CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Jamil Ahmad; Moaaz Akbar

Project Number

S1001

Project Title

Frontiers of 5G: Sparse Adaptive Battery-less Ambient Backscatter Communication Networks

Abstract

Objectives

This research project explores the interconnected schemes of ultra-low power ambient backscatter to function as the basis of the next generation of telecommunications technology integration, namely, globalizing Internet of Things (IoT) networks in next-generation 5G networks . However, current telecommunication schemes suffer from connectivity and complexity issues as a result of these highly-overloaded, highly connected networks. Because of this, a novel network structure is developed to facilitate the communication of high-user battery-less ambient backscatter devices. A physical and link layer network structure is devised with the key objectives of minimizing power backscatter-device power consumption and Bit Error Rate (BER) while maximizing network throughput and connectivity among a large population of backscatter devices. This network was then evaluated for accuracy by Monte Carlo simulation of Bit Error Rate optimizing parameters of the network structure compared to current schemes of telecommunications. Finally a theoretical and experimental investigation of this backscatter system as battery-less implant devices in an signal-constrained environment to enable implant longevity without the risks and expense of traditional battery-implants.

Methods

A novel implementation of this signal network was developed using MATLAB and bash/packet sniffer scripts on Raspberry Pi computers integrated with a Software-Defined Radio. We also devise open-form theoretical and Monte Carlo simulations of our project using MATLAB. We use Wireshark, a packet sniffing software, to detect incoming packets from a demonstrated receiver to client network pathway (using a wireless AP and a client laptop). Moreover, Fusion 360 was used to design the backscatter tag 3D model (tailored for an implant environment), as well as Autodesk tools to design electrical circuits and diagrams.

Results

We successfully devise a novel network structure to facilitate resource-constrained, high-user ambient backscatter communication. We simulate various orders of signal modulation relative to changes in Additive White Gaussian Noise (AWGN) replicating real-world conditions to quantify the most effective modulation order for our network. Through cluster analysis of Constellation Plots of various orders, the most effective modulation was deemed the Quadrature Phase Shift Keying Scheme. Overall, thorough Monte Carlo analysis highlights that the novel network had significantly lower Bit Error Rate relative to changes in Signal to Noise Ratio (SNR) compared to traditional time-dividing, code-division multiple access schemes used in state-of-the-art telecommunications schemes. We also quantify the benefits of the network system in

Summary Statement

We develop a new type of communication network for highly connected, battery-less interfaces that is much more effective than state-of-the-art telecommunications methods and effective in specific application environments

Help Received

No direct help was received by any institution or professional scientist and engineer. We met with our science fair advisor to occasionally discuss the broad direction of our research.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Akash Anand

Project Number

S1002

Project Title

Optimal Phased Array Antenna Systems for Radio Astronomy

Abstract

Objectives

Collecting cosmic data to understand the universe and its beginnings is very time-consuming and expensive. Current radio stations require vast areas of isolated space and expensive hardware which must be manually modified, making the design costly and laborious while simultaneously limiting the number of telescopes to the number of analogue paths and land available. The goal of this project is to develop an innovative system design for radio stations that increases efficiency and optimizes data collection via the creation of a radio station with eight subsystems that each contain 64 phased array receivers.

Methods

The project consisted of two parts: designing efficacious arrangements of antenna arrays and formulating techniques to correlate the subsystems images. For each array, original programs in MATLAB were written to compute both the sidelobe suppression and the Half-Power-Beamwidth (HPBW) angle which determines the selectivity of the array. Subsequently, additional MATLAB programs were created to combine data from each subsystem to generate an image with a greater Signal-to-Noise-Ratio (SNR).

Results

The research discovered that a concentric circle array design produces the greatest sidelobe suppression, increasing the SNR to 44.67 compared to the standard rectangular array which possesses a SNR of 39.61. Furthermore, the other models, a line, circle, triangle, pentagon, modified circle, and spiral, contained SNRs of 19.25, 17.69, 10.51, 17.65, 18.24, and 43.52 respectively. The HPBW of the concentric circle array increased to 0.05783 radians compared to a rectangular array which contains a HPBW of 0.05236 radians. Moreover, the new MATLAB correlation programs increased the SNR from 1.72 to 13.8 when correlating the data from 8 subsystems, decreasing the average noise by approximately 86%.

Conclusions

Compared to the standard rectangular array used by current radio stations, the SNR increase for a concentric circle phased array allows for shorter integration times for data collection at each subsystem. Also, the correlation of images from each phased array subsystem results in much less time needed for the production of a high-resolution image, thereby dramatically diminishing the total time, cost, and power required to produce cosmic images. Thus, the implementation of a concentric circle array design would offer great benefits for modern radio stations.

Summary Statement

I designed an innovative model for radio stations using original phased array design patterns to optimize the cost, efficiency, and area needed to generate high-quality cosmic images.

Help Received

None. I designed the receiver array patterns and developed the MATLAB programs by myself.

Name(s)

Om Anavekar; Tarun Chichili; Arnav Gupta

Project Number

S1003

Project Title

An Intelligent Glove that Converts Hand Gestures and Sign Language Into Spoken Text

Abstract

Objectives

The objective of the experiment is to design and create a glove for people with speech impairments, which can convert hand gestures and basic sign language into spoken text for anyone to understand.

Methods

Key components in this project are the glove equipped with 5 flex sensors, the central PCB housing the electronic components, and the Arduino IDE. The software was developed if the IDE by us. All electronics were designed and assembled by us. The device is tested for 9 specific hand gestures ("A" "B" "C" "D" "E" "F" "No" "I need food" "I need help") over 10 trials by team members. Over each iteration, hardware and software (made by team members) changes are performed to improve hand gesture recognition. Additionally, participants are asked to use the device and provide feedback regarding its improvement.

