CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Brent A. Avery

Project Number
S0901

Project Title
Electromagnetism

Abstract

Objectives/Goals
The objective of my project is to see if electromagnetism is a viable form of transportation. It is also to see whether weight, mass, and surface area have an affect on magnetic attraction. My hypothesis is that they definitely affect magnetic attraction.

Methods/Materials
A coppor wire was wrapped around the PVC pipe, put through a switch, and attached to a 12-volt battery. This was repeated three times at different points in the PVC pipe. A ferromagnetic nail or steel ball bearing was loaded at the start of the PVC pipe. To launch the projectile, the switches were turned off and on in quick succession. The results were recorded.

Results
The ferromagnetic nail beat the steel ball in all four trials, traveling twice the distance.

Conclusions/Discussion
It seems that not only is electromagnetism a viable form of transportation, but also a very efficient one. It launched a 500 gram ferromagnetic nail over 5 meters with only 36 volts of power.

Summary Statement
My project is about how electromagnetism can be used as a possible form of launching projectiles and a form of mass transportation.

Help Received
Mother gave ideas for cosmetics on the poster board; man at a winder shop taught me how to wrap the copper wire around the pipe.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Sarah Y. Bai

Project Number
S0902

Project Title
Designing a More Ergonomic QWERTY Keyboard Layout by Analyzing Punctuation Frequency

Abstract

Objectives/Goals
The purpose of this project was to design a keyboard layout that was more ergonomic than the current QWERTY keyboard layout yet less time-consuming to learn than alternative keyboard layouts. Since there are fewer punctuation marks than letters (which alternative keyboard layouts primarily focus on), this design rearranged positions of punctuation marks based on punctuation frequency in 21st century texts, thereby providing a more manageable method to reducing the risk of carpal tunnel syndrome and other repetitive strain injuries in the wrist.

Methods/Materials
A Java program was coded that read in 100 open-source works retrieved from Project Gutenberg, a website that distributes free ebooks. All works selected were published in the 21st century to reflect current punctuation frequencies. The frequencies of the following punctuation marks were recorded: period, comma, semicolon, colon, exclamation mark, question mark, apostrophe, quotation mark, hyphen, left parenthesis, and right parenthesis. Punctuation marks with greater frequencies were placed in less strenuous keys while punctuation marks with lower frequencies were placed in more strenuous keys. Positions were selected based on published strain rankings and other strain considerations.

Results
From greatest to least percent frequency, the punctuation marks were as follows: comma, period, quotation mark, hyphen, apostrophe, semicolon, right parenthesis, left parenthesis, and colon. The following punctuation marks had less than 5% frequency: semicolon, right parenthesis, left parenthesis, and colon.

Conclusions/Discussion
The punctuation marks with less than 5% frequency were not given priority in the designing process. A total of five keys on the QWERTY keyboard were altered. The punctuation marks rearranged were as follows: comma, period, quotation mark, hyphen, apostrophe, semicolon, and colon. The new design can easily be implemented by manually changing the keyboard layout settings on a computer. Switching to this keyboard layout is important because the ergonomic improvement gained reduces the risk of carpal tunnel syndrome and other repetitive strain injuries in the wrist.

Summary Statement
This project designed a more ergonomic QWERTY keyboard layout that rearranged punctuation marks based off punctuation frequencies to provide an easy to learn and implement way of reducing the risk of repetitive strain injuries in the wrist.

Help Received

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Arjun V. Balasingam

Project Number

S0903

Project Title

Design and Optimization of a Novel Flexure-Enhanced Piezoelectric Wind Power Generator for Remote Wireless Sensors

Abstract

Objectives/Goals

There is a growing demand for small on-site electricity generators to power wirelessly networked sensor nodes that are suitable for monitoring the built and natural environments. Though wind is ubiquitous, research on milliwatt-scale wind power has just begun. Miniaturized windmills are not suitable for these applications because they require frequent maintenance. In this context, I investigate the wind energy harvesting performance of a low-maintenance mechanism, and demonstrate novel methods to boost its performance by 50-100x.

Methods/Materials

The core element of my power generator is a piezoelectric transducer that is laminated on to a fin. As the fin bends, the piezo will bend with it, and as the piezo bends, charges in the crystal will redistribute. The flowing charge will in turn deliver power to an electrical load connected across the piezo. I used the root-mean-square (RMS) power delivered to a resistor as the figure of merit to assess the optimality of the design variations, described below. I studied the electrical performance of this core setup when cylindrical obstacles (bluffs), sized to shed turbulent vortices at typical wind speeds, are placed in the vicinity of the fin. The materials consisted of several piezoelectric transducers, rectangular brass fins, pieces of cylindrical tubing, an oscilloscope, and an anemometer.

Results

I discovered that the performance of the system can be improved dramatically (>50x) when two bluff objects are placed within whisking distance of the fin. I investigated the performance of this system as wind speed, load resistance, fin length, and bluff separation are varied. I then showed that the wind power extracted by the device per unit volume can be enhanced further by affixing a T-shaped "nose" to the front of the fin.

Using follow-on experiments, I studied two alternative hypotheses to explain my results, and found evidence that the observed improvement in power production is most plausibly attributed to non-linear self-excitations, rather than to the resonant transfer of energy from the vortices to the vibrational modes of the harvester.

Conclusions/Discussion

I demonstrated a novel family of energy harvesters that can yield in excess of 1mW of power under modest wind conditions of < 5 m/s. This is sufficient to power many useful remote sensing applications that utilize emerging ultra low power wireless and CMOS technologies.

Summary Statement

I demonstrated a small-scale device (active volume ~ 0.002 m^3) that can generate over 3mW of power at modest wind speeds of U ~5m/s.

Help Received

I would like to thank my advisors Professor Ping Hsu (San Jose State University), Dr. Kucherov (Formerly of The Moscow State University), Dr. McAdams (AP Physics Instructor), and Mr. Nicoletti (AP Calc Instructor) for their valuable advice and encouragement.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Weston D. Braun

Project Number

S0904

Project Title

FPGA-Based Digital Controller for High Frequency Induction Heating

Abstract

Objectives/Goals

The goal of this project was to design a prototype induction heating system utilizing a digital control loop implemented on a FPGA. This would replace the analog phase-locked loop conventionally used to control induction heaters, which must be reconfigured when the induction heating work coil or load is changed and require retuning for each specific system.

