# ELEVATOR CONTROLLER FOR INDIVIDUAL WITH MS

Biomedical Engineering Design 201/301

University of Wisconsin - Madison

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## Abstract

The goal of this semester is to finalize work on a device that will enable an individual with limited mobility to press elevator call buttons in multiple hallways, as well as the internal elevator control buttons. Design constraints are defined by the environment in which the device must operate as well as the user's physical capabilities. Last semester, a mechanical prototype was designed and constructed. The remaining aspects of this project include integration of controls, attachment to the wheelchair, weatherproofing, and ultimately the installation of a working system. Adaptive controls were selected based on the user's preferences, and tasks that remain are currently in developmental stages.

## Statement of Design Problem

Our project involves the integration of adaptive controls into a prototype created in the spring of 2006. This device is capable of covering the distance from a wheelchair to an elevator call button, then exerting a horizontal force sufficient to push the call buttons in both the standard elevator car and the corresponding hallway. The controls to be integrated must be operable by stimulus generated by movement no lower than the user's neck. The device should be attached to the wheelchair in such a way that mobility and other wheelchair functions are not compromised. The final mounted prototype should be protected from physical and environmental damage by a weatherproof enclosure.

## Background

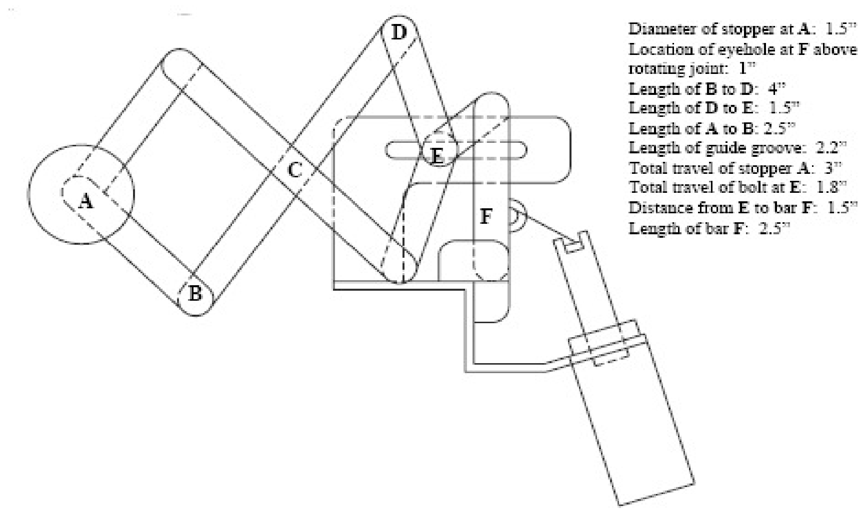
Work on this project began in January of 2006, for an individual who will be referred to as D.P., and will continue for a second semester in order to see it through to completion. Due to the complexity of the problem, last semester the project was divided into two main parts. The two tasks to be accomplished included the design and construction of a mechanical device, followed by mounting and integration of the device onto the user's wheelchair.

Last semester a unique device that can accomplish the pressing of the elevator buttons in D.P.'s apartment was designed and built. This device makes use of a linear actuator to cover the vertical distance between buttons and a six bar mechanism to cover the horizontal distance to the buttons (Figure 2). The device is powered by a 12 volt battery, and requires two separate switches for operation. A toggle switch is responsible for moving the actuator up and down, while pressing a momentary contact switch extends the six-bar mechanism. The device was

**Background** CONTINUED

tested on similar elevator buttons and it was confirmed that sufficient force can be exerted to engage the buttons.

The design of this mechanical device requires that it be mounted in a specific position on the left side of D.P.'s wheelchair. The linear actuator has a 12 inch stroke, and this entire stroke must be utilized in order to reach the full range of elevator buttons. Therefore, the device must be mounted at the proper vertical height. D.P. has the ability to maneuver in the elevator cab such that the left side of his chair is parallel to the wall containing the buttons (Figure 1). Limited space in the elevator cab restricts how far forward D.P. can move up alongside the buttons, so the device must be mounted at a particular distance from the front of his chair.