Results

Each of the different gestures tested had over a 70% success rate. The "C" and the "No" gesture had an 80% success rate and the "B", "D", "E", "F", and "I need food" gestures had a 90% success rate. All gestures were successful for every trial after Trial 6.

Conclusions

The glove proved to work as the accuracy improved over time. This innovative device is groundbreaking and will bridge the communication gap between those who are speech impaired and those who are not. People will no longer have to spend time learning sign language, and those who do not know sign language can communicate with medical staff. With further advancements, grants, and research our group will be able to improve the accuracy of the glove and test more gestures.

Summary Statement

A glove which converts custom hand gestures and sign language to spoken text for those with speech impairments was created and refined, making it efficient and cost-effective.

Help Received

The device, along with its hardware and software components, have been developed by us. School equipment was used to fabricate the device. Additionally, tests including human participants will be conducted at East Bay Post-Acute Healthcare Center.

Name(s)

Akhilesh Balasingam

Project Number

S1004

Project Title

Brain-Inspired Circuitry for the Future of AI: Optimizing the Analog Response of RRAMs Under Pulsing for Synaptic Use

Abstract

Objectives

On tasks such as pattern recognition, the human brain, which consumes 20W of power and takes up 1.5L of space, substantially outperforms artificial intelligence (AI) algorithms running on large clusters of von Neumann (vN) computers. To close this glaring gap, intense research is underway on brain-inspired alternatives to vN. Like the brain, these alternatives capture the computationally-intensive parts of AI algorithms in massively parallel circuitry, interweaving low-power computing and analog memory (synapse) elements.

My research optimizes the analog response of resistive random access memories (RRAMs), to permit their use as synaptic elements in brain-inspired architectures for AI-centric computing. I chose to study non-filamentary (nf) RRAMs, because their conductance can be adjusted in a continuous, or analog, fashion with voltage pulses applied between their 2 terminals.

Methods

Key steps of my research: (a) Write a Kinetic Monte Carlo simulator (KMC), capturing mixed ionic-electronic conduction central to nf-RRAM operation. Model conductance using nonlinear resistor network--apply Kirchhoff's Laws and Newton's Method. (b) Use KMC to study nf-RRAM response under different pulsing schemes. (c) Find pulsing schemes that yield the best synaptic response. (d) Benchmark the system-level accuracy of my synaptic designs in NeuroSim, a neural network simulator.

Results

My contributions: (a) Developed physics-based KMC simulator in Python. (b) Validated KMC by comparing its predictions with published experimental data. (c) Using KMC characterized the synaptic behavior of nf-RRAMs under several pulsing schemes: standard, stepping, hybrid. (d) Standard pulsing yielded the poorest synaptic behavior. (e) Hybrid scheme yielded the most linear/symmetrical synaptic response. (f) Analyzed the system-level behavior of my synapses in NeuroSim and showed that my hybrid scheme yields nearly-ideal learning accuracy.

Conclusions

I studied and optimized the synaptic behavior of nf-RRAMs, using a KMC simulator I developed. Using my simulator, I identified a pulsing scheme that yields synaptic behavior with the desired analog properties of linearity and symmetry, and at the system-level I showed that this scheme yields 90% accuracy, which is very close to the 93% rate achieved by the ideal synapse.

Summary Statement

I developed a hybrid pulsing scheme that allows nf-RRAMs to be used as synapses in massively parallel brain-inspired architectures, which can enable AI to be performed on small IoT (Internet of Things) devices.

Help Received

I developed and performed the simulations and analysis on my own. I would like to thank my mentor for guiding me through the current literature. I would like to thank my school math teacher for helpful discussions and encouragement.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Christopher Caligiuri

Project Number

S1005

Project Title

BrainBot: Multielectrode Data Modeling and Stem-Cell Derived Brain Stimulation through a Real Time Robotics Platform

Abstract

Objectives

Human iPSC-derived brain organoids are human "mini-brains," consisting primarily of the cortex area of the brain and are similar to those of premature babies. As the organoids currently cease development after nine months, this project aims to develop a robust robotic system for interpreting, modeling, and interacting with these brain organoids via a multielectrode array for more mature development of the brain organoid. These combined features constitute a research mechanism that will further scientific studies into developmental biology and critical neurodevelopmental treatment and prevention.

Methods

A quadruped base containing 12 Servos, 3 Arduino-based microcontrollers, an Ultrasonic and IMU sensor, Bluetooth Bee, and Bluetooth Module were used in the design of the BrainBot. A custom C++ based application was developed and used with an Arduino board for interpreting high level commands from the computer and calculating Servo positions through inverse kinematic equations. A custom Python-based application (running on a local computer) is used for interpreting the multielectrode neural data and sending the commands to the quadruped via a Bluetooth channel.

Results

The initial design used hard-coded Servo positions sent by a Python application directly to the Servo controller for static robotic movement. A neural interpretation application was developed to allow the initial design to receive commands from the organoid. After integrating each respective aspect, the robot's movement varied based on changes in neural activity. A significant redesign was required for more natural movement by introducing a microprocessor that calculates effective positions that simultaneously move all 12 Servos with the center of gravity taken into account. Two additional sensors were also integrated through simultaneous processing, allowing for a closed-loop system for stimulation of the organoid.

Conclusions

The final design of the system met all the specified requirements as it effectively interpreted, modeled, and interacted with the organoid. This integrated platform, alongside the brain organoids, allow for an improved disease modeling and treatment testing system. Indeed, organoids currently used to model disease are limited as the disease pathways are not complex enough. These pathways, however, will be improved through the robotics platform as it will induce a more complex organoid.

Summary Statement

An integrated real time robotics platform that incorporates external stimulus and fluid movements for stem-cell derived brain stimulation and multielectrode data modeling, thereby acting as an artificial body for these brains.