Methods/Materials

Signal acquisition hardware and power electronics were built to work in conjunction with a Nexys-2 FPGA development board running Verilog code. The primary components of the induction heater developed were the power electronics, which perform the actual duty of induction heating, the digital control loop, which generates drive signals and regulates the power output, and the data acquisition system, which is responsible for converting analog signals from the induction heater into a digital representation.

Results

The digital control loop developed for this project was tested and demonstrated to be capable of tracking the maximum power point of the induction heater while adapting to variations in loading of the work coil. The functionality of the overcurrent protection system was verified and the heating efficiency of the all-digital controlled induction heater averaged 72%, which is comparable to current analog-based controlled induction heaters.

Conclusions/Discussion

This project has successfully demonstrated the feasibility of an all-digital FPGA-based controller for high frequency induction heaters. The digital controller developed presents a promising alternative to the analog controllers currently used for induction heating.

Summary Statement

An induction heating system under the control of an all-digital control loop which was implemented on a FPGA was designed, constructed, and evaluated.

Help Received

Used equipment in high school metal shop to construct parts for project.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Bryan E. Carbaugh

Project Number

S0905

Project Title

A Virtual Thunderstorm: Experimenting with a Kelvin Electrostatic Generator

Abstract

Objectives/Goals

The objective of this project was to determine whether variation of water flow rate on a Kelvin Electrostatic Generator has a significant impact on the DC voltage as well as the time in between each spark produced by the generator. My hypothesis was that an increase or decrease in water flow rate would have no significant effect on the DC voltage output of the generator, but would result in considerable differences between the spark times, with higher flow rates resulting in less time in between each spark, and vice versa.

Methods/Materials

The generator utilizes a standard PVC pipe assembly design modified for stability. A water jug at the top of the generator supplies water to two polyethylene droppers. The water flow rate of these two droppers is controlled by a polypropylene valve containing 5 distinct markings designating 5 different flow rates, which I measured using a graduated cylinder. The droppers effectively distribute oppositely charged water streams in between two metal inducers, made of tomato cans, and into two adjacent coffee cans, where opposite charges are utilized in the formation of a spark between two nails, which serve as electrode "probes". I acquired my DC voltage data by connecting the two electrodes on the generator to the probes on a digital multimeter, taking the first 40 voltage readings of each of the 5 flow rates for a total of 200 voltage readings. Using a stopwatch, I also measured the time in between the first 40 sparks produced by each flow rate, for a total of 200 time readings.

Results

My data showed that the direct current voltage changed contiguously with the flow rate, exhibiting a discernible change between each flow rate. My data also showed that an increase in flow rate is accompanied by a significant increase in spark generation frequency.

Conclusions/Discussion

Ultimately, my results did satisfy my objective in carrying out this experiment. My first hypothesis was disproven, which I accredit to my initial lack of understanding of voltage. My second hypothesis, however, was proven to be correct. In experimenting with this generator, I found that varying humidities often produced inconsistent results, and that it took several tries to ensure that my tests ran smoothly. Hopefully, with further experimentation with this apparatus, scientist can find ways to obtain massive amounts of clean energy from electrostatic sources, such as lightning.

Summary Statement

I built and experimented with an electrostatic generator to ultimately determine that variation in water flow rate of this generator has a significant impact on both the DC voltage and the time in between each spark produced by the device.

Help Received

My mother and father helped to purchase all of the parts and tools required to build the generator. My father also assisted me in the assembly of the generator.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Alexander L. Chen

Project Number
S0906

Project Title
A Foldable Solar Panel with an Improved Hill Climbing MPPT Circuit

Abstract

Objectives/Goals
This project aimed at developing a compact, foldable solar panel with an improved hill climbing (HC) maximum power point tracker (MPPT) to address the need for efficient and portable power generators. The solar panel could be reconfigured to produce different currents and voltages.

Methods/Materials
Instead of using low efficiency solar films, this project employed more efficient Si solar cells to construct the foldable solar panel. Two 6#x6# cells were serially connected and enclosed in a thin, transparent Plexiglas case to form a module. Eight modules were mounted on a fabric to form a panel. Modules were connected to one another by bullet connectors which made the panel reconfigurable. An MPPT circuit was design and assembled to control the solar panel voltage. It included a boost converter and a microcontroller which executed the improved HC algorithm developed in this project.

Results
Two solar panels were constructed. Each had a size of 3x7.5x14 cubic inches and weighed less than 8 pounds. They produced >60W of total power. The MPPT circuit achieved >98% of electrical power that could be achieved by manually optimizing the converter duty cycle. It showed fast and robust maximum power point tracking under rapidly changing light intensities.

Conclusions/Discussion
The results were significant because the solar panel design addressed many practical needs and the improved HC MPPT algorithm addressed the deficiencies of the popular perturb-and-observe algorithm with simple modifications. The solar panel can be used as power generators for outdoor events, campers, and dwellers in remote areas where grid power is not available.

Summary Statement
High power, foldable solar panels and an improved hill climbing maximum power point tracking circuit were developed and successful operation of the system was demonstrated.

Help Received
Mr. Peter Starodub, my science research teacher, guided and monitored my progress throughout this science project. Dr. Richard Moyer has also provided much helpful guidance. My parents have supported me financially and stimulated my imagination.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Andrew M. Chen

Project Number
S0907

Project Title
Utilizing Novel Graphene Oxide Langmuir-Blodgett Film Catalysts to Enhance the Cost Efficiency of a PEM Fuel Cell

Abstract

Objectives/Goals
Using graphene oxide to improve power output of a PEM fuel cell.

Methods/Materials
Graphene oxide was created using the Hummer's method and thin films were created on the polymer electrolyte membrane using an LB trough. Power output testing was done with new membranes. Characterization tests included AFM, TEM, and FTIR.

Results
The new membrane improved power output by 106%.

Conclusions/Discussion
The results verified the hypothesis and have potentially opened a new direction for research.

Summary Statement
Using graphene oxide to increase power output of a PEM fuel cell.

Help Received
Used lab equipment at Stony Brook university under supervision of Dr. Rafailovich; participant in Garcia MRSEC program

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Caelan Creekmur; Gaelan Skye

Project Number
S0908

Project Title
Attraction/Repulsion of a Tesla Coil

Abstract

Objectives/Goals
The goal of are project was to see if the electromagnetic field put off by a tesla coil would be of positive charge and attract the balloons or be of negative charge and repeal the balloons.

