ENGI 4933
Electromechanical Systems

Term Project Report
Automatic Pet Door

Group Members:
Zack Butler
Andrew Hitchen-Underhay
Shanna Nolan
Elizabeth Drover
Abstract

Many North American households include at least one cat or dog. Pets such as cats and dogs enter and exit the house frequently for purposes of personal evacuation. Because pet owners cannot schedule the bowel movements of their pets around their lifestyles, it follows naturally that pets should have the ability to let themselves in and out of the house. For this purpose, pet doors were invented. Unfortunately, these pet doors have insurmountable downfalls.

Many animals, especially cats and aging dogs have trouble physically opening the doors. Even if the animal does manage to open the door, it can get stuck in the entrance or hit by the door. With these shortcomings in mind, the team Automatic Pet Doors undertook the endeavor to introduce safety and convenience to every pet’s entrance.
1.0 Introduction

With the goal of developing a creative new solution, we began the prototyping process. The idea behind our final product was to automate the pet door such that the animal could open it on its own by stepping on a sensor pad. The process leading to this design concept is outlined in section 3.0 (The Design Process). The electronics and programming of our final product is discussed in detail in section 3.3 (Overview of System). Once built, our automatic pet door was tested and met with the approval of our two most discerning team members; Barkley Elizabeth Nolan and Amber Oubou Drover.
2.0 Objectives

Throughout the design and prototyping process, we kept several overarching objectives in mind, as well as a number of subsidiary objectives. Our list of main goals and objectives from the project outset are as follows:

- Design a pet door suitable for use of pets of all sizes, ranging from cats to large dogs
- Program the door to open automatically when the pet steps on a sensor pad
- Program the door to close automatically after a time delay, giving the pet time to pass through the door safely, but without leaving the door open for a long period of time
- Implement a locking mechanism, so that the door cannot be opened if the power is off. This will be a safety mechanism to prevent injury to the pet, as well as to provide a security feature when the door is not in use or when the family is not home

Aside from our overarching goals, we had a number of smaller objectives in order to optimize our design:

- Create an aesthetically pleasing prototype through the use of quality building materials and a well-designed and constructed door, including:
  - The use of extreme care and precision when constructing the prototype
  - The use of accessories for the purpose of visual appeal, such as a door knob and mailbox
- Make use of structural supports to facilitate a lab demonstration during the final presentation

With these primary and secondary objectives in mind, we commenced the design and prototyping process.
3.0 Design

3.1 Design Iterations

Shortly after forming our design team, the idea of creating an automatic pet door became a reality. With 3 of our 4 group members being proud pet owners, the idea spawned itself in our first brainstorm session. From this point forward, our overall design had a few iterations which helped to troubleshoot and improve our overall design. With the help of Tom Pike, we armed ourselves with a PIC Microcontroller, 8.4V Stepper Motor and two limit switches.

Concept #1

In our initial design, (REV 0 shown below) we have a standard exterior door with a doggy door coupled to a stepper motor, which would be activated by stepping on a sensor pad. In the operation of this initial design, there would be a sensor pad on either side of the door, and when the pad was activated by placing a weight to close the circuit of the switch, the doggy door would swing open in the associated direction. In other words, this means that if your pooch was inside and stepped on the pad, then the doggy door would swing outwards so that it wouldn’t hit the animal in the face. This design would have worked in the opposite direction as well (dog outside, doggy door would swing open).
Following the completion of our first design review, we came to realize that there were some major design issues with our original proposal. Firstly, the operation of the sensor pads gave rise to some major issues. For example, mounting the sensor pads separate from door would create a troublesome install whereby wires would have to be run from the bottom of the exterior door to the sensor pads. In addition to the wiring, the sensor pads are weight activated. Whether a human or an animal stepped on the pad, the doggy door would open. This would become rather annoying, as it would restrict the exterior door from fully opening due to creating an obstruction perpendicular to the door once fully extended. From here, we began to realize that the vertically mounted stepper motor had to be changed. Not only was our doggy door creating a perpendicular obstruction but the creation of a weather seal for this two-way swinging door would be much more difficult as well. These complications led us towards another brainstorming session whereby we needed to mitigate the above problems.
In our second design, (REV1) you will notice the horizontally mounted stepper motor. This operates by rolling canvas over the attached wooden dowel and causing the door to open in the vertical direction. The main advantages of this design include the ability to seal the door while it no longer obstructs the operation of the exterior door due to the motion being contained within the door. Similarly, with the vertical motion, the pet will never be exposed to a door swinging in towards its face. Our next major improvement came with the elevated sensors that are attached to the door. Without obstructing the human operation of the exterior door, the new sensors are activated by the pet’s paws or nose. Once activated, the program opens the door at a moderate pace, delays for three seconds, and then closes at a slow speed. This allows the pet to pass through the door with ample time, and with no chance of obstructing the animal as it passes. The greatest accomplishment with this new design will be the ease of installation. Having the same
dimensions as a standard exterior door and being battery operated, to install this new product will only require placement on your existing hinges.