Figures 1 & 2. Photo demonstrating most forward position possible for D.P.'s wheelchair as well as the target elevator call buttons (left) and diagram of component parts of the six-bar mechanism constructed last semester (right).

This semester, proper mounting and integration of the mechanical device onto D.P.'s wheelchair will be accomplished. Integration requires both installation of switches which D.P. can operate to control the device and connection of the device to the existing wheelchair battery. Since D.P.'s mobility is limited to the neck and head, controls must be selected based on ease of use and installation must not compromise his field of vision. Also, before connecting the device to the wheelchair battery, further research needs to be done to ensure that the device will not inhibit the wheelchair functions.

Finally, the entire device must be made weatherproof in order for D.P. to be able to move about outside with the device attached. While the actuator is encased in a metal covering, the six bar

**Background** CONTINUED

mechanism is fully exposed. A weatherproofing design should allow the device to withstand the elements as well as protect the device from being damaged by direct contact. Similarly, there are moving parts on the six bar mechanism that could potentially catch outside objects or materials if it is not encased appropriately.

One final detail to be taken care of this semester is the incorporation of some sort of visual feedback which will inform D.P. when his chair is in the proper position and the actuator is at the appropriate height to contact a particular button. To manipulate the horizontal position of the chair it may be possible to mark the elevator floor to indicate the distance to which D.P. should pull forward. Feedback about the vertical height of the actuator may take the form of a laser pointer or a marking on the actuator itself that indicates when the device is extended to the proper height for contacting each button.

## Motivation

Our client, Dr. Fleming, currently treats a patient with multiple sclerosis (MS). This patient (D.P.) was fully mobile earlier in life, but has since been diagnosed with MS. The early stages of the disease consisted of attacks followed by partial recovery, but now MS has progressed and left him nearly paralyzed from the neck down. D.P. retained minimal use of his right hand for some time, but lack of use has led to atrophy of this last appendage. He lives independently in a second-floor apartment by making use of infrared technology produced by SiCare; this system allows him to operate many household appliances with his voice alone. D.P. can control his lights, fan, TV, DVD player, and change the channels and volume on the latter devices by speaking the appropriate command. Similarly, D.P. can nudge a switch mounted on his wheelchair to open the main apartment door.

When D.P. leaves his apartment, he travels around using the Madison Metro bus service, and is thus very mobile. The rate-limiting step, however, is his inability to press the elevator buttons in his apartment complex to move between his apartment and the building exit. He is dependent on others to press the elevator call button in the hallway as well as the appropriate floor button in the elevator. When no one is available in the apartment to assist D.P., he is unable to travel between his home and any exterior environments. Our device aims to provide D.P. with a means by which he can press the elevator buttons to get around independently (Karle *et al.* 2006).

## Design Constraints

*User/Chair Constraints*

The device built during the spring semester meets the requirements of vertical movement and ability to push necessary buttons and is currently controlled by a small toggle switch and push button. However, a more accommodating control system must be designed so that D.P. can manipulate the device using voice control or body movement from the neck up. The current voice control system, SiCare, which allows D.P. to control appliances such as the TV, DVD player, lights, and other appliances, is an option for controlling the elevator button device. However, the SiCare system requires the device desired to be powered by an AC source, making it impossible to apply to a battery-powered environment (NanoPac Inc. 2002).

The other option is a system of switches that can toggle the linear actuator and trigger the extending mechanism. D.P. must be able to activate these controls using just head movement. According to D.P., a joystick-type control attached to the existing control bar (Figure 3) would be ideal, but he is open to other ideas. The user must be able to accurately raise and lower the linear actuator in order to trigger the device to hit the desired button. This requires unobstructed vision of the linear actuator as well as the elevator buttons. The switch for the extension mechanism should be placed out of the way to prevent accidental triggering of the device during other activity by D.P.

Figure 3. Graphic depicting detail of control bar on user's wheelchair, which currently includes a chin joystick for total control of chair movement, a tilt joystick to change the angle of the seat, and an unused lever previously connected to the user's telephone system.