Methods/Materials
We made a tesla coil using: nuts,bolts, wires, glass bottles, wooden boards, tubing and a neon sign transformer. With the tesla coil we placed it in an open area free of any metal objects and plugged the neon sign transformer in to an extension cord then we placed six balloons around the tesla coil than we plugged the extension cord into an outlet.

Results
Some of the balloons where repealed but not all of them where repealed show us that the electromagnetic field put off by a tesla coil was negative and pushed the balloons away. Also the coil field was able to jam any electronic singles around a 10 foot radius of it.

Conclusions/Discussion
We believe that this info can be helpful because it allows us to understand how a tesla coil can affect an area around it. Also an negatively charged field may be helpful in some cases like ionizing an surrounding area.

Summary Statement
Will a Tesla coil electromagnetic field be positive or negatively charged

Help Received
Father helped build the tesla coil;mother helped write the board.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Julie A. Fukunaga

Project Number
S0909

Project Title
Building a Non-Contact Soil Sensor Using Electromagnetic Induction

Abstract

Objectives/Goals
Farmers can maximize crop yields by measuring soil electrical conductivity (EC), the soil#s ability to conduct electricity. By determining the soil#s EC, farmers can decide how to control their crops based on the amount of nutrients and moisture available in the soil. Two methods of testing exist: contact probes (frequently used but bulky) and non-contact devices (high cost and not accessible to most farmers). I designed and built a low cost, accessible, and portable device using electric components and computer programming to measure the soil#s electrical conductivity without contacting the soil.

Methods/Materials
This device consists of one transmitting and one receiving coil that work through the principle of electromagnetic induction. An oscillating signal is produced and sent through the transmitting coil which induces a magnetic current in the ground. The receiver reads both the transmitting coil and the eddy currents produced by the conductive soil. A microcontroller then interprets this data to determine the soil#s electrical conductivity.

Results
The sensor was tested in a controlled environment with different soil types and moisture levels. These results were compared to a gravimetric system (soil moisture) of measuring which corresponds with soil EC (the higher the EC reading, the greater the moisture in the soil). Both results showed correlation with each other.

Conclusions/Discussion
The design criteria and engineering goals were met. This non-contact sensor can greatly help farmers and gardeners determine soil EC, which correlates with other properties of soil such as salt and moisture content in the ground. This prototype is inexpensive to produce and can be distributed for widespread use. Outside of agriculture, this device can be adapted to the mineral, oil, mining, water, and archaeology industries/studies and has many potential applications.

Summary Statement
For my project, I designed and built an efficient and low cost electromagnetic induction (EMI) non-contact soil sensor to measure soil electrical conductivity.

Help Received
My father helped explain the computer programming, and my mother helped with my display. I would like to thank Mrs. Anderson and Dr. Oliver for their guidance and Telefunken for providing materials.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Yootak Jin; Kevin Wang

Project Number

S0910

Project Title

Fractal Antennas: Fractal Geometry and Wireless Networks

Abstract

Objectives/Goals

Through our project, we wanted to measure the effectiveness of increasing the number of iterations of a fractal in a fractal antenna and the wireless signal reception strength as a result. We believe that fractal iteration and signal strength have a direct and linear relationship.

Methods/Materials

We have built 6 iterations of a fractal antenna from aluminum foil. We tested each of their signal strengths by connecting them wirelessly to a router, and measured the signal strength using a computer program on a Linux OS laptop.

Results

Our data shows that increasing the fractal iteration by one, on average, increased the wireless reception strength by approximately 1-2 decibel-milliwatts. Though, the wireless router did fluctuate leading to a somewhat substantial margin of error.

Conclusions/Discussion

Drawing from the gathered data, we have learned that increasing the number of iterations increases signal strength tremendously since decibel milliwatts are a logarithmic unit. It did not support our hypothesis that the relationship would be linear; the relationship is direct and exponential. Though the data did have a somewhat substantial margin of error, we believe that the amount of data gathered offsets the error.

Summary Statement

Through our project, we wanted to measure the effectiveness of increasing the number of iterations of a fractal in a fractal antenna and the wireless signal reception strength as a result.

Help Received

Consulted with my father on how to measure the wireless signal strength; Consulted with my physics teacher, Doug Miller, on how to control external variables

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Maitreyee R. Joshi

Project Number

S0911

Project Title

TouchProsthetics: Bringing Tactile Sensations to Upper-Extremity Prosthetics Using Haptic Devices

Abstract

Objectives/Goals

The goal of this engineering project is to improve the usability of upper-extremity prosthetics for amputees by creating a tactile feedback device that would allow them to feel intuitive tactile sensations, such as contact and pressure, through the prosthetic arm.

Methods/Materials

The major components of this tactile feedback system are fingertip sensors, an embedded control system, and haptic tactors; more specifically, force-sensing resistors for used for sensors, DC motors are used for haptic tactors, and a Buffer IC and a Arduino Uno Microcontroller Board are used for the embedded control system. According to the amount of force detected in the force-sensing resistors, different amounts of voltage are sent through the circuit. In accordance to the amount of input voltage, the DC motor rotates at a particular speed. The faster the DC motor rotates, the more torque it creates and thus the greater amount of force it pushes with.

Results

To determine the accuracy of tactile feedback device, the amount of force placed on the force-sensing resistors on the end effectors of the prosthetic arm was compared to the amount of force that was outputted by the DC motors. The graphs of the resistance and voltage outputted over time from the circuit containing the force-sensing resistors and the power source were used to calculate the approximate amount of force placed upon the end effectors of the prosthetic arm; this was compared to force outputted from the DC motors, calculated by measuring the approximate number of rotations of the motor and then calculating torque and force it created. By examining the graphs of input force and output force, it is evident that the tactile feedback device is quite successful in recreating the approximate amount of force that is being applied at the sensors.

Conclusions/Discussion

By examining the amount of force outputted by the motors in relation to the amount of force placed upon the end effectors of the prosthetic arm, it is evident that the method of using several haptic devices to correspond to the sensors was extremely successful. Consequently, this engineered device has demonstrated that, by placing sensors on the end-effectors of the prosthetic arm and motors on the nerves of amputees, a sense of force can be recreated. Using this same method, other senses of tactile sensation, such as temperature, vibrations, and shear force, can be recreated as well.

