New Paltz
STATE UNIVERSITY OF NEW YORK

Division of Engineering Programs

SENIOR DESIGN PROJECT PLAN

Fall 2017 and Spring 2018

Who Let The Dog Out?

Student Name	Student Major	Grade Received
Bryan Darcy	CE	
Samuel Darkwah Boahen	CE	
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Stephanie Fernandez	ME	
Daniel Pineda	ME	

Advisor's or Stakeholder's name	Affiliation
Dr. Baback Izadi	SUNY New Paltz

ABSTRACT

In this project, we plan to create an optimized smart pet door that implements an Internet of Things architecture. The project will utilize Firebase, a cloud service to receive, store, and send data, an Android app to provide user/consumer interaction, and a microcontroller to automate the door's mechanical aspects (i.e. sensors, motors, LEDs, sounds). The expected outcome of this project is a marketable smart pet door and Android app.

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INTRODUCTION

We are going to redesign and add an important feature to a smart pet door. A smart pet door is a pet door that opens automatically when it senses a chip on the pet's collar. We will be redesigning the door to have a sliding elevator door motion and we will be adding Internet of Things (IoT) to this product. IoT will allow for the pet door to be controlled from a phone in order to lock or unlock the door from either side depending on where you want your pet to be.

Many people would like to let their dog out into the yard while they are at work or away. With this project, the user will be able to choose when their dog gets to go out into the yard while also being able keeping them in the house if, for example, it's raining. In addition, the elevator door is important to this project because there are many animals that do not feel comfortable walking into a door to open it; some animals are shy. The door sliding open by itself is not daunting and it is actually inviting because the animal just has to walk through.

The expected benefits are to allow a sense of safety and a convenient way of keeping an eye on where your dog is. In addition, this could be great for handicapped or busy people who will no longer need to physically go to the doggy door in order to unlock it.

PROJECT SCOPE STATEMENT

The objectives for this design are to create a physical (mechanical) pet door and design an Android app that allows the user to control it at any time and place. Additionally, a cloud server and user interface will be designed to provide smooth interaction. This project needs to be safe for pets, allow for multiple collars to have access to the door, and needs to be able to work from the phone or buttons on the mechanism.

Economic: Affordable consumer price

Environmental: door must account for weather, leaks, insulation

Health and Safety: Wires must be covered, sensors must function properly

THEORY

In order for our project to work, we will be putting a door that slides up and down with a gear on each side of the door. The sides of the door will have a rack gear and the two gears on the sides will be pinion gears. An example of a rack and pinion gear is shown below.

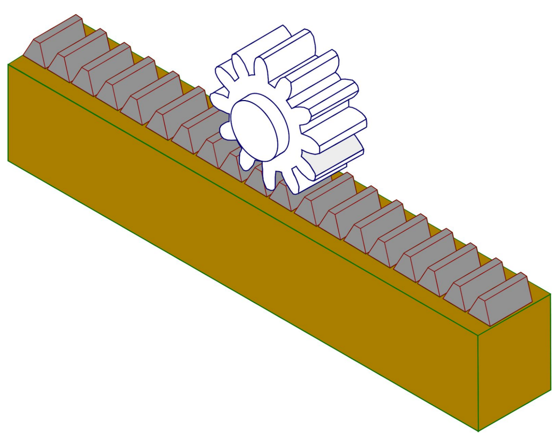

Figure 1: Rack and pinion gear [2].

This works for the project because of the gear equations for gear teeth and this will help us determine the length of the rack gear and the radius of the pinion gear, as well as the amount of teeth on each. The equation that is used for this are shown below.

$$\frac{\omega_{pinion}}{V_{rack}} = \frac{1}{r_{pinion}}$$

Figure 2: Rack and pinion gear equation for the radius of the pinion [2].

With these equations, the door will be able to slide up and down in order for the animal to get through.

Next, with the door we need to consider the weight of the door and the force that the gears will need to push up and hold. This can be explained with the simple force equation (shown below), with m being the mass of the door and a being the acceleration of gravity.

$$F=ma$$

Figure 4: Force equation.