The device will be mounted to D.P.'s chair so that he can use it while entering and exiting the apartment building. When mounting the device the functional range in different positions, possible interference by other moving parts of the chair, and powering of the device must be considered. In testing the device, it was found that the linear actuator must be vertical in order for the horizontal extending arm to fully retract after use. The chair can be reclined at various angles while retaining the ability to move around, but the device must stay vertical despite this variation in angle. Our device will be powered by the battery already on D.P.'s chair. We have yet to definitively obtain specific electrical information about our device, but we must rule out the risk of draining D.P.'s chair battery.

**Design Constraints** CONTINUED

*Environmental Constraints*

Since the goal of this device is to allow D.P. to successfully enter and exit his building using the elevator, dimensions of the hallways and elevator must be considered. Measurements of the doorway dimensions, hall widths, interior elevator car dimensions, and heights of elevator buttons were taken. Keeping in mind that extra room is necessary to move a chair about accurately, the device should add no more than 7" of width to the chair. This is based on the measured chair width of 28" from elbow to elbow, and the measured doorway width of 35" (Figure 4). Minimizing the width of D.P.'s wheelchair is crucial to maneuverability in the elevator and other confined areas. When D.P. positions himself next to the buttons in the elevator, the gap between his chair and the button panel can be as small as 3", within the 6" range of the existing prototype.

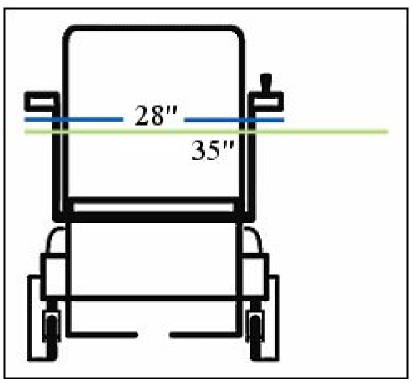



Figure 4. Illustration of maximum dimension allowed on one side of user's wheelchair to preserve normal maneuverability through standard doorways (width of 35 in).

The device must be mounted at a height to allow the 12" actuator stroke to reach all of the buttons inside the car and the elevator call buttons in the hall (Tables 1 and 2). The alarm button is the lowest at 35" off the ground, while the highest is the third floor, located 47" from the ground. The third floor button is out of range by 0.3" if the device is mounted so it is at its lowest when aligned with the alarm button. Unless the range of the device can be expanded, the ability to push the third floor button must be eliminated.

If D.P. wishes to leave the apartment in other than ideal weather, the device must continue to function. The temperature range in the Madison area over the course of a year can be roughly -20º Fahrenheit in the winter and up to 110º Fahrenheit in the summer. Weather conditions include rain, snow, hail, wind, and varying humidity. The device must be protected to withstand the dynamic weather conditions and still function properly so D.P. can enter and exit the apartment building.

Tables 1 & 2. Heights of buttons, measured from the floor, inside the elevator car (top) and hallways (bottom).

| **Function** | Help | Alarm | Open | Close | Basement | Floor 1 | Floor 2 | Floor 3 |
|---|---|---|---|---|---|---|---|---|
| **Height (in)** | 20.5 | 35.0 | 37.1 | 37.1 | 41.3 | 43.3 | 45.3 | 47.2 |

| **Function + floor** | Elevator up (1) | Elevator down (1) | Open automatic door (1) | Elevator up (2) | Elevator down (2) |
|---|---|---|---|---|---|
| **Height (in)** | 20.5 | 35.0 | 37.1 | 37.1 | 41.3 |

**Alternative Solutions**

The initial phase of this semester has focused on integrating user input with available products with respect to switches for controlling the device. Based upon the user's environmental and capability constraints, the field of possible adaptive controls was narrowed to several arrangements, including a set of three membrane/pad switches, a set including a tongue or eyebrow movement switch and several pad switches, or a combination of a lever switch and dual-circuit sip/puff switch. An evaluation of the advantages and disadvantages of each arrangement was performed based upon several design criteria and user's individual preferences.