Summary Statement

This tactile feedback device brings tactile sensations to upper-extremity prosthetics for amputees, allowing them to feel sensory information through their prosthetics as if it were coming from a real body extremity.

Help Received

Family friend provided soldering material and gave advice on the different types of materials available on the market to build the device

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Eesha Khare

Project Number

S0912

Project Title

Design and Synthesis of Hydrogenated TiO2-Polyaniline Nanorods for Flexible High-Performance Supercapacitors

Abstract

Objectives/Goals

With the rapid growth of portable electronics, it has become necessary to develop efficient energy-storage technology to match this development. While batteries are currently used for energy-storage, they suffer from long charging times and short cycle life. Electrochemical supercapacitors have attracted attention as energy-storage devices because they bridge the gap between current alternatives of conventional capacitors and batteries, offering higher energy density than conventional capacitors and higher power density than batteries. Despite these advantages, supercapacitor energy density is much lower than batteries and increasing energy density remains a key challenge in supercapacitor research. The goal of this work was to design and synthesize a supercapacitor with increased energy density while maintaining power density and long cycle life.

Methods/Materials

To improve supercapacitor energy density, I designed, synthesized, and characterized a novel core-shell nanorod electrode with hydrogenated TiO2 (H-TiO2) core and polyaniline shell. H-TiO2 acts as the double layer electrostatic core. Good conductivity of H-TiO2 combined with the high pseudocapacitance of polyaniline results in significantly higher overall capacitance and energy density while retaining good power density and cycle life. This new electrode was fabricated into a flexible solid-state device to light an LED to test it in a practical application.

Results

Structural and electrochemical properties of the new electrode were evaluated. It demonstrated high capacitance of 203.3 mF/cm2 (238.5 F/g) compared to the next best alternative supercapacitor in previous research of 80 F/g, due to the design of the core-shell structure. This resulted in excellent energy density of 20.1 Wh/kg, comparable to batteries, while maintaining a high power density of 20540 W/kg. It also demonstrated a much higher cycle life compared to batteries, with a low 32.5% capacitance loss over 10,000 cycles at a high scan rate of 200 mV/s.

Conclusions/Discussion

This project successfully designed, synthesized and characterized a novel nanorod electrode supercapacitor with increased energy density while retaining power density and long cycle life. This work is an important initial step in introducing this new electrode material in supercapacitors to replace conventional batteries in flexible electronic devices.

Summary Statement

This project designed and synthesized a novel supercapacitor with increased energy density while maintaining power density and long cycle life using a new core-shell structure.

Help Received

Used lab equipment at University of California Santa Cruz under the supervision of Dr. Yat Li

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

B.J. Kim

Project Number

S0913

Project Title

The Effect of Control Mechanisms on the Stability of an Electronically Reproduced Meissner Effect Levitation System

Abstract

Objectives/Goals

Current systems of magnetic levitation transportation are restricted by its high costs, its inability to become compatible to conventional tracks, and the weight of the large electromagnets on the maglev trains. My aim of my project was to produce a working, stable levitation system which was capable of levitating an object clear of any support on the same level of elevation with the levitated object. Then I experimented to investigate various configurations of electromagnets in order to achieve stable magnetic levitation.

Methods/Materials

I modified the system known as the "magnetic cradle" desgined by Bill Beaty which electronically produces a Meissner-like effect. Instead of applying a switched current control, I worked to develop a magnetic levitation system that would use continuous current control to the elctromagnets. I first tested the control circuitry and the Hall Effect sensor system. Then, I worked to duplicate this system for each electromagnet necessary for the levitation system. From that point, the control circuitry was designed, added, and modifed as necessary to the system. Thus, I created an improved version of the magnetic levitation system from the one with which I began with.

Results

At the completion of my project, I was able to achieve complete stable magnetic levitation. My current system was able to perform stable levitation of a bar magnet with support in the lateral direction. However, various configurations to the control circuitry created an effective electronically simulated Meissner effect. Furthermore, driving of the electromagnets using the continuous current control method provided a relatively simple solution to integrating control circuit.

Conclusions/Discussion

There were two designs used throughout the development of this project - one using a single opamp summer circuit and one with the addition of a phase lead network for speed and position information. However, taking into account the time required for the construction of the system, modifying the control circuit, and the maintenance, the inital single opamp design is more effective. Its results aligned with expectations and it becomes simpler to work with as the system becomes increasingly complex.

Summary Statement

I electronically reproduced the Meissner Effect through five different types of circuitry and linked it to a negative feedback loop in order to create stable bottom-held magnetic levitation of an alnico bar magnet.

Help Received

Father helped with conceptual physics and circuitry. Received help from Professor Konstantinos Michail at the Cyprus University of Technology.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Timothy R. Le

Project Number

S0914

Project Title

Roger Do You Copy? The Design of a Wireless Emergency Communications System (WECS)

Abstract

Objectives/Goals

The goal of this project is to remedy the low reliability of the Internet as a communications medium for emergency communications during a disaster. The network created would be suitable for use by both civilians and first responders.

Methods/Materials

Wireless data radios operating in the 900MHz and 2.4GHz frequencies were obtained and configured extensively to enable the creation and use of a self-healing mesh network. A software radio controller, D-RATS, was obtained and configured for use with the mesh modules. A homing module, designed to track firefighters entering a burning building or police officers as they are patrolling potentially hostile environments, was created using an Arduino microprocessor, a wireless module, a GPS receiver, an accelerometer, an altimeter, a thermometer, and a compass. A notification module was designed that would parse out alerts from the RF data so that alerts could be sent to civilians and/or first responders via a LCD screen without requiring the sending party to switch to a different radio channel. This module consisted of an Arduino microprocessor, a wireless module, a LCD screen, a buzzer, and a LED. Wireless propagation tests were run to ensure the operation of the mesh network. Emergency simulations were staged and the operation of each portion of the designed network was confirmed.

Results

At the end of my project I was able to determine that a mesh network is capable of handling critical emergency data. Through wireless propagation tests at my school and at other areas, it was concluded that the self-healing capabilities of the network allowed for the efficient re-routing of packets around obstructions in the RF pathway. The operation of the homing module was confirmed and the response times of each of the emergency simulations were recorded. The operation of the notification module was also confirmed.

Conclusions/Discussion

As shown by my results, I was able to create a wireless mesh network that would work as a feasible supplement or replacement to the Internet in the case of emergency communications. I would like to further develop this project by creating a unified communications platform through the addition of Internet access through the mesh network and the integration of the current voice communications radios into the system. The dead reckoning of the homing module will be further developed for higher accuracy.