This will help us to make sure that the gears can hold up the door so it doesn't fall on any animals and to know how fast the gears can make the door lift.

For the CE aspect of the theory, we will be focusing on making state machines and programming the board, along with programming the app and Firebase. There are two types of state machines: Mealy and Moore. By analyzing the way the microcontroller moves between states we will be able to determine the most ideal machine to use. In most cases, having less states is ideal where in other cases it is more ideal to have a system that considers all input and output options, which could mean more states.

Another aspect to consider is the real time aspect of the system. We need to determine if the system will be hard real time or soft real time and how to optimize the timing, not only to have a faster system that can provide better data, but also so that the door mechanism will not fail and potentially hurt a pet due to delayed reaction time of the system.

PROJECT APPROACH

For the mechanical engineering application the first approach of the project will be to determine the necessary constraints as well as an organization to the project itself. The build of the door will be approached first by looking at the characteristics of the door itself, as far as insulation and strength, then coming up with a design for the doggy door that will not subject the door to improper insulation. Materials for the door will be chosen as well as the best design possible for smooth operation. The gears and motor, as well as linkages that will be used to make the door open and close will also be determined considering the strength of certain gears and linkages, as well as gear ratios. All of the mechanical components also need to be a specific size as they need to fit in the doggy door. The doggy door will be a specific size as we want it to be a sleek design, and pleasing to the consumers eyes. After the design components are determined a prototype will be designed using solidworks. The gear trains as well as the linkages used will be designed on this software as well as the outer shell for it. After the design is implemented a scaled model will be 3D printed for all of the components, due to a size constraint for the 3D printer. This 3D model will help us determine any flaws in the design. Once any flaws are corrected and the model is what we want, a proper real model will be built. A model will be built with the proper materials chosen, and all the gears in the proper orientation with everything working properly. Once the doggy door is ready, a half door will be used with a cutout for the dimensions of doggy door, to demonstrate how the doggy door itself will fit in a real application

As for the computer engineering side of the creation of this project, we will be focusing on the computer system itself. We will approach this by considering the architecture of the system, the three programming aspects (Firebase cloud server, Android app, and microcontroller programming), and the electronic components (power source, sensors, wires) with proper function. After these are done, the system will be debugged and verified. The general architecture of the system is that the Android app and device must read and write data from the Firebase cloud server, the Firebase cloud server must send and receive data from the Android app and device and the microcontroller and sensors on the door, and the microcontroller must send data and receive signals from the Firebase cloud server.

The first aspect to focus on would be the Firebase cloud server and the microcontroller programming as these will be the most complex and vital parts to the project. These parts will be an ongoing work in progress while the Android app, wiring and sensors are being developed. To be more specific on the timeline, the Android app will start to be developed, then the sensors will be implemented into the microcontroller programming, and then the wiring will be added to the door all while the Firebase cloud server is being optimized and changed based on project needs.

PROJECT SCHEDULE

The time range of this project will be approximately 10 Months (2 Semesters at SUNY New Paltz). The first semester of this project is Fall 2017, and the second semester is Spring 2018. The plan for each semester is in the following sections.

Fall 2017

For Senior Design 1, we are designing a small-scale 3D printed prototype of the pet door with all working pieces and circuitry. As for Senior Design 2, we will be making a full size model of the pet door with all working pieces and circuitry. This will probably include a big, half-door-sized piece of wood that we drill a hole into and install the pet door.

From the Gantt chart, in this semester, the MEs expect to have the 3D model designed by the end of the 10/20 week and printed by the end of 11/03 week. By the end of the 11/16 week, any parts that need to be reprinted parts should be printed. Then, the gears and motors should be put in and working by the end of the 11/23 week. As for the CEs, we expect to have all Firebase research and the Android app skeleton done by mid-week of 10/26. The Firebase/microcontroller programming would take the most time, being done by the week of 11/30. After that, the debugging and app implementation should be done by the week of 12/07.