*Membrane Switch Array*

The simplest option involved the use of one flat, touch-sensitive pad (Figure 5) to operate each of the three circuits involved in this project. Very small forces are needed to activate most pad switches designed for adaptive applications, and a set of three could be mounted on or around the user's current control bar in locations easily accessible using his current range of motion (Enabling Devices 2006).

Figure 5. Example of a membrane switch distributed by Enabling Devices.

*Advantages and Disadvantages*

Using three identical, simple switches would be inexpensive and easy to install. Depending upon the space available and the user's abilities and preferences, various sizes and colors of pads could be purchased to differentiate between the functions of each switch and create an efficient environment for controlling the device. Specific testing to determine the most suitable size, however, was not performed due to the expense of purchasing switches simply for trial purposes.

A major disadvantage in relying completely on pad switches is their lack of flexibility with respect to method of activation. The circuit controlling the in and out motion of the device only requires a momentary contact switch for operation, but the fine control of the linear actuator requires that each of the two circuits, one for upward motion and one for downward motion, is activated and deactivated by a latch switch. Using pad switches alone would be insufficient, as the majority available for purchase are simple momentary contact switches. In order for the user to raise or lower the device, he would have to maintain contact with the switch for the entire movement. It is also possible that the user would prefer to have larger switches so that activation would not require uncomfortable movement or straining of the head and neck. In this case, using a set of three large pads would most likely take up too much space on the wheelchair around the user's head and interfere with daily activities.

*Tongue/Eyebrow and Pad Switch Array*

Another combination of switches that could be used to perform similar actions as the three-membrane switch array would involve one tongue- or eyebrow-controlled switch and either one or two membrane/pad switches. One alternative to using all membrane switches would be to integrate a specialty control called the "Twitch Switch" which is manufactured by Enabling Devices (Figure 7) and allows users with upper extremity disabilities to engage a switch using motion of their forehead or eyebrow muscles. The latch mode of this switch enables the user to send continuous current through a circuit with one twitch of the eyebrow and stop the flow of current at their leisure with a simple second twitch of the eyebrow. Another dual switch option could be the PRC Tongue Switch (Figure 6), which activates one circuit by pushing up on a lever, and a second circuit by pushing down. The final component of this array would be a simple momentary contact pad switch to engage the solenoid of the device and accomplish the in and out motion of the elevator controller (Enabling Devices 2006).

Figures 6 & 7. Examples of tongue switch (left) and eyebrow twitch switch (above) distributed by Enabling Devices

*Advantages and Disadvantages*

Utilizing a more complex and powerful switch to operate the linear actuator would allow the user to pay closer attention to the movement of the device and worry less about maintaining contact with a pad switch to perform the same action. Two switches would also require less space than three, especially if the necessary size of the pad switch is substantially larger than expected.

The twitch and tongue switches would cost considerably more than simple membrane/pad switches, and may require more accommodation from the user. While the twitch switch would greatly simplify the task of moving the actuator up and down while in latch mode, requiring the user to wear a headband was unnecessary and not preferred over other options.

*Lever and Sip/Puff Switch Array*

Taking into account the specificity of user partiality towards simple, low-key solutions for the controlling aspect of the device, we looked further into “smarter” switches. The Ultimate Switch (Figure 9), also produced by Enabling Devices, is a momentary contact lever switch designed to be activated by only 0.02 pounds of force. Compact and lightweight, the lever also includes a spring and clicker at its base to provide slight auditory feedback when the switch is activated. The Sip/Puff Switch (Figure 8) manufactured by the same company involves a pneumatic dual switch activated by a small inhalation/exhalation through a provided tube. While the switch itself does not offer activation in latch mode, a simple flip-flop chip could be added to the circuitry of the switch to enable this type of control (Enabling Devices 2006).

Figures 8 & 9. Sip/Puff switch (left) and Ultimate Switch (right) distributed by Enabling Devices.