Despite all of our improvements, there were still a few issues that needed to be addressed. With our final design, we used a 12” wide by 15” high doggy door in order to fit large canines, such as golden retrievers. However, a new problem exists to secure such a large door. To overcome this feat, we added a spring-loaded solenoid lock. Acting as a dead bolt, once the power is turned off by the kill switch, the electromagnet no longer operates and the spring pushes the lock into the side of the doggy door. The beauty of this design is that the doggy door will remain locked even when your batteries drain. Not to worry, once your batteries drain, they can be easily replaced by unscrewing the panel underneath the interior sensor pad and folding down the hinged panel.

Lastly, our final addition to the door was the addition of a front-mounted mailbox used to conceal the PIC microcontroller and stepper motor while maintaining easy access. In a production model, this issue would not exist, because a stepper motor and microcontroller that fit the inside dimensions of the door would be used.

To conclude, all of these issues were resolved for our final design which is shown below. (This model is based on regular exterior door dimensions; however, it is only 48” high for ease of transportation).
Final Design
3.2 Obstacles Overcome

This project was subject to obstacles and challenges, as with any engineering design process. As a student project, our capabilities were limited by time, cost, and availability of materials.

Ideally we would have used a larger stepper motor with more torque. Originally we used a pet door made from sturdier but heavier materials, but the torque provided by the smaller stepper motor, but the torque provided by this motor was insufficient to overcome the forces due to gravity acting on the door. In order to create a functioning prototype, we sacrificed the original design for the pet door itself and used a less sturdy but lighter material.

Initially we had the pet door rising at a faster speed, but again the motor’s torque limitations were an obstacle, and we were forced to slow down the pet door to accommodate this.

In order to secure our push buttons in the pet sensor pad, we needed a soft pliable material that hardens when dries, but is easily removable for access to the buttons. For this application we chose play-doh. Through an exhaustive troubleshooting process, we discovered that play-doh, a conductor, was causing all of our buttons to short, resulting in a door entering, but never exiting a programming loop. With this discovery, we removed the play-doh and cleaned the buttons, and proceeded to secure the buttons with electrical tape.

Our initial design for the pet sensor pad involved a small platform supported by beams at 45-degree angles, and the batteries were to be mounted inside the door. However, when we began constructing the door, we realized that it was not practical to put the D-cell batteries inside the door due to size constraints and the need for accessibility. We overcame this obstacle by including in our design a hinged box beneath the sensor pad to encase the 6 batteries and make them accessible for replacement.
Challenges and their solutions are a natural part of the prototyping process. In this case, they made an important contribution to the final design of our automatic pet door.

**3.3 Overview of Final System**

3.3.1 Hardware

- Spruce 2” x 4”
- Meranti Board
- Pine 1” x 4”
- Pine 1” x 12”
- Door Stop Molding
- #8 2-1/2” Screws
- Finishing Nails
- Staples
- 1/2” Dowel
- Vinyl Sheet
- Door Knob
- Mailbox
- Hose Clamp
- Cold Weld (Adhesive)
- Weather Stripping Adhesive
- Weather Stripping
- Rubber Matting

3.3.2 Sensors and Electronics

- Buttons
- Solenoid and Spring
- Batteries and Holder
• Various Wires
• Terminal Strips
• PIC Microcontroller Circuit Board
• Bipolar Stepper Motor