Summary Statement

This project is characterized by the creation of a wireless mesh network by repurposing and designing equipment to fit the needs of a reliable emergency communications system for the first responder and civilian community.

Help Received

Henry Stann (friend) helped with math concepts not yet taught in math class; Gianluca Allen (friend) helped with organization of people to help me run emergency scenarios.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Yibei Li; Wanming Teng

Project Number

S0915

Project Title

Electricity Generating Shoe

Abstract

Objectives/Goals

Our project is to capture kinetic energy generated while walking and transform it into electric energy by induction, and to modify the system into a shoe and is comfortable and convenient to use. This idea, if worked out, not only will offer convenient and portable solution to a personal electricity emergency, but also will provide a legitimate approach to the environmental struggles and energy shortage we are facing and grant an impetus for a healthier and more active lifestyle.

Methods/Materials

1) First we did some useful research on electricity shoes and employed a comparatively simple concept-induction to achieve the goal at a low cost to conduct our experiment.

2) In order to better understand the characteristics of induction and to assure the feasibility of the shoe, we performed a few preliminary experiments with a shake flashlight that applies a similar principle as the shoe.

3) Having analyzed the flashlight tests, we came up with a design involving a diode bridge. We then employed an oscilloscope that offered a visual evidence of the process, to prove the diode bridge to be helpful and effective. We then made several necessary adjustments after further testing with various specifications of electronic components, especially the material of the tube the magnet is going through.

4) We then further modified the size of the system to meet the average sole thickness of shoes on market and made other improvements for customary convenience.

Results

The induction system was made more efficient, that is it can charge up a battery with 500mAh and 5.5V standard voltage within 9 hours under normal walking pace. Also, the core part of the system can be dismantled from the shoe for other uses.

Conclusions/Discussion

The inductance is affected by 4 major factors: number of coils, coil area, length of solenoid and core material. During system improvement, we had to sacrifice one factor for another, and finally came up with this design of a better performance. We believe that there is a better model than what we have currently, and we will keep exploring new methods to perfect the model until the efficiency can reach a level high enough to be widely accepted as a product people would embrace in their daily life. Even if the efficiency is ultimately limited, a far-ranging application of this product would still be a boon to the recycling of energy; just as the old saying implies: many a little makes a mickle.

Summary Statement

Building an electricity-generating shoe that is able to convert the kinetic energy to electrical energy when a person is walking

Help Received

Physics teacher Jack McAleer helped with concepts

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Jonah S. Mau

Project Number
S0916

Project Title
Dirty Energy

Abstract

Objectives/Goals
My project was to determine whether or not dirt build up has an effect on the amount of energy made by a solar panel.

Methods/Materials
Two Identical solar panels were placed outside on a table, while the sun was out, the experimental solar panel was covered with dirt that ranged from 10mL of dirt all the way to 100mL of dirt, 10mL of dirt being added every trial until 100mL of dirt was reached. The control solar panel was clean of dirt. Each solar panel was connected to a current sensor and a voltage probe to see how much energy was made by the two solar panels, four trials for each amount of dirt were done over the lapse of a week.

Results
After 100mL of dirt had been applied to the expiramental solar panel 26% of its energy was lost as compared to the clean control solar panel.

Conclusions/Discussion
My conclusion is that a solar panel loses energy when dirt builds up on it, and that cleaning your solar panels will ensure that you get the most energy that you can out of them.

Summary Statement
My project tested the difference in the amount of energy made between two solar panels, one that is clean and one that is dirty, to see how much energy is lost when dirt builds up on a solar panel

Help Received
Mr. Magni, my teacher, helped me with any questions i had, he also proof read my work.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Isfar S. Munir

Project Number

S0917

Project Title

The Effects of Temperature and Relative Humidity on the Path Taken by an Electric Arc Generated by a Tesla Coil

Abstract

Objectives/Goals

Electric arcs have found much fame for their chaotic and unpredictable behavior. The purpose of this experiment was to determine if properties of the air, such as temperature and relative humidity, had any influence in the behavior of electric arcs. It was hypothesized that both factors would be correlated with arc behavior in some form.

Methods/Materials

A Tesla Coil was used as the electric arc generator. A plant growth chamber capable of controlling both temperature and humidity to a high degree of accuracy was used as the vessel for the experiment. Data would consist of pictures of arcs taken from two different angles. One camera rig had the camera look down vertically upon the arc, and another rig had the camera look horizontally at the arc. These pictures were then process through Microsoft Paint. Maximum deflections of the arcs from an ideal path of the arc were collected, as were areas bounded between the arc and the ideal path. Statistical analysis on this data was then done through Microsoft Excel.

Results

It was found that temperature had a very strong correlation with arc movement within the x-axis of motion (horizontal deflection). As temperature increased, the arc tended to move straighter, closer to the ideal path. Relative Humidity was found to have no significant correlation with arc movement within the x-axis of motion. Within the z-axis of motion (vertical deflections), neither temperature nor humidity were found to have correlations with arc deflection.

Conclusions/Discussion

Overall, the results of the experiment show a much less chaotic picture of arc behavior. No previous studies on the effects of environmental factors on electric arc behavior have been done. This study represents a step forward in the field. The implications of the study are that arcs are predictable phenomena, and that they can be controlled through the manipulation of the air. This opens the future possibility of controlled lightning, or at least predictable lightning. Controlled lightning could be used as a tool to power the world; predicting where lightning would strike would save lives by identifying areas in danger of a lightning strike. Future studies would focus on creating statistical distributions to account for the variances of arc behavior within a data set and on manipulating the arc to strike specific targets through the manipulation of air.

Summary Statement

This project determined the previously unknown effects of relative humidity and temperature on deflections of electric arcs from their ideal paths.

Help Received

Professor Randy Harris and Professor Cort Anastasio of UC Davis assisted in the data analysis portion of the experiment. Mr. Dennis Lewis of the UC Davis Controlled Environment provided the climate chambers used for the experiment.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Mihir S. Sirdesai

Project Number
S0918

Project Title
Sustainable Household Appliance: Magnetic Induction Clothes Dryer

Abstract

Objectives/Goals
The objective is to determine if magnetic induction dryer will dry clothes more efficiently than conventional gas or electric dryers.

