounds the NAPs represent. DTW allows the PDM to search the NAPs from stimuli of different time-lengths for the lowest possible perceptual difference. It does this by warping the relative timing so that parts of the stimuli that are most similar are aligned temporally. In essence, this estimates the floor of possible estimated perceptual differences. These perceptual difference scores are stored in a matrix structure similar to the confusion matrices of the actual human data. However, unlike in the confusion matrices of the human data where a higher number in a cell represents a higher rate of confusion between two sounds, it is theorized that a higher perceptual difference score corresponds to a lower probability of confusion between two sounds.

The matrices generated by the collection of human data and through the generation of NAPs and the use of DTW are compared to each other using a correlation coefficient. Since the perceptual difference scores are inversely related to human scores, there should be an inverse correlation, and therefore a negative correlation coefficient. Preliminary results indicate a strong inverse correlation between actual CI user data and computer-modeled perceptual differences comparing NAPs of both 0 and 6mm simulator sounds to each other. A high positive correlation coefficient was indicated between actual CI user data and experimental 0mm simulator data, suggesting a direct relationship between CI and 0mm simulator users.

POLYGLYCOLIC ACID MODIFIED MICROELECTRODE FOR IMPROVED IMPLANTABILITY

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INTRODUCTION

When a neuron is damaged a person may lose some physical functions associated with that neuron. In the future, neural implants may provide a way for doctors to help re-establish lost functions. Such a system might one day be useful for aiding persons with deafness or blindness. Implantable electrode systems for humans present bioengineers with a variety of design problems ranging from biomaterial selection, appropriate stimulation waveforms and choice of the geometrical shape of the stimulating neural probe. In recent times, bioengineers have developed microelectrodes small enough to be implanted, but these devices are often mechanically stiff while the brain itself is relatively soft. This may be the cause of implant failure (in animal tests) because stiff electrodes do not move well in the 'soft' brain tissue. The use of flexible polyimide microelectrodes has been proposed to help reduce electrode failures due to stiffness. However, polyimide causes problems because the material is not stiff enough to be implanted through the tough covering tissue of the brain. One solution to this problem is to temporarily stiffen a flexible electrode by coating electrodes with biocompatible polyglycolic acid (PGA). PGA is a solid at room temperature and thus would allow the electrode to maintain stiffness during implantation. Once implanted, PGA biodegrades leaving the flexible electrode to move freely along with the brain. The main purpose of the project is to develop and characterize a PGA coating technique for temporarily adding stiffness to polyimide microelectrodes.

METHODS

PGA biodegradability testing: The biodegradation rate of PGA was assessed by using 0.0028 gram samples of PGA, from Dupont. Samples were tested by placing them into 5ml volumes of: water, saline, NaOH, and cell media. Samples soaked for a period of 2 weeks. Applying PGA onto polyimide electrodes: 1g of powdered PGA was heated to 210 °C, melting temperature of PGA. Polyimide electrodes were hand-dipped into the melted PGA to create an exterior coating. Thickness measurements were made with a micrometer. pH testing: 2 (0.0028g) cubes of PGA samples were used. One was placed into 5ml of water and the other was placed into 5ml of cell media. The pH measuring probe was used to measure pH every 10min for 1hr to monitor the pH change. Force testing: Four PGA coated electrode were tested to determine the approximate force needed for penetrating through the surface of the brain membrane. Electrodes with different numbers of shaft ranging from 1 to 6 were tested on agar samples of different concentration (and thus different mechanical properties) ranging from 1%-4%. Forces were determined by using a micromanipulator to slowly lower the electrodes into the agar placed into a dish on a digital scale. The measurements were in grams, and later converted into Newtons.

RESULTS

Two week testing showed that PGA dissolved (<10% remaining) in both water and saline. It was 100% dissolved within 2hrs in NaOH and >90% dissolved in neural cell media. While dissolving, the local pH is raised by at most 1 unit and the average pH was about 7.5. By analogy, knowing the pH range of dissolving PGA allows us to conclude that PGA would not likely be harmful (chemically) when placed in 5ml of brain volume. Furthermore, we need to find a way that allowed us to apply PGA onto the electrodes evenly and consistently. Electrodes coated with a layer of PGA (~0.48mm) showed improvements in physical performance. The electrode no longer buckles easily, and the electrode penetrates easily when inserted into a 3% agar gel. The results from the force testing showed that as the number of electrode shafts increased and as the agar percentage increased, the greater the force needed for penetration. For example a single shaft electrode requires 0.254N, 0.4508N, 0.740N in 1%, 2%, 3% agar respectively. At 4% agar the electrode was not able to penetrate. In future experiments, we will implant electrodes *in vivo* and then compare the neural recordings of coated electrodes with those taken from the previous stiff electrodes. We should then be able to make assessment on which kind of electrode and implantation techniques leads to long term electrode improvements.