3.3.3 Software

• Pseudo Code
• C Language Code
• PIC Downloader

3.3.4 Tools Used

• Table Saw
• Planer
• Chop Saw
• Palm Sander
• Belt Sander
• Jig Saw
• Circular Saw
• Hand Saw
• Hammer
• Staple Gun
• Various Drills
• Miter Box
• Soldering Gun and Lead-Tin Solder
• Drill Press
• Hack Saw
• Various Screw Drivers
• Electrical Tape
• Needle Nose Pliers
• Tin Snips
• Chisels
• C-Clamps
• Level
• Tape Measure
• Ruler
• Square
• Paint Brushes and Paint

Additional details and specifications regarding materials can be found on our webpage.

### 3.4 Analysis, Experimentation and Modeling

To lift the door, we used a bipolar stepper motor affixed to a dowel. Specifications of the motor as well as a graph of Speed versus Torque can be seen below.

<table>
<thead>
<tr>
<th>Model #</th>
<th>Frame Size</th>
<th>Length (in)</th>
<th>Volts</th>
<th>Current (Amps)</th>
<th>Holding Torque (oz-in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4018L-01S</td>
<td>17</td>
<td>1.88</td>
<td>8.40</td>
<td>0.56</td>
<td>41.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistance (ohms)</th>
<th>Inductance (mH)</th>
<th>Rotor Inertia (oz-in^2)</th>
<th>Weight (lbs)</th>
<th>Lead wires</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.00</td>
<td>24.00</td>
<td>0.20</td>
<td>0.66</td>
<td>4</td>
</tr>
</tbody>
</table>
In an ideal system, free of friction and other limiting factors, the motor has enough torque to lift a 7.5 lb door. In contrast, our door weighs approximately 0.5 lb, and is therefore well within the lifting capability of the motor. This conclusion was reached through a set of sample calculations shown below.

**Motor Speed Settings from Programming**

1 half step per 3 milliseconds

400 half steps = 360°

1 pulse = 0.9°

Therefore,

1 half step = 1 pulse
0.333 pulses per millisecond

\[
0.333 \text{ pulses} \times \frac{1000 \text{ ms}}{1 \text{ sec}} = 333 \text{ pulses / sec}
\]

Interpolation from attached Torque curve at 333 pulses/s gives Torque (\( \tau \)) = > 30 oz \( \bullet \) in

**Torque Required:**

\[
\text{Weight of door in oz} \bullet \text{ radius of dowel} = 8 \text{ oz} \bullet 0.25 \text{ in}
\]

\[
\text{Required Torque (}\tau\text{)} = 2 \text{ oz} \bullet \text{ in}
\]

Therefore, with a much greater supply of torque, our motor can easily overcome unwanted friction within our system. The dowel is supported by a smooth collar opposite the motor. As mentioned before, the friction caused by this connection is easily overcome by an abundance of torque produced by the motor.
4.0 Recommendations and Conclusions

The goal of this project was to design a pet door such that an animal could open it on its own by stepping on a sensor pad. Through a series of design iterations, and after overcoming numerous obstacles related to our design, we developed a final product. The door uses a stepper motor to lift a pet door that is encased in a standard exterior door. It also includes a solenoid lock for safety and security. Additional features have been included for aesthetic appeal. This achieves our initial goal of creating a more convenient and safe automatic pet door.

Prior to introduction to the pet-owning market, our product would need to undergo a final iteration implementing the following changes:

- A PIC microcontroller circuit board designed specifically for a stepper motor would take up less space, and would be easier to use and maintain
- A stepper motor with smaller dimensions and more torque would completely fit inside an exterior door, while being able to lift a pet door that was made of a heavier, sturdier material
- Better lubrication between the dowel and its support would better facilitate motor rotation, thereby increasing efficiency of the system

This project, from initial concept to completion, has been a significant learning experience for all group members. We increased our inventory of technical skills such as programming, construction, circuit wiring, and the use of power tools. We learned through trial and error that play-doh is not a good insulator, and therefore not a good product to encase and stabilize our buttons. We learned how to effectively wire a circuit for efficient use of space, and the importance of organization and photo documentation for troubleshooting.

Skills developed and enhanced through this project will prove useful in our future careers, both as students and as professional engineers.