Help Received

The multielectrode data used to develop the BrainBot was collected by the Muotri laboratory, specifically Dr. Alysson Muotri; all other aspects of the project were researched and conducted independently.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Rachel Chae

Project Number

S1006

Project Title

FMCW Radar Driver Head Motion Monitoring Based on Doppler Spectrogram and Range-Doppler Evolution

Abstract

Objectives

Drowsy driving is one of the leading causes of road accidents. However, existing technologies such as the Driver Alert System by Volkswagen monitor the movement pattern of the vehicle rather than the driver. Other radar-based driver monitoring researches focus on vital signs and facial features recognition, which are not only difficult to separate from other body motions but also requires a very narrow and precise beamwidth. The object of this research was to determine if an FMCW radar could serve as a driver monitoring system.

Methods

A coherent FMCW radar was used to observe the changes in range and Doppler caused by five different head and neck motions: dorsal flexion, dorsal hyperextension, lateral bending, lateral rotation, and forward body motion. The Doppler and range signatures produced by these movements were analyzed using a range-Doppler evolution and a Doppler spectrogram. The Doppler spectrogram was created within the LabVIEW program by extracting Doppler history from the range-Doppler evolution and indexing the data to display Doppler information at a specific range. Preliminary experiments were performed to determine the ideal angle of inclination of the radar, and additional programming was added to make the prototype more resistant to errors.

Results

After analyzing frames of range-Doppler evolution and Doppler spectrogram, Doppler and range characteristics of dorsal flexion of the neck the motion indicative of low driver alertness were distinguished from those of other driver head and neck motions.

Conclusions

Ultimately, experiments demonstrated the potential of radar-based head motion detection as a driver monitoring solution. With the help of image-processing software, the radar-based head-motion monitoring technology can be implemented by itself or integrated with other sensing methods to serve as a reliable driver monitoring system.

Summary Statement

This work demonstrates the potential of an FMCW radar to monitor driver's head motions with real-time Doppler spectrogram and range-Doppler evolution.

Help Received

I would like to thank Prof. Changzhi Li and Anna Wang for helping me use the equipment at Texas Tech University's Electrical Engineering Laboratory, and the Clark Scholars Program for supporting my research.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Jiahan Cheng; Thomas Rife; August Wetterau

Project Number

S1007

Project Title

Seeing Reality

Abstract

Objectives

The objective of this project is to help people who are visually impaired by creating a device that enhances their vision.

Methods

2 Eye charts, iPhones, 3D printer, laptop computer with Xcode and headsets. 2 apps were designed for this project, one was text to speech, the other was a zooming app. Tested subjects 10 feet away from eye charts, recorded how many letters on each line was spoken correctly. Do for all lines.

Results

We tested 5 subjects with 2 vision charts. Our zooming application allowed the one of the subjects to read up to 9 more lines on a vision chart than they could with their raw vision.

Conclusions

We built a device that can assist people with visual impairments. To do this, we designed two apps, one that does text to speech, while the other uses zoom functionalities. Our device was able to help people with visual impairments go about their daily lives as a person with 20/20 vision would.

Summary Statement

We built a device that can assist people with visual impairments in their daily lives.

Help Received

We designed our apps after doing research on which platform and language to program with.

Name(s)

Aryia Dattamajumdar

Project Number

S1008

Project Title

An Early Warning AI-powered Portable System to Reduce Workload and Inspect Environmental Damage after Natural Disasters

Abstract

Objectives

My goal is to develop an early warning AI-powered portable system that can monitor environmental damage during natural disasters. Both air and water quality need to be monitored with the aim of providing early intelligence to incident commanders to plan search and rescue operations. Additionally, intelligence on physical stress of front-line environment protectors will guide incident commanders on optimal resource planning.

Methods

A multi-spectral sensing system to monitor air and water quality that can operate in dangerous environments for safer and accessible rescue operations was developed. The prototype has 1) search and inspection multi-sensor drone, 2) AI-powered intelligent base station, 3) a low-cost portable spectral water quality inspection system and 4) rescue system based on robotic crawler and hand. The search module has 4 drone-mounted sensors: gas sensors, thermal camera, GPS sensor, a visual camera, and wireless communicator. The gas sensor monitors smoke situations while thermal camera detects hidden hot objects. Spectral water quality monitoring system analyzes water samples and quickly analyzes turbidity levels indicating potential pollutants such as salt and bacterial contaminant levels. The AI-powered intelligent base station is based on Nvidia Jetson TX2 and powered by open-source object recognition and localization AI algorithms (imagenet and detectnet). It receives target images and GPS from the search system. The GPS results of target location are sent to the robot for retrieval. The retrieval robot has 3 sensors: ultrasound sensors for obstacle avoidance, LIDAR for fine gripper control and PixyMon camera for texture-based target matching.

Results

The prototype has four key functioning modules: Search and inspection drone with multi-spectral sensors; AI-powered intelligent base station; Portable water quality spectral analyzer; and Rescue retrieval system based on robotic crawler and hand. The search module has four drone mounted sensors i.e. gas sensor to evaluate the environment, thermal camera to detect hidden objects, iPhone5 unlocked sensors like GPS and visual camera, and a wireless communicator. Gas sensor monitors rescue operation viability while visual and thermal cameras detect search targets. AI-powered intelligent base station receives target images and GPS from search system and automatically searches for target. Open-sourced AI algorithm imagenet was used to identify targets with 60-95% confidence, while another AI algorithm detectnet was used to localize target. Target image and GPS location were transmitted to robotic retriever. The prototype robotic crawler could carry loads of up to 2 kg and navigates by comparing the GPS location of the target with the current

Summary Statement

I have developed and tested an early warning AI-powered system to help firefighters and others in the first-line of environment protection to reduce their workload, inspect the environmental damage after natural disasters and plan actions.