Spring 2018

For the Spring 2018 semester, the MEs expect to work on the life-size model from the beginning of the semester until about the week of 03/05. Then, the motors and gears should be working by 03/12, and the circuitry should be done by 04/09. The CEs at this point will have optimized and debugged the code for the microcontroller, the Firebase cloud server, and the

Android App, so that the systems are working properly and efficiently. We are considering being able to market the project by the time the Senior Design 2 presentations are being done.

RISKS

A practical risk with this project is someone breaking into the door. It would take quite a bit of work to make the door withstand punching or kicking (or maybe even a really strong dog pushing it trying to open it). Another practical risk could be weather. This product may be more attractive to people in warmer climates, for example Florida. This may be due to pets being able to be outside all year round. An issue we can run into is the product being used in colder climates, and how the doggy door will react.

CONCLUSION

The main points of the plan is to research, design, and implement the best doggy door for consumers, and to engineer a doggy door with features that make it more convenient for a user. The proper materials need to be chosen with safety, as well as reliability strongly considered. The door will be designed to operate smooth, and be built to last. Allowing for the user to have more control over the door is also a major goal. Overall this doggy door will be different from competitors as it carries features others do not have. This will make life easier with the use of a doggy door.

After much research, planning, and deliberation, our team has figured out many of the risk, restrictions, and limitations that may be encountered. One of the biggest difficulties was trying to create a balanced project where Computer and Mechanical Engineering expertise can be incorporated. Each team member is now aware of their contributions and specialties, and how they will be called upon for the success of this project.

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[3] “Building Elements - Heat Loss and Thermal Resistivity.” The Engineering ToolBox, Engineering ToolBox, from <www.engineeringtoolbox.com/heat-loss-buildings-d_194.html.>

[4] “ B18 STANDARDIZATION OF BOLTS, NUTS, RIVETS, SCREWS, WASHERS, AND SIMILAR FASTENERS.” Committee Pages - B18 Standardization of Bolts, Nuts, Rivets, Screws, Washers, and Similar Fasteners, from <cstools.asme.org/csconnect/CommitteePages.cfm?Committee=C18000000>

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APPENDIX

I. Project Stakeholders and Communication Plan

Stakeholders: Dr. Baback Izadi, SUNY New Paltz

TEAM MEMBER ROLES	
Name	*Role*
Bryan Darcy	Android app design
Samuel Darkwah Boahen	Sensors, Project Management
Lunmar Alcantara	Microcontroller programming, Cloud server setup
Stephanie Fernandez	Sliding door & safety, heat transfer testing, insulation
Daniel Pineda	Sliding door & safety, material selection, insulation

MEETING TIMES	
Team Meetings	*Advisor Meetings*
TF 12:30PM-1:45PM	M 3:30PM-4:30PM or T 12:00PM-1:00PM

Presentations and Reports:

Team Charter - 09/18/2017
Professionally written paper that documents the start of the project.

Team Charter Presentation - 09/26/2017
Professionally present the start of the project to spark discussion and collaboration between teams.

Project Plan - 10/17/2017
Professionally documents a detailed project plan. This plan will form the baseline for the project and is to capture all key technical elements and work items required to describe and complete the

project. This plan will also document the engineering constraints that will drive the project, the codes and standards that apply to the project, and the different disciplines planned for use in the project.

II. LESSONS LEARNED:

A lesson learned, is to increase the depth of research in a design idea. Research was done to see where the advancement of pet doors has moved As we continued to develop our ideas, we realized that the enhancements we were planning to make to the product we originally stumbled upon, already exists. Finding that this product exists was not the major issue; the bigger issue was the features available on the more advanced doggie door made the team begin to think further about security. The original concern regarding security was more so cybersecurity, but now we are considering physical security.

Other expected issues may be physical proper fitment as a whole, as well as the space inside the product for the electrical parts to be contained properly.