Methods/Materials
Experiment 1: The control experiment was carried out as follows: A piece of cloth (to simulate light load) was weighed. It was wetted with water and weight was noted. To simulate conventional dryer, bubble wrap covered the inside of the drum roller. The hair dryer was placed in the holder directing hot air inside the drum roller. The cloth was the placed inside this drum roller, and heater and gear motor were turned on simultaneously. The weight of cloth was determined at specified intervals by removing the cloth and placing it on a balance. When the weight reached the original weight (the weight of cloth before it was wetted), I surmised that cloth was fully dry. In the test experiment a similar procedure was carried out. The same cloth was weighed, wetted with exact amount of water and placed in drum roller. This time the bubble wrap covered the outside of the roller instead of inside. Magnetic Induction Cooktop with magnetic coils was turned on along with gear motor. The cloth was weighed at regular intervals mentioned in the control experiment and its weight recorded till it achieved its original weight.
Experiment 2: The exact procedure mentioned in Experiment 1 was followed except the cloth was folded to resemble a heavy load.

Results
The following parameters were used for calculating the energy used.
Control Experiments used Hair Dryer which was 1875 watts/sec
Test Experiments used Magnetic Induction Cooktop + Fan = 1200 + 10 = 1210 watts/sec
Total Energy Used (watts) = Power (watts/sec) x Time (seconds)
In Experiment 1 for light loads, the control experiment used 618750 watts while the test experiment used 435600 watts which was 29.6% more efficient.
In Experiment 2 for heavy loads, the control experiment used 3,600,000 watts while the test experiment used 2,904,000 watts which was 19.3% more efficient

Conclusions/Discussion
Test results show that clothes dryer with magnetic induction principles will dry clothes efficiently. The reduced power will account for roughly 25% reduction in carbon dioxide emissions. Or U.S. households will be emitting 14.4 million tons annually less carbon dioxide. Moreover, U.S. consumers will encounter 25% savings of cost for drying clothes.

Summary Statement
The project is about drying clothes more efficiently through magnetic induction and reduce carbon footprint.

Help Received
Friend helped to build apparatus.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Amit S. Talreja

Project Number
S0919

Project Title
3D Volumetric Projection Using a Microprocessor Controlled LED Array

Abstract

Objectives/Goals
To create a true 3D display that does not rely on illusion of depth, design should be capable of projecting simple geometric shapes and some animation in three dimensions.

Methods/Materials
An Arduino# microcontroller is main processing unit and is programmed to control the display. The mechanical structure is built using Lego# components and consists of five horizontal arms rotated at very high speeds around a central axis by a DC electrical motor. Blue LEDs placed on these arms are sequenced by the C-based computer program to produce the desired image.

Results
The objective of the project was met because the design is able to display simple geometric shapes such as cones and cylinders. It can also project simple animations. The design accepts an input of a 3D shape and the computer program I developed is able figure the LED sequence in order to produce the desired shape.

Conclusions/Discussion
Though the project met its objective by developing a proof of concept for the display. I have identified the different improvements that can be done to make the design more robust. The concepts in this project can be applied to a number of real world applications. For example the software algorithm can be implemented in current 3D display technologies to make them more efficient. The mechanical design can be scaled up to make a practical display for hospital MRI scan projection or teleconferencing.

Summary Statement
Design and fabrication of a portable 3D display capable of projecting geometric models

Help Received
Mother helped lay out and glue board

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Nathaniel G. Varghese

Project Number
S0920

Project Title
A Robust Human Fall Detection Wireless System

Abstract

Objectives/Goals

One third of people over age 65 in USA fall every year; the average healthcare cost due to fall related injuries is ~$20,000 per year per person. In many falls, timely help is more critical than the damage due to the fall itself. Automatic fall detection and alerts can improve responsiveness at lower costs and help avoid critical health conditions.

My project is a system designed to automatically detect a human fall and wirelessly send an alert to a remote monitoring station. It improves existing solutions in this domain by the automatic nature of the fall detection and improving the robustness of the solution through a unique algorithm that reduces false alerts

Methods/Materials

The system consists of two hardware modules - a detection system and remote monitoring system. Both use the Arduino platform for the code development. An accelerometer is used for sensing the fall and XBee radios are used for wireless communication. LEDs are used to visually indicate the occurrence of various alert conditions. The main algorithm for fall detection consists of four steps based on the physics of what actually happens when a person falls down.

There were 3 stages in this project. The Stage 1 was the building the fall detection hardware and writing the basic software for fall detection. In Stage 2, I built the wireless radio setup using XBee radios, the radios configured using the X-CTU program on the PC and got basic wireless communication between two XBee radios working. In Stage 3, I put the fall detection system and the radio together. Then I tested various fall conditions and tuned the parameters to make it work robustly

Results

The system was built successfully and tested under various fall conditions and results are demonstrated

Conclusions/Discussion

I demonstrated that a Robust Human Fall Detection Wireless System could be built meeting the design goals set out. Key novelty in my system compared to prior approaches:
1) No human intervention to detect fall and generate alert
2) Robust algorithm that minimized false alerts
3) Wireless communication built in for immediate remote alert

Summary Statement

It is a system designed to automatically detect a human fall and wirelessly send an alert to a remote monitoring station

Help Received

My Dad ordered all the parts and helped with soldering the components.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Haotian Xu

Project Number

S0921

Project Title

EEG Cortical Signal Acquisition System for Automatic Artifact Removal, Evaluation, and Monitoring of Cochlear Implants

Abstract

Objectives/Goals

The electrical stimulation from a cochlear implant (CI) must be fine-tuned (fitted) regularly by an audiologist for each individual user. Recent research has shown that it is possible to objectively assess CI performance by measuring neural responses of the cortex to a sound stimulus using an electroencephalogram (EEG) system. However, this EEG system has not been optimized for CI applications. The purpose of this project is to determine the minimum system requirements for a CI-specialized EEG system to accurately measure the cortical evoked potentials from the brain and filter out the large electrical artifact from the CI.

Methods/Materials

For the hardware component, I designed and implemented a single-stage differential amplifier circuit and a low-pass filter and combined these with a sound card found in computers to create a simple, low-cost EEG system. On the software side, I wrote computer software in the MATLAB programming language to control the experiments and to collect, display, and analyze the data. An expensive, professional-grade system (~$5000, 4 stage differential amplifier and 3 stage band-pass filter) was used as the baseline. For each experiment, I sampled the average of two hundred N100 neural response signals to a 300ms tone at 1000Hz.