Help Received

All experiments were done in home environment and in my garage lab. I appreciate the financial resources provided by my parents to procure experimental devices. I appreciate the time and feedback provided by officers of Sunnyvale Fire Department, Sunnyvale, California.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Yahvin Gali

Project Number

S1009

Project Title

Rethinking Braille with Pi Reader: Raspberry Pi Based Optical Reader for the Blind and Visually Impaired Using OCR & TTS

Abstract

Objectives

The scope of this project is to design an easy to operate low-cost Raspberry Pi based Optical Reader using Open Source Optical Character Recognition (OCR) and Text-To-Speech (TTS) modules to provide a technical solution to assist the Blind and Visually Impaired (VI) in gaining access to various text resources.

Methods

The device uses a Raspberry Pi connected to a Pi Camera and an audio output device; Open Source Tesseract OCR and Pico2Wave TTS modules; and Python. With a single button press, the Pi Camera acting as the main vision captures the image of the document or book placed in front of it. The image is then passed onto the Raspberry Pi with the loaded OCR which enables the recognition and automatic conversion of printed characters in the image into machine-encoded digital format. Next, the digital text is passed on to TTS which uses predefined libraries to convert it into audible speech waveforms that can be played through an audio output device for a visually disabled to hear. Approximately 170 lines of python code were written for automation.

Results

The device was evaluated using metric proposed by Information Science Research Institute at UNLV for the Fifth Annual Test of OCR Accuracy. Although the accuracy of the TTS depends on the OCR, it was observed that some words were mispronounced despite correct extraction. Out of 60 documents tested, Plain-Text showed an avg. of 99.73% and 97.23%; Different-Fonts 89.17% and 87.37%; Text-on-Image 70.84% and 62.36%; Text-with-Images 63.43% and 59.25%; Text-on-Colored-Background 45.14% and 44.61%; and Handwriting 21.59% and 18.79% OCR and TTS accuracy respectively. The Plain-Text books with 430 and 459 pages showed an avg. of 93.42% OCR and 90.07% TTS accuracy.

Conclusions

Since the OCR and TTS are downloaded onto the Raspberry Pi, the Pi Reader can operate as a standalone without the need for internet or WiFi, making it suitable for remote areas. At a total cost of $59 when compared to similar devices that run into 1000s of dollars, it is cost effective. It gives the visually disabled more self-sufficiency in accessing printed text without assistance. Finally, it can be used in schools for ELA and students with learning disabilities; learning a new language; for the illiterate; and general multi-tasking.

Summary Statement

I designed a simple low-cost Optical Reader to assist the Blind and VI to access various text resources, without the learning of any new concepts.

Help Received

My mentor, Mr. Roice, educated me on Raspberry Pi and Python; my parents provided funds for materials and adult supervision.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Saurav Gandhi

Project Number

S1010

Project Title

A Hand Dynamometer Controlled Computer Vision Based AI Robotic Navigation System for the Visually Impaired and Elderly

Abstract

Objectives

Parks, downtowns, malls, and stores are places we frequently visit in our daily lives for socializing, dining, shopping, etc. Out of the 7.5 billion global population, around 285 million individuals suffer from some form of visual impairment. The K9 was developed with the following feature-set in mind: provide user the ability to control the speed of the guide vehicle on a predetermined path, ability to detect & avoid obstacles and return to the path, ability to Identify multiple objects on the shelf of a mock-up store aisle, ability to provide audible feedback to the user based on signatures of the objects

Methods

The K-9 is based on the Arduino platform using an inexpensive computer vision camera on a servo-motor pan mechanism and a variety of sensors for capabilities. The low-cost cmuCam5 Pixy Cam computer vision camera is capable of recording signatures of objects by its hue, and this was used to detect pre-programmed objects. Ultrasonic sensors were used for hand dynamometer and obstacle avoidance, and the line follower for tracking around a store. The custom hand dynamometer allows the robot to change its speed based on the strength of one's grip. An option is provided for the user to use a flexible cable or a cane-like stick to connect the dynamometer to the vehicle. An emergency help button which triggers an SMS text was incorporated at the top of the device using an Arduino shield.

Results

A well-lighted grocery store based test environment was created with pegboards for aisles of the store, with plastic grocery items and electrical tape for the predefined path. Multiple tests were conducted with a blind individual as well as blindfolded individuals for navigation, object detection, and obstacle avoidance. K-9 s success rate was 96% for navigation, 75% for object detection, and 66% for obstacle avoidance with an average success rate of 79%.

Conclusions

The inclusion of a sophisticated computer vision camera with a cloud library would help tremendously in object identification. Future tests could also include leveraging multiple cameras for faster processing and incorporating voice feedback. From the results of the test data, as well as qualitative observations and learnings, one can conclude that an improved version of this product has very high potential to help guide visually impaired individuals around public venues.

Summary Statement

This project focuses on developing a hand dynamometer controlled robotic navigational aid leveraging computer vision for the visually impaired.

Help Received

I built, designed, and programmed the K9 on my own. My teacher provided guidance on the scientific process, and my parents supported me throughout.

Name(s)

Melina Ghodsi

Project Number

S1011

Project Title

Monitoring Respiration Utilizing a Low-cost Accelerometer Sensor to Prevent Sudden Infant Death Syndrome (SIDS)

Abstract

Objectives

Develop an inexpensive and effective sensor that would be able to prevent SIDS by recognizing when respiration in infants stopped while also being easy to wear and easy to alert parents through a wirelessly connected smartphone.

Methods

An accelerometer sensor was created by connecting the sensor to an adafruit feather board that has a built-in microcontroller to process the information and bluetooth to send the data to a smartphone. The system includes an attached Lithium Polymer Battery to power the sensor and a mini-usb port to charge the battery. The system was programmed with Arduino to be able to send the alert to the phone when there was no breathing.

Results

The sensor was able to detect the movement of the test subjects bellies when breathing. When the test subject was asked to hold their breath, the system was also able to recognize the no breathing stimulation. After 10 seconds of no breathing, the system sent an alert to the parents smartphone so that the parents could reach their child in time.