III. DESIGN CONSTRAINTS THAT ARE DRIVING THIS PROJECT

This table shows the design constraints that will drive this project:

Table 9.1: Design constraints that drove this project

Design Constraint	**Check if applied to this project**
Economic	✔
Environmental	✔
Health and Safety	✔

The Engineering constraints have to be kept in mind to keep the project moving in the direction that we want it to. For economic constraints we have to keep in mind that we have a budget of 200 dollars to spend, but we also have to keep in mind that similar products exist and we need to make a product that costs less while offering more. Another constraint is health and safety; we need to make sure that no one, person or animal, will be harmed because of our project. We need to make sure that the material is sturdy enough and that all electrical wiring is properly covered. We also need to have safety mechanisms in place on the door. Environmental constraints include making sure the materials can handle the weather extremes in the region where it will be used. In addition to insulating the door year round.

IV. ENGINEERING STANDARDS THAT WILL BE USED IN THIS PROJECT

This table shows the engineering standards planned for use in this project:

Table 9.2: Engineering standards used in this project

Engineering Standard	Where it was used
Thermal Resistance Inside and Outside Walls [3]	This is used for the pet door because we have to be aware of the heat coming in or out.
Animal Welfare Act (AWA) [1]	This is used for the project as a whole because we are making sure that there is no animal testing involved in the whole process.
B18 Standardization of bolts, nuts, rivets, screws, washers, and similar fasteners [4]	This is used for the fasteners that will be used to hold the door together.

IEEE Standard for Software Quality Assurance Plans [5]	This standard will be used to maintain and deliver working software which includes software quality assurance.

\V. DIFFERENT DISCIPLINES PLANNED FOR USED IN THIS PROJECT

The first column of Tables 9.3, 9.4 and 9.5 show that different disciplines that will be used in this project. More specifically, the second column shows the course(s) within the disciplines whose learning outcomes are planned for use in the project.

Table 9.3: Electrical Engineering (EE) Disciplines and Courses within discipline in the EE program

Discipline	Course in the discipline	Check if used
D1) Computers	EGC251 C/C++ Programming	✔
	EGE331 Computer Simulation (MATLAB)	
	EGC331/EGC332 Microprocessors + Lab	✔
D2) Analog Electronics	EGE200/EGE201 Circuit Analysis + Lab	✔
	EGE320/EGE322 Electronics I + Lab	✔
	EGE321/EGE323 Electronics II + Lab	
D3) Signals/ Systems	EGE311 Signals and Systems	
	EGE416 Control Systems	
	EGE417 Digital Control Systems	
	EGE412 Communication Systems Theory	

	EGE493 Applied Digital Signal Processing	
D4) Electromagnetism	EGE340 Applied Electromagnetics	
	EGE445 Antenna Systems	
	EGE493 Intro to MEMS	
D5) Energy Systems	EGE350/EGE351 Electric Energy Systems + Lab	
	EGE452 Electric Power Systems	

Table 9.4: Computer Engineering (CE) Disciplines and Courses within Discipline in the CE program

Discipline D1) Computers	**Course in the discipline**	**Check if used**
D1.a) Software	EGC251 C/C++ Programming	✔
	CPS210 Computer Science I	✔
	CPS310 Computer Science II (Data Structures)	✔
	CPS353 Software Engineering	✔
D1.b) Computer Systems	EGC331 Microprocessors + EGC332 Microprocessors Lab	✔
	EGC433 Embedded Systems	✔
	EGC442 Computer Architecture	
	EGC451 Real-Time Systems	✔

D1.c) Digital Systems	EGC220 Digital Logic Fundamentals + EGC221 Digital Logic Lab	✔
	EGC320 Digital System Design	✔
	EGC441 System On Chip	✔
	EGC445 VLSI Design + EGC446 VLSI Lab	
	EGC447 Functional Verification	✔

Table 9.5: Mechanical Engineering (ME) Discipline and Courses within Discipline in the ME program

Discipline	**Course in the discipline**	**Check if used**
D1) Computers	EGE331 Computer Simulations	
	EGM302 Finite Element Analysis	✔
	EGM393 Advanced Computer Aided Design	✔
D6) Mechanics & Machines	EGM211 Statics	
	EGM212 Dynamics	
	EGM311 Kinematics of Machines	✔
	EGM312 System Dynamics	
	EGM393 Biomechanics	

D7) Thermodynamics/ Fluid Dynamics	EGM331 Thermodynamics	
	EGM332 Fluid Mechanics + EGM333 Fluid Mechanics Lab	
	EGM334 Heat Transfer	✔
	EGM335 Thermosystems Design	
D8) Materials	EGM221 Engineering Materials	✔
	EGM322 Mechanics of Materials + EGM323 Materials Lab	✔
	EGM393 Composite Materials	
	EGM393 Design of Machine Elements	

Kinematics of Machines will aid in the development of the gears/ door mechanism as well as any linkages associated with the door.