Results

The results showed that the simple, low-cost EEG system (<$50, 1 stage differential amplifier and 1 stage low-pass filter) is able to measure cortical evoked potentials in CI users. It can remove the large CI-induced electrical artifact obscuring the neural response and yield comparable data to the expensive, professional-grade EEG system.

Conclusions/Discussion

This EEG system has two significant advantages over the professional-grade system. First, its low cost allows it to be accessible to CI users and small audiology clinics. This system can be used at home by CI users to monitor the functionality of the implant and to objectively track the user#s hearing development. The system will also allow parents of infant CI users to ensure that the CI is functioning properly and that the child#s auditory system is developing normally. Secondly, its simplicity in design allows the system to be much more compact than existing models, paving the way for future developments to integrate the EEG data acquisition system into the CI itself to create a closed-loop, self-monitoring, and self-fitting system.

Summary Statement

This project determines the minimum requirements for an EEG system specialized for cochlear implant (CI) applications to remove CI-induced electrical artifact and measure neural responses of CI users to objectively assess CI performance.

Help Received

Dr. Myles McLaughlin assisted in writing the computer software in the MATLAB programming language; Used lab equipment in the Hearing and Speech Lab at the University of California, Irvine under the supervision of Dr. Fan-Gang Zeng and Dr. Myles McLaughlin.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Daniel S. Yang

Project Number

S0922

Project Title

A New Radio Propagation Model at 2.4 GHz for Wireless Medical Body Sensors in Outdoor Environment

Abstract

Objectives/Goals

This project investigates the effect of antenna height, receive antenna on human body, and path distance on the loss of wireless signal power in order to systematically develop a radio propagation model for wireless body sensors. While many studies looked at only distance, this project is novel as it also examines the effect of antenna height and on-body antenna. Studying the effect of on-body antenna is central to wireless telemedicine sensors, which have notable healthcare benefits.

Methods/Materials

Received power in dBm was measured as a function of 4 independent variables: transmit (Tx) antenna heights of 1, 2, and 3m, receive (Rx) antenna heights of 1m (waist height) and 1.65m (head height), Rx antenna placed on-body and off-body, and 11 distances from 1 to 45m--resulting in 132 data points. For Tx unit, a home wireless router hung on a vertical plank was used. For Rx unit, a wireless USB device hung on a vertical stick, a laptop and spectrum analyzer software were used to measure received power.

Results

Multiple regression and t-test are used to analyze data. Significance of a variable is tested by comparing its p-value with alpha (5%); model fit is assessed using adjusted R^2 and standard deviation (sigma) of residuals. Experimental results support the 3 hypotheses that placing Rx antenna on-body and increasing distance would decrease received signal power; increasing antenna height would increase power--but only for Tx antenna. Rx antenna height has a surprising/opposite effect in on-body case, in which mean received power for waist-height antenna is significantly higher than that for head-height antenna, a phenomenon possibly due to a focusing effect in antenna pattern when Rx antenna is near the abdomen.

Conclusions/Discussion

Successive models improved as adjusted R^2 increased. Regression coefficients are incorporated in an extension of classical log-distance model to generate new on-body and off-body empirical propagation models. More accurate models allow lower Tx power margins, making devices more energy-efficient and saving battery--important in small wireless sensors. The final, off-body and on-body multiple regression models have respective sigma of residuals of 3.0 and 4.2dB (measures of model accuracy), as compared favorably to those of past studies (e.g., sigma=6 to 10dB reported). The new empirical model can be utilized to design more reliable wireless links for medical body sensors.

Summary Statement

This project collected field data on received power as a function of distance, transmit antenna height, receive antenna height, and antenna on/off the body to develop a new multivariate radio propagation model for wireless medical sensors.

Help Received

My teacher supervised the project and my parents helped me on the background research and field measurement setup.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Mike Zhao

Project Number
S0923

Project Title
A Novel Method of Lens Velocity Detection in the Vibrating Linear Motor

Abstract

Objectives/Goals
The Voice Coil Motor is a miniature autofocus component widely used in cellular phones and tablets, with yearly shipment close to 1 billion units. However, the VCM has two main drawbacks: lens tilt and high power consumption.
Galaxycore Inc. (an image sensor company) is developing a next generation miniature autofocus component called the Vibrating Linear Motor. The VLM#s design avoids the VCM#s two main drawbacks. Also, the VLM is able to increase its lens height during operation. The increased lens height will significantly improve camera module performance.
In the VLM, a series of springs clamps the lens assembly in place. Permanent magnets surround a coil of wire, which is attached to the lens assembly. Applying current to the coil of wire will generate force to move the lens assembly along the optical axis. Once optimal focus is obtained, the series of springs holds the lens assembly in place via friction. Autofocus in this manner is precise and energy efficient.
Precisely moving the lens assembly step-by-step is very challenging. Galaxycore Inc.#s engineers suggested vibrating the lens assembly to achieve step-by-step lens motion. Therefore, successful detection of the lens assembly#s vibrations is the key to building the next generation miniature autofocus camera component.

Methods/Materials
Instead of adding extra components for motion detection, which was recommended by Galaxycore Inc.#s engineers, I considered the possibility of using the existing coil of wire (which is used to move the lens assembly) for motion detection. To prove my hypothesis, a weight was super glued to a VCM camera module lens assembly, and the VCM was flipped upside down and set between two stands, and on a table. The wire leads of the VCM were connected to an oscilloscope. Knocking the table gently with a mallet would cause the table to vibrate, and so would the lens assembly. Lens assembly vibration would create induced current, which would be recorded by the oscilloscope.

Results
Because the lens assembly was attached to a coil of wire, when this coil of wire moved inside the VCM#s magnetic field, the change in magnetic flux would create induced current.

Conclusions/Discussion
By measuring this induced current and analyzing the data, we can conclude that we can indeed use the coil of wire during vibration to detect the lens assembly#s velocity.

Summary Statement
I am trying to find a new way to detect lens motion inside miniature cameras.

Help Received
Used lab equipment at Stevenson School under the supervision of Mr. McAleer, Used lab equipment at the company Galaxycore Inc.

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Neil Gandhi; Quentin Wetherholt

Project Number

S0997

Project Title

Implementing an Optical Method in an Open Platform Multi-touch Computer Interface

Abstract

Objectives/Goals

Our goal is to build a multi-touch computer interface that combines both the powerful processing power of a modern day computer and effective interface of a touch screen device in an open platform.