*Advantages and Disadvantages*

While both of the switches are complex and more expensive than most of the earlier options, they offer the necessary fine control requested by the user. In addition, the simple activation method for each switch ensures the user’s comfort when engaging the elevator controller as no unnecessarily prolonged movement or other input is required. Some extra work will have to be done to make the sip/puff switch powerful enough to allow the user to start and stop each of the up and down motions with individual sips and puffs, but research has indicated

## Alternative Solutions CONTINUED

that this supplement will not add excessive complexity to the design. With respect to the Ultimate Switch, the minimal force required for activation may pose a problem if the user's wheelchair accelerates at such a speed to activate the lever accidentally.

## Proposed Solution

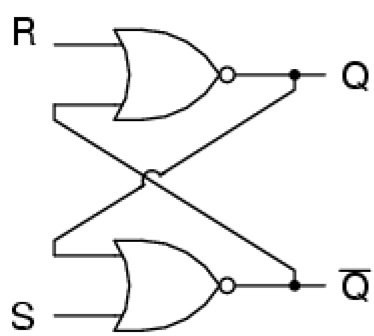
Based on client preferences, available products, and grant funds provided by the National M.S. Society, two different switches will be incorporated into the user's wheelchair to control the linear actuator (up and down motion for accessing the desired button) and the solenoid (pushing motion to depress the desired button). A sip-puff switch (970) will be utilized for movement of the linear actuator, and a momentary contact switch (Enabling Devices, part # 986) will control the solenoid.

The sip/puff switch will allow for two motions, one controlled by the sip action, one by the puff action. Because of this feature, controlling the up and down movements of the linear actuator can easily be accomplished.

One downfall of this option, though, is that both the sip and puff switches are momentary contact switches, so current is only delivered to the system for as long as the user is sipping or puffing. Controlling the actuator with momentary switches would therefore require large amounts of breath from the user. To address this problem, circuitry involving a flip-flop path (Figure 10) will be integrated with the prefabricated switch to convert the momentary contact switches into a continuous circuit that will require less user input:

- One puff engages the upward motion of the actuator; another puff stops the upward movement.
- One sip engages downward movement, and a second sip stops this action.
- In either case, if a second stimulus is not produced, the actuator will raise or lower completely, depending on if a sip or puff initiated the actuator movement.

Figure 10. Circuit diagram for an S/R latch switch, enabling a momentary closure of one circuit to maintain current until a second input is used to disengage the circuit.




| S | R | Q | $\overline{Q}$ |
|---|---|---|---|
| 0 | 0 | latch | latch |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |

**Proposed Solution** CONTINUED

The switches will be mounted on the same control bar as the user's chin joystick to allow for convenient access. Care will be taken to mount the switches close enough for the user to easily reach; requiring a large range of motion in the neck must be avoided. Both controls also must be mounted in a way that they do not hinder the user's view during normal functions or while using the device.

The Ultimate Switch will provide the momentary contact required by the solenoid. This will allow the user to depress the desired button with one touch of the switch. A possible modification to the switch may involve creating a timed circuit so that current is always delivered to the solenoid for the same period of time; this would minimize the amount of accuracy required by the user.

**Potential Problems & Resolutions**

Throughout the semester, we will likely encounter various problems dealing with the electric as well as mechanical aspects of the device integration. Our first electrical problem deals with altering our current switches to allow for easy operation of the device. For instance, the sip and puff switch ordered is a continuous switch, meaning the "sip" or "puff" action must be held continuously for the actuator to move. To allow for easier operation, it will be necessary to convert this switch to a latch switch, such that one instantaneous "sip" or "puff" would activate the actuator. Devices exist such as flip-flops to convert this signal. We will likely need help from faculty such as Burke O'Neal to accomplish this transformation. Secondly, our device must be integrated effectively into the battery. We must do this in such a way that our device draws power from both batteries on the user's chair. Otherwise, electrical problems could arise. To accomplish the above tasks, we must contact Tracy at Meriter Home Health, the primary service and maintenance provider, for more information regarding the complexities of the wheelchair.