Conclusions

As a result of the sensor being able to accurately detect when breathing stops, it is able to prevent sudden infant death syndrome by alerting parents. The global issue of SIDS has not been able to be stopped because of the high cost of the available sensors on the market. However, with this novel, low-cost accelerometer sensor, it is accessible to all people and can tackle this issue on a larger scale. This system can also bring peace of mind to parents when they know that even when they are not watching, a simple sensor is monitoring their child.

Summary Statement

In order to prevent sudden infant death syndrome, I devised a low-cost accelerometer sensor that is able to detect when breathing stops and able to send an alert to parents smartphones.

Help Received

My mentor throughout the project was Professor Majid Sarrafzadeh from UCLA. He allowed me to do this project with the guidance of a PhD students in his research laboratory.

Name(s)

Lauren Harris

Project Number

S1012

Project Title

Piezoelectric Energy Generation from Roadways and Pedestrian Walkways: A Practical Field Test of a Piezoelectric Speed B

Abstract

Objectives

The purpose of this project is to capture green energy from the Piezoelectric Effect. This is the ability of piezoelectric materials to generate electricity in response to putting mechanical stress on it. The effect is reversible. It generates electricity when stress is applied but it can also generate stress on the piezo material causing it to deform and vibrate when electricity is applied. It has common uses such as the ignition source for lighters and in producing the speaker sounds from electric guitars. Many piezoelectric energy-generating approaches are done on a small scale, like using piezoelectric shoes to charge personal electronics. However, my project tests a potential way to harvest much larger amounts of energy from road vibrations caused by cars driving over a speed bump or from floor vibrations caused by pedestrian traffic over a floor panel. Many natural materials are piezoelectric such as crystals (quartz, sucrose), bone, enamel, and even DNA. Synthetic materials like ceramics have also been created. I generated naturally occurring Rochelle salt crystals and used a quartz crystal to demonstrate the piezoelectric effect for this project. However, I used synthetic ceramic piezo tiles to build a speed bump and floor panel. I tested the energy generated and stored by my design using different car models and people of different weights and made estimates of energy generation for its use on a typical neighborhood street like my own and if used on the floor of a Metro subway entrance during peak use times.

Methods

Speed Bump Design:

The speed bump is designed with 32 piezoelectric generators wired together in parallel. The piezoelectric generators are mounted onto a black, rubber, cable protector in a line. When tested, the speed bump was hooked up to a multimeter to record amperage and an oscilloscope to record the voltage.

Foot Pad Design:

The foot pad was designed where the piezoelectric generators were set towards the center of the pad. Each generator is secured with a double-sided piece of thin tape on the underside of them. Like the speed bump, when tested, the foot pad was hooked up to a multimeter to record amperage and an oscilloscope to record the voltage

Results

My experiments demonstrate that my piezoelectric speed bump could produce enough power (average 8 kilowatt-hours per day) to power 3 incandescent or 16 LED traffic lights saving $1800-$6000 per year for the city.

Summary Statement

Piezoelectric Energy Generation from Roadways and Pedestrian Walkways

Help Received

I received support from my parents in driving the cars used for my project and buying materials.

Name(s)

Arya Joshi

Project Number

S1013

Project Title

Energy Generation from Motor Vehicle Drag through Piezoelectric Processes

Abstract

Objectives

As concluded by the U.S. Department of Energy, aerodynamic drag exerted upon motor vehicles dissipates approximately 8-12% of potential energy provided by finished motor gasoline as heat. In proportion to the daily average gasoline consumption, energy provided by ~39.17 million gallons of gasoline is dissipated as heat in contemporary vehicles with an average drag coefficient of 0.30 Cd.

The presence of aerodynamic drag, though the phenomena dissipates usable energy as heat, can potentially generate electricity with the use of polyvinylidene fluoride (PVDF) film, a piezoelectric polymer. If such piezoelectric semi-crystalline material connected to a storage capacitor by a circuit is placed on the frontal body of a vehicle, mechanical stress produced by an accelerating vehicle can induce polarization within the PVDF film as per the piezoelectric direct effect, and electrical energy (Uout) can be harvested.

Methods

An Arduino Uno R3 microcontroller was uploaded with written code using the Arduino IDE platform to read input voltage values at the analog port. The PVDF film was attached to the upper center of a 2002 Toyota Prius (0.29 Cd) registration plate and connected to a 1 M ohm load resistor via a breadboard. Another set of test leads connected the breadboard to the analog port (A0) of the microcontroller, which was connected to a computer. The vehicle was then accelerated, thus inducing changes in stress upon the semi-crystalline film. Voltage was generated and measured by the microcontroller. The voltage values were plotted onto the Arduino IDE serial plotter. 20 trials were conducted with a time duration of 500 ms. and the amount of electrical energy (Uout) generated was calculated.

Results

The total electrical energy (Uout) generated for all trials by the PVDF piezo film was determined to be minimal, ranging within nanojoules. The potential electrical energy that could be harvested if all usable vehicle frontal surface area was covered in PVDF film was also estimated.

Conclusions

With the stated results, this energy harvesting method is deemed possible and is able to produce electrical energy. However, due to current inefficiencies in energy conversion ratios of piezoelectric polymers, this energy harvesting method is of now not entirely possible for compact vehicles. However, this method would be much more suitable for larger vehicles with greater surface area and drag coefficients such as aeroplanes and trucks.

Summary Statement

I produced electricity by converting mechanical energy from vehicle drag using the direct piezoelectric effect of polyvinylidene fluoride (PVDF) film.

Help Received

None. I myself designed my engineering model, constructed the prototype, and gathered/analyzed the experimental data.