Methods/Materials

When light strikes a boundary of a medium at an angle higher than the critical angle, all of the light will be internally reflected within this medium, hence the name total internal reflection. In this project, 850 nm infrared light was illuminated into a sheet of acrylic at a near-parallel angle, causing total internal reflection. When a human finger touches the acrylic surface, the light would scatter downwards at that point and a webcam modified with a visible light filter situated orthogonally underneath the acrylic surface would pick up these disturbances and send this data to software, which would translate it into mouse clicks, thereby allowing multi-touch control of the computer. By illuminating an LED projector onto an opaque acrylic surface, we were able to build the entire multi-touch computer interface for under $400.

Results

Our devices forty-inch display and ability to translate over thirty fingers of interaction combined with a strong processing power has revolutionary implications for a wide range of uses. For example, while currently airport kiosks can only service users individually, our 40-inch multi-touch table would allow a family of three to easily input all their information on three different windows and process their boarding passes simultaneously. As another example of the computer's broad utility, users who want to learn the piano can simply open up the virtual piano application on the first half of the screen and video tutorials from Youtube on the other half of the screen to learn how to play the instrument. These are unique and patentable applications.

Conclusions/Discussion

In this novel approach to building a multi-touch interface, our project combines three unique ideas. While most touch screens are limited to ten finger input, our computer's unique design allows up to thirty fingers to input information simultaneously, allowing for multiple user interaction. Also, the computer is an open platform, so it is not limited to a specific operating system. Most importantly, the multi-touch effect can be powered by any PC unit, so it maximizes both a strong processing power and an effective interface.

Summary Statement

Our project employs the theory of frustrated total internal reflection in order to create an open platform multi-touch interface for less than four hundred dollars by using skills from electrical and civil engineering.

Help Received

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)
Dylan T. McNamara

Project Number
S0998

Project Title
Speeding Up the Superhighway

Abstract

Objectives/Goals
The objective of the experiment is to boost ones household internet signal without spending a lot of money and to eliminate off property signal. I believe that by placing a parabolic dish around the antenna of my wireless router, I will be able to eliminate off property signal and boost my internet speed by 50%.

Methods/Materials
The materials which will be used are a wireless router with an antenna, an internet connection, a computer, a wireless receiver card, a parabolic dish, and a 3D printer. The tests will be conducted at four places. I will be measuring the straight path of the connection time at 0 feet, 50 feet, 100 feet, and 150 feet. Each distance will be tested on a) Ping time without the Dish; b) Ping time with the dish; c) Connection speed without the dish; d) Connection speed with the dish. This will add up to a total of 400 tests. I will be testing each category a total of twenty-five times each. Each test is to be conducted at 30 second intervals to ensure the router has refreshed.

Results
The results conclude that my hypothesis was correct in assuming that by placing a parabolic dish around an antenna of a router that the speed would be increased. After testing the #ping#, of the router before and after the placing of a parabolic dish on the antenna, at 0ft, 50ft, 100ft, and 150ft I noticed a significant decrease in the time it took to ping the router. The dish hadn't effectively improved the signal at [ZERO ft] but the further you went away from the router [50ft-100ft-150ft] the longer it took to complete a ping test. But after placing the dish on the antenna, the speed was significantly increased.

Conclusions/Discussion
My conclusion is that all routers send signal in areas where you might not need nor want it. By placing this parabolic dish around your antenna it can harness that unused internet and send in right back into your home (preventing others from logging into your router) and boost the connection speed by 50%.

Summary Statement
My project is primarily to increase internet speeds for the common people who can't afford to pay for a more expensive plan by engineering something that can be available to everyone.

Help Received
Velma Lomax helped with networking; Karen Reynosa helped with planning; Dennis from TDC provided his 3D printer and supplies; Mr. Tolkmit helped with the math; Jake Stelman helped with SolidWorks design;

CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Paul A. Dennig, Jr.

Project Number

S0999

Project Title

ZigBee-based Indoor Positioning System with Intelligent Assistive Technology for Alzheimer's Patients

Abstract

Objectives/Goals

Alzheimer's Disease (AD) is a neurodegenerative disorder that causes problems with memory and spatial orientation. Today, over 15% of the 5.4M Americans with AD live alone. I want to improve their lives by building an affordable indoor positioning system (IPS) that serves two functions: (1) guide them to their destinations indoors and (2) allow caregivers to locate them and to monitor vital factors remotely.

Methods/Materials

Materials used were 5 ZigBee digital radios, 4 Arduino microcontrollers, an audio wave shield, an infrared motion sensor (IR), LEDs, a switch, and a 9V battery. I built a small remote control for the patient with a ZigBee, a battery, and a switch. I installed ZigBee-Arduino pairs at the same height from the floor in the four extreme corners on the first floor of my home. The bathroom is in one of the corners, where I added the wave shield, IR, and LEDs to the master Arduino. I wrote and loaded a program into this bathroom setup. To test the spatial-orientation procedure, I pressed the button on the remote control. Then the LEDs in the bathroom went on and the wave shield played "Bathroom is here" repeatedly until the IR detected my motion. I tested the procedure starting in four positions, 30 times each. For the second function, I wrote a program with a 2D mathematical trilateration algorithm. Then, from an accurate map of the floor, I modeled the distances between the remote and each one of the corner ZigBees for five different scenarios (e.g. living-room). These data were put through my trilateration algorithm.

Results

The bathroom setup worked 100% of the time in all positions after I improved the spatial-orientation algorithm so that it matched the flow chart more accurately. The computer simulation on the trilateration algorithm worked to within 6% of the actual position in the five scenarios.

Conclusions/Discussion

GPS only works outdoors. My IPS is low cost, simple to install, and has low battery consumption and radio power. It is also integrated with intelligent assistive technology and can be expanded to include more functions. In the future, I will implement the trilateration using RSSI from the ZigBees and connect the main Arduino to the Internet so that caregivers can see the patient's indoor position by logging onto a secure web site.

Summary Statement

I created an affordable indoor positioning system with intelligent assistive spatial-orientation technology to help Alzheimer's patients and their caregivers.

Help Received

My math teacher and advisor, Dr. Carol Evans, helped me understand the math for trilateration. Dad helped me resolve engineering and programming problems. Mom helped me with edits.