As far as the mechanical aspects are concerned, the device must be mounted onto the chair such that it is non-obtrusive but effective. The device must be placed between the user's knee and footrest (Figure 11) in order to reach the elevator buttons. This will

Figure 11. Photo of proposed position of device for mounting on user's wheelchair for optimum pressing of elevator buttons

**Potential Problems** CONTINUED

require additional attachments, which must be strong, but also small as to not hinder the user's range of motion. Furthermore, because the chair footrests rotate when the user is entering and leaving the chair, our device must rotate as well as to not interfere with this movement.

Lastly, we must mount both of the controls to the user's wheelchair for easy operation. Because the user currently has a control bar on which other switches and levers are currently attached, we will most likely use this same bar to mount controls for the elevator device. However, placement is constrained by the user's limited range of motion. Consequently, mounting one or both controls on the headrest of the chair may be necessary in order for easy access.

**Resources & References**

"Enabling Devices: Online catalog." 2006. Enabling Devices. 10 Sept 2006. <http://enablingdevices.com>

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**Appendix A: Product Design Specifications**

# Elevator Controller for Individual with Multiple Sclerosis

## Product Design Specification


**Team Members:**

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**Problem Statement/Function:**

Our project involves the integration of adaptive controls into a prototype created in the spring of 2006. This device is capable of covering the distance from a wheelchair to an elevator call button, then exerting a horizontal force sufficient to push the call buttons in both the standard elevator car and the corresponding hallway. The controls to be integrated must be operable by stimulus generated by movement no lower than the user's neck. The device should be attached to the wheelchair in such a way that mobility and other wheelchair functions are not compromised. The final mounted prototype should be protected from physical and environmental damage by a weatherproof enclosure.

**Client Requirements**:

- The device must be attached on the left hand side of the wheelchair and engaged manually by adaptive controls using stimulus generated at the neck or above
- Device does not need to be universal with respect to the elevator controls in other buildings
- Device must be weatherproof and protected
- Width added to the wheelchair cannot hinder maneuverability

**Design Requirements:**

1) Physical and Operational Characteristics
   a) Performance
      - Used multiple times daily
      - Two unique sets of controls (one involving toggle options and the other a momentary contact switch) must move the actuator vertically and engage the solenoid respectively
      - Device should not draw an excessive amount of power from the wheelchair battery
   b) Safety
      - Can't alter normal wheelchair or elevator operations
      - Device must be mounted in such a way that all elevator buttons can be reached

- Device controls should not compromise ease of use of current wheelchair controls

c) Accuracy & Reliability

- Should be able to move to a specific button based on the input of the user

**Appendix A: Product Design Specifications**

- Should provide visual feedback about the position of the pushing component
- Sensitivity of controls should allow for at least 90% success when the user attempts to engage the device
- Device should not engage without user input

d) Life in Service

- 10 years or until upgraded parts are available
- Individual parts should be easily serviceable as needed (including batteries)
- Each individual part should withstand use multiple times daily
- Weatherproof covering must be removable to allow for maintenance

e) Operating Environment

- Weatherproof: temperature ranges from 20-90 degrees Fahrenheit, humidity and rain
- Must withstand vibrations and dust upheaval caused by wheelchair motion, especially over uneven/bumpy terrain

f) Ergonomics

- Should not require physical interaction, with the exception of head/mouth movement
- Should not require unnecessary physical stress

g) Size

- Total width of chair and device may not exceed 35" and should be significantly less to avoid unnecessary maneuvering by the patient
- Additional dimensions of device should not cause unnecessary adjustments to normal movement (turning corners, etc.)
- Size and location of manual controls should not obstruct vision but should be large enough for easy operation

h) Weight

- Device should not compromise the existing stability of the wheelchair

i) Materials/Aesthetics & Appearance

- Exterior materials should be weatherproof
- Simple user interface
- Uncluttered components

2) Production Characteristics

a) Quantity

- One unit needed for individual client

b) Target Product Cost

- Minimize overall cost, preferably under $500

3) Miscellaneous

a) Competition

- Patent searches returned no similar devices (but components may be individually patented)

b) User Preferences—Control

- User prefers device be controlled using preexisting infrared signaling so voice commands can be used