Name(s)

Andy Kapoor

Project Number

S1014

Project Title

SensorSafe Baby Car Seat

Abstract

Objectives

The purpose of my project is to is to prevent the average of 40 babies, dying in temperature unregulated cars each year. Using weight, noise, and accurate humidity and temperature sensors, sensorsafe baby car seat can alert clueless parents about a potential danger to their infants. Many engineering companies such as Childminder have attempted to create a budgeted safety implement to a baby car seat. I have decided to use an arduino, due to the various sensor add ons available. Meant for engineers and hobbyists, arduino has the ability to create a sensorsafe baby car seat that can classify different details needed to save babies from hot cars. Others have approached the problem of children deaths in hot cars in different ways, like creating an app with a camera, or having a full seat that connects to a smartphone device. Child heatstroke in cars is a critical issue, that is rising, even till today. From 1989 to 1997 an average of 12 babies died of heatstroke in vehicles each year. From 1998 to 2006, an average of 38 babies died each year; a drastic increase. As the years go by, new distractions emerge, causing less attention to be derived to babies, leaving them without life in scalding vehicles. My sensorsafe arduino baby car seat will have the capabilities to rescue children from this undervalued conflict.

Methods

Adding the Noise Sensor:

The process for connecting the noise sensor was relatively simple compared to the other two. The main thing I needed to do was to make the sound and temperature sensors work together, because they did not seem to work on the same breadboard. My alternative was to take two different breadboards, with one sensor on each. This benefits the locations the sensors will be placed.

Adding weight sensor:

The biggest issue I had was with the different weight sensors. I purchased a pack of 4 weight sensors from Amazon, but they weren t compatible with the arduino R3, so I needed to buy a different weight sensor. The new sensor was the HX711 5 kg one bar weight sensor, which was compatible with the Arduino R3, and relatively easy to code. A large issue I had was that my output for the sensor kept reading various intervals on the screen. It turned out to be an issue with the soldering I did on the board. I managed to fix it and get it up and running.

Adding temperature sensor:

The temperature sensor was the first sensor I included on my project. I had major problems with the libraries. In order for the code to work, there needs to be certain libraries. I attempted to download the

Summary Statement

Using technology to create a sensorsafe baby car seat that prevents heat stroke in vehicles

Help Received

Dr. Li

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Rohil Khare

Project Number

S1015

Project Title

Vacuumed Linear Accelerator Launchers: The Future of Space Launches

Abstract

Objectives

Rockets today are extremely expensive to launch due to the cost of fuel. If we want to get closer to commercial space travel, we must make the cost of launching rockets to space as cheap as possible The way we can achieve this is to reduce the cost of fuel because according to NASA's official website, the cost of fuel is 1.39 million dollars per launch.

Methods

This project aims to reduce the fuel cost for rockets by replacing the initial boosters with a magnetic linear accelerator which is then placed in a vacuum tube to further amplify the speed. The accelerator was first discovered by a man named Rolf Wideroe who was a physics teacher who wanted to show his class the principles of magnets. Over time, this idea was lost to time but the prototype is a much-improved version of the older accelerator first created by Rolf Wideroe. Multiple more magnet chains were added so the accelerator can go faster than what it did during Wideroe s time. Placing the accelerator in the vacuum tube is used to efficiently decrease drag to make the probability of launching rockets with the prototype more likely in a full scaled version. Photogates were used to help get extremely accurate velocities. Each photogate was placed at a varying distance to see if the vacuum tube actually helped.

Results

It was also calculated that the prototype is 1/1000 or 1/10000 of the size compared to this prototype being built at a full scale. With this information and seeing that the escape velocity of earth is 7 miles in a second, it was determined that the prototype must travel 39.6 or 3.96 feet in 1 second. The prototype exceeded this limit and went about 260 feet in 1 second. The vacuum tube helped decrease the drag on the rocket and the data supports this claim because the velocity 12 inches away from the launch gate in the vacuumed tube was 3 meters/ second greater than the launcher without the vacuum.

Conclusions

This means that the idea of a magnet launching a rocket ship in a vacuum tube is completely plausible and can be done on a full scale to successfully launch a rocket. This can be concluded because my project achieved the goal speed I had set. This idea is also applicable to many other things like launching weather balloons and gliders. Imagine instead of using jet fuel, gliders are launched using the prototype and they slowly glide down. It can also be used for train systems such as the Hyperloop.

Summary Statement

The vacuumed linear accelerator launcher is a magnetic powered accelerator, which is placed in a vacuum, to create an ideal prototype which aims to launch rockets to space and its possibilities do not end there

Help Received

My dad helped me buy the materials. My science teacher, Mrs.Brown supplied me with the photogates.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Patricia Limon; Elissa Monterroso; Lizbeth Romero

Project Number

S1016

Project Title

Expanding the Lifespan of a Plant through a Self Watering Flower Pot

Abstract

Objectives

Caring for specific plants can be difficult, especially for individuals with busy schedules. Many existing solutions to this problem deliver limited functionality at a significant cost. To address that issue, we designed an affordable and visually appealing self-watering pot for small indoor plants. The pot would automatically water plants depending on the moisture level of the soil while monitoring other important data of the growing plants including light levels, humidity, temperature, and the water level of the water supply. To accomplish this, we designed, printed, wrote code, and tested our design. We utilized an Arduino as the microcontroller for the monitoring and controlling the devices.

Methods

To make a functioning planter we had to consider the many factors that plants need to survive. For this reason, we researched the topic and found that water, temperature, soil, and light are crucial elements that plants need. We decided as a group to incorporate those on our planter as sensors. These sensors will detect the elements stated above while at the same time interacting with the plant. We tested our sensors and made sure our 3D printed pot was large enough to fit the plant, wires, and plumbing. Most codes for the sensors we chose to incorporate were provided by the internet, despite this they required modification. After conducting a trial and error with the design of our pot, we were able to redesign it so it holds and hides everything properly and most importantly, achieves our goal of making a self-watering pot

Results

We accomplished our goal of creating a self-watering pot that compliments human interaction because we were able to program, code and design a self-watering planter that could sustain itself. This can be done through our many sensors because it is capable of informing the plant owner of their plants living conditions.