Finite Element Analysis will be used when testing the door under any applied forces the door may undergo. This may include vibrations, temperature, or any other physical forces.

Computer Aided Design will be used when to design the physical prototype of the product. This will be useful for the design and any 3D printing.

Heat Transfer will will aid in the selection of the materials to be used. It is important to make sure the door can sustain a wide range of temperatures and also be durable.

Engineering Materials will help select the material based on strength.

Mechanics of Materials will also help in the selection of materials based on three point bending and stress. Choosing the proper material for the door and the frame will utilize mechanics of materials.

C/C++ Programming, Computer Science I, and **Computer Science II (Data Structures)** will be used to program the cloud server (Firebase) and the Android app. Also, experience from these classes will help to optimize the programs.

Microprocessors + Lab and **Embedded Systems** will be used to choose the correct board with an ideal microcontroller for this project.

Circuit Analysis + Lab and **Electronics I + Lab** will be used to create and simulate the wiring and power consumption for the system.

Real-Time Systems and **System On Chip** will be used to create compatibility between the microcontroller, cloud server, and the Android application and will facilitate the creation of the door system. Also, it will allow the system to provide real time data.

Digital Logic Fundamentals + Lab and **Digital System Design** will be used to form the system's logic functions and formulas in order to make the system do what it should do based on inputs and outputs. It will also allow for state machines and lookup tables to be created to streamline the system.

Functional Verification will be used to verify that the system is working properly and facilitate analysis of the bugs in the system.

VI. EQUATIONS TO BE USED

[$P = IV$]

P=IV is the power formula and we need this to determine the power we need for the whole system. P is what we need to figure out, I is the current through our wires and V is the sum of the voltage needed for everything

[$V = IR$]

V=IR is the voltage equation and we need this for all circuitry. Also to figure out what kind of batteries we need and how many. V is the voltage that we need to figure out, I is the current through the wires after we put resistors, and R is the amount of resistance we have in our circuit.

[$F = ma$]

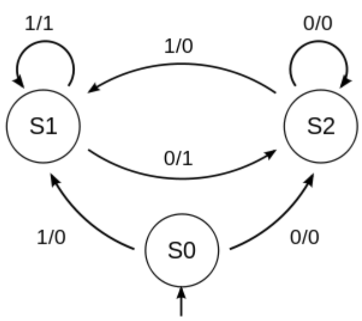
F=ma is a general force equation but we need this in order to figure out how heavy the door is going to be so that our gears are able to hold it up and it won't fall on an animal. F is the force downward due to gravity, m is the mass of our door, and a is the gravitational acceleration

[$V_{out} = V_{in}(\frac{R_2}{R_1+R_2})$]

Voltage division is Vout=Vin*(R2 / (R1+R2)) and this is to figure out how much voltage we need for each section of the whole assembly. Vout is the total voltage, Vin is the voltage going into R2, R2 is the resistor (or section) that we are worried about, and R1 is the resistance apart from R2.

[$\frac{\omega_{pinion}}{V_{rack}} = \frac{1}{r_{pinion}}$] $\frac{\omega_{Pinion}}{V_{rack}} = \frac{1}{r_{pinion}}$

This is the an equation for rack and pinion gears. If we choose the speed that we want the door (the rack gear) to move, and the radius of the pinion gear that we are going to use, then we can determine the speed that the pinion gear needs to turn at. This needs to be known in order to code the motors to turn the gears.

[]

This is an example of a Mealy finite state machine (FSM). A key aspect of a Mealy machine is that the output is dependent on the current state and the current input, whereas in a Moore FSM, the output is determined by its current state. This will be used to program the microcontroller.