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Design and Development of a Modular Door Actuator

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Abstract

Door actuator systems ("automatic doors") are available for commercial use, but much less so for temporary residential use. An innovation of door actuator systems may make the products simpler and more convenient for consumer use. To test this, the system was redesigned for a modular and temporary mechanical configuration, interfacing with the bottom of the door rather than the top, and requiring no damaging means of installment. Five means of electronic activation inputs via a computer system ("button," "sonar," "keypad," "Bluetooth," and "SCADA") were also designed and physically implemented. The system was fabricated and tested for functionality on a 1:8 scale ("experimental system"). The system passed the criteria for success in the data collection tests, so it appears to be an effective solution.

Introduction

Most public spaces have standardized accommodations for individuals with physical disabilities, but incorporating them into a residence can be costly and time-consuming. Automatic doors are a prime example. They are sold commercially but are arguably expensive and typically need to be professionally installed in a permanent configuration. If these devices were made less expensive and modular to be set up in a temporary fashion, maneuvering in one's own home with a physical disability could be a much less strenuous task. Therefore, this project aimed to solve this problem with the invention of a new device.

Purpose

This project involved the research, design, and creation of a modular door actuator (i.e., door opener). An actuator is defined as the automated means through which a physical task is accomplished. Conception of the project began in Fall 2021, with the goal of selecting a project that 1) involved as many areas of Millersville University's Applied Engineering program as possible, and 2) had a practical output that solved a problem. Based on personal experience of friends and family, and the societal need, the goal to solve the problem of door accessibility was chosen.

Materials and Methods

The system was comprised of an actuator that rotates to open a door 90° using a mechanical arm. It was designed to not require any permanent or damaging means of being affixed in place. Instead, the actuator was designed to be weighed down by a water jug, and the mechanical arm simply clamps around the bottom of the door. To be more modular and customizable by the user, this door actuator system used multiple electronic activation inputs, including push button, motion, passcode entry, smartphone activation, and supervisory control and data acquisition (SCADA) communication. SCADA is a means of connecting all electronic devices to the same communication network, typically in an industrial setting. To determine the most ideal devices and components to use for this experimental system, research and calculations were conducted.

Further research was conducted to determine the exact design of the system. Accounting for door weight, size and the angle requirements of the mechanical arm, the necessary torque was calculated, and an actuator of appropriate strength was selected. An overhead view of the system's functionality was designed in AutoCAD and is pictured in Figure 1.

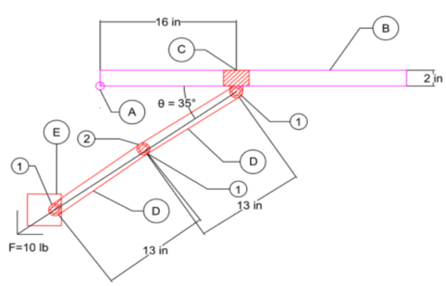

Figure 1: Mechanical Arm Diagram

The system was fabricated and physically tested on a 1:8 scale experimental system (see Figure 2) due to time and budget constraints. More specifically, a swing door with working hinges was constructed to be 1:8 the size of a traditional door. To test this system for validity as a door actuator, a scientific experiment was conducted. Ninety data points were collected from three runs of ten trials each. The time of day at which each run was conducted was randomized before the data were collected, and the input device used was randomly chosen prior to each trial. Three binomial variables were collected during each trial as a pass/fail: *function*, *time*, and *rigidity*. The variable of function was used to evaluate the system's ability to open and close the door, time was used to evaluate the actuator's timeliness of completing a cycle, and rigidity was used to evaluate the clamp's ability to remain rigid on the door.

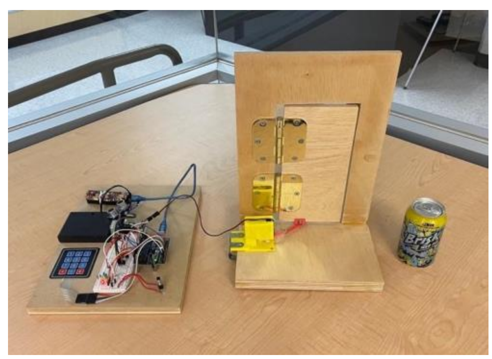

Figure 2: Experimental System

Results

When the experimental system was physically tested, it was discovered that some slight design changes were necessary for the system to be physically efficient. The mechanical arm's initial angle was reduced, and the actuator swiveled counterclockwise instead of clockwise to improve the efficiency. This required the actuator's ideal spot on the floor to change, resulting the creation of revised calculations and diagrams. These changes were implemented before data was collected based on the experimental setup previously explained.

Data were then analyzed in an analysis of proportions using Minitab to verify the ratio of passes to fails in different configurations. The ratio of total passes to fails was $\pi = 1.00$ (95% CI: 0.967). $\pi = 1.00$ means that all data were passes. "CI" represents the confidence interval of the study and explains that larger data sets lower the interval to tighter confidence ranges.

SCADA's functionality was also independently confirmed, but not within an experimental setting. This was because SCADA was an auxiliary element from the beginning, and it required a different electronic setup than the rest of the system.

Conclusion

All data were "passes," and the resulting CI was 0.967, which is greater than the goal of $\pi = 0.95$, meaning the system appears to be a viable door actuator. Because the inputs used were randomized as well, the inputs appear to have reliable functionality. In short, the experiment was successful, proving that this design has the potential to become a more convenient alternative to traditional automatic doors. This study was not completely comprehensive of the subject matter, however, and some elements for future research were noted. These topics include, but are not limited to, testing at full-scale, cybersecurity, design accommodations for different door types, and greater electronic robustness. Examples and suggestions for furthering this experimental design were briefly explained at the conclusion.

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