Conclusions

The initial purpose of our watering pot was to help busy individuals extend the lifespan of their plant. However, upon further reflection, this cheap invention would also able to contribute to research in the botany field. For example, if a researcher wants to see how much water, fertilizer, pesticide, etc, is best for a plant, the watering intervals allow one to see what works best for a plant instead of worrying if it is time to feed water the plant or not.

Summary Statement

Overall we were able to accomplish our goal of creating a self-watering plant that was self-sufficient.

Help Received

Most aid was provided by our Physics Honors Teacher, Mr. Gagnier and our Teacher s Aid, Mr. Mao. Both teachers provided insight pertaining to coding, programing and organizational skills.

Name(s)

Farid Manshaii

Project Number

S1017

Project Title

Designing an Affordable Advanced Mind-Controlled Robotic Arm

Abstract

Objectives

The objective of this project is to improve an amputee's mobility and the ability to manage daily activities, as well as provide the means to stay independent. Along with the arm is a glass-encapsulated chip which would be capable of relaying electrical signals from the spine to the arm through the use of NFC (otherwise known as Near Field Communication) enabling the amputee to have better control over the arm itself. Currently, a typical robotic prosthesis cost substantial amounts of money and have a limited quantity of functionality. With this design, an amputee would be capable of living life as they once used to but at an affordable price.

Methods

Carbon fiber composite PLA, NinjaFlex filament, 3D printer, Dupont wires, Arduino Mini Pro, heat shrink tube, SG90 servos, fishing line, braided nylon sleeves, 9V battery, NFC chip, glass wafer, glass capsule, graphene capacitors and taptic engine. Tested the functionality of a robotic arm through the use of rapid prototyping and conducted stress tests through the use of OnShape and SolidWorks. In order to test the functionality of the robotic arm, I utilized EMG sensors as a form of input. Simulated connectivity between the robotic arm and glass-encapsulated microchip relaying the electrical signals from the spine utilizing Unity. Developed the code required to run the arm in collaboration with Loma Linda University and redesigned the chipsets by designing my own silkscreen. Utilized a modified injector from Loma Linda as a way to deliver the glass-encapsulated chip to the spine.

Results

The glass-encapsulated chipset was successful in relaying the electrical signals from the spine in simulations. The arm was also capable of having similar functionality to a normal arm with 290 degrees of freedom.

Conclusions

We can conclude that the affordable prosthesis designed would have similar functionality to a regular arm and be capable of allowing the user to have full control of the arm itself through the use of a glass-encapsulated chip capable of relaying the electrical signals from the spine to the arm.

Summary Statement

I built a robotic arm which would have similar functionality to a normal arm through the use of rapid prototyping and utilized a glass-encapsulated chip capable of relaying the electrical signals from the spine to the arm via NFC.

Help Received

I designed the robotic arm by myself utilizing some of the resources at Harvey Mudd College and received help writing the code necessary to operate the robotic arm at Loma Linda University along with the modified injector used to inject the glass-encapsulated chip into the spine.

Name(s)

Sohom Roy

Project Number

S1018

Project Title

Camera & Stabilization System to Provide Object Detection/Tracking in Real Time for Assistance of the Visually Impaired

Abstract

Objectives

The visually impaired often have trouble navigating their environments due to a lack of knowledge about the environment around them. My project hopes to solve this issue by creating a hand-held camera stabilization system that can assist the visually impaired by using multiple sensors, motors, and audio feedback, providing object recognition tracking, at a lower cost than guide dogs and more effective than canes.

Methods

To complete the object detection and tracking part of this project I tested the different tracking systems on a laptop and a Raspberry Pi to evaluate the best one, measuring them in terms of speed and ability to track effectively, recover from occlusion, changes in light, and other factors. I then designed a camera mounting system that contained 3 motors and multiple sensors including a camera, gyroscope, and rangefinders, and I collected data on the system. The initial goal was to tune PID constants quickly, less heuristically and more algorithmically. I was able to notice correlations in PID data that allowed me to complete the project.

Results

The final system was able to adequately stabilize a system (< 5-10 degree oscillation when encountering rotations (max angular velocity of 1 rad/sec). In addition, with a laptop, the system was able to track people quickly (>100 fps), perform object detection adequately quickly (>15 fps), and read information.

Conclusions

PID Constants can be tuned faster and more effectively with careful analysis of data. I also analyzed multiple tracking algorithms and object detection algorithms on constrained, low cost systems like the Raspberry Pi. The final system was able to adequately stabilize a system when encountering rotations of different speeds and in different directions. In addition, along with the assistance of the computing power of a laptop the system was able to track people and objects and perform object detection adequately quickly. It can then read out detections, helping the visually impaired navigate their environment.

Summary Statement

I built a camera stabilization system to provide object detection/tracking in real time and a voice readout to help the visually impaired navigate their environment.

Help Received

None. I designed and programmed a gimbal and wrote code to detect objects myself.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Suhina Sharma

Project Number

S1019

Project Title

Cost-Effective Device that Analyzes Gas and VOC Concentrations in Exhaled Breath for Prevention of Chronic Lung Diseases

Abstract

Objectives

The goal was to create a cost-effective device using Arduino Uno kit that utilizes mathematical modeling of different gases and volatile organic compounds to detect chronic obstructive pulmonary disease (COPD) and other fatal diseases. Gases being monitored are Carbon Monoxide (CO), Ammonia (NH3), Hydrogen (H2), VOCs like Propane (C3H8), Butane (C4H10), and Ethanol (C2H5OH). There has been lot of interest in the analysis of breath constituents to measure inflammation and oxidative stress in lungs. I was doing research on fatal pulmonary diseases and realized that there is no device that exists which can proactively monitor medical emergencies like COPD and fatal conditions related to lungs, liver, stomach, and kidney.

Methods

Arduino Uno microcontroller, multi-channel gas sensor, cables, plastic pipe, LED, and buzzer were used to build the device. I performed testing on kids, adults, and elderly people. Testing variables were age, gender, effect of food, healthy vs people with mild pulmonary disease that I was building design for, smoker vs non-smoker. Testing was done for three different motion conditions subject being stationary, walking at 3 mph, running at 5 mph. Time interval was 1 min, 2 min, and 3 min. All motion tests were done on treadmill under supervision. Device was cleaned after each test. I also researched to study readings from medical devices that doctors use to validate my test results.

Results

Device worked in most cases and showed concentration of different gases in exhaled breath of healthy human. It was observed that food did not cause much variation in the reading of CO. It was also observed that smokers have high CO in exhaled breath than non-smokers. H2 Testing was done on healthy humans of different age to study variation in gases of exhaled breath at regular interval after ingesting Lactose. In healthy subject only, slight increase of hydrogen was observed. VOCs were at very low concentration and so it was difficult to get accurate readings. It was observed that most accurate readings are when subject is stationary. Walking, running variables in testing did not make any noticeable difference.

Conclusions

I observed that various gases and VOCs can be measured accurately using this device in healthy human. I also created a threshold limit for each gas that I was monitoring and device alerted for anything over this limit. I wanted adults to be alerted once a threshold limit was reached and device did that. The device can be calibrated so that it can alert differently for different gas concentrations. I would like to make this device work using blue tooth technology and build a mobile application that can be integrated with this device.

Summary Statement

I created a portable cost-effective breath sensing device that measures gas concentrations of CO, NH3, H2 and VOCs (C3H8, C4H10, and C2H5OH) to prevent fatal medical conditions related to lungs, liver, stomach, and kidney.

Help Received

I created and programmed the device myself. I researched on internet by watching videos and joining programming forums. My science teacher reviewed my findings.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Isabel Sperandio

Project Number

S1020

Project Title

Harnessing the Power of the Ocean: Designing an Efficient and Portable Wave Energy Converter Prototype

Abstract

Objectives

My goal is to design and build a small-scale device that generates electricity from the force of ocean waves. My purpose is to help people who do not have access to electricity, for reasons such as natural disasters, rural locations, and poverty.

Criteria:

(1) Efficient: able to supply power to basic needs such as light and radio, cost-effective

(2) Durable: impact and ocean water resistant

(3) Practical: simple, transportable, and safe to use

Methods

After working on an unsuccessful design based on river hydropower last year, I was inspired by the algae being tossed around in the ocean and a shake-to-light-up toy to change my design to a shaking magnet and coil system. First, the device is thrown into the ocean. As it tumbles around and hits rocks, the magnet slides through a coil, inducing a current.

I used thin plastic tubes wrapped in magnet wire nested inside of PVC pipes. I used 12 coils assembled in a cube formation to capture energy in all 3 directions - X, Y, and Z. I built a circuit with rectifiers and added sails to the cube to improve efficiency.

I built 4 different prototypes with many iterations in between. I tested them in the ocean measuring voltage & current 20 times per second using a Vernier Energy Sensor and calculated power & energy.

Results

Prototype 3 produced 1.7 Joules in 10 minutes, with a peak of 11 Volts and 35 mA. On average, it can produce 2.8 milliwatts. It weighs about 1 kg and is under 30x30x30 cm.

It withstood 15 minutes in high surf and was waterproof. To use the cube, I tied the extension cord/rope to part of a rock, threw it into the ocean, and waited.

Conclusions

Prototype 3.1 of the "Wave Power Cube" has met my engineering goal. It successfully converted the chaotic and powerful ocean waves into enough usable electricity to power LED lights. It is durable, safe, and easy to use. It can easily be scaled up and mass produced because of its simplicity.

If developed further, it has the potential to be much more efficient and cost-effective through improved circuit design, coil configuration, sail panel improvement, and more testing.

This is impactful because it s a new way of using the ocean s power that could give an extra boost of

Summary Statement

I designed and built a small-scale and practical device that generates electricity from the power of ocean waves.

Help Received

I did the designing, building, and testing myself. Mr. Dunbar, my physics teacher, answered my questions about electricity and magnetism. Ms. Wilson helped me with writing. My dad made sure I was safe while testing at the beach.

CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

Xin (Anna) Wang

Project Number

S1021

Project Title

Analysis of Energy Efficiency in a Linear Induction Motor

Abstract

Objectives

The goal of this project is to build a linear induction motor using electromagnets and circuits. Then, the power and energy both lost and consumed are calculated and compared with the traditional induction motor (train). The linear induction motor does not interfere with the track or any other object thereby reducing friction of the motor when accelerating. This allows the linear induction motor to travel ina great distance with the same force being applied to the traditional train.

Methods

The linear induction motor is designed by my teacher and I. Magnets are placed on track and electromagnets are attached to the cart. The program used to code the Arduino UNO R3, as a master control of the circuit and the hall effect sensor, is written by myself. My computer science teacher then revised some of the errors in the program.

After completing the design of the linear induction motor, a force applier is used to apply an equal amount of force to the linear induction motor and the traditional train which allows me to calculate the energy lost and used in different conditions.

Results

The project is currently still in progress. Some changes will be made to the linear induction motor. This project didn't function ideally during the LA County Science Fair which required extra time to finalize the motor.

Conclusions

The project is currently still in progress. Some changes will be made to the linear induction motor. This project didn't function ideally during the LA County Science Fair which required extra time to finalize the motor.

Summary Statement

The project includes a self-built electromagnetism linear induction motor which is then compared with the traditional train in terms of energy being wasted and total energy needed to be consumed during acceleration.

Help Received