Escalator Efficiency Control

Engineering Design VI – HW4

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Group Members and Responsibilities

- James Ray
    - Microcontroller Implementation
- Andrew Hyduchak
    - Human-Device Interactions
- Michael Murphy
    - Escalator Power Consumption
- Leo Dormann
    - Hardware Requirements

SWOT Analysis

- Strengths – The project is based on sound logic and simple systems that can be retrofitted or built into new installations. Such systems exist to an extent, but do not incorporate more sensors to customize the use of the escalator. Many systems would have common retrofits.
- Weaknesses – Technologies like this are still being refined. The reliance on sensors carries with it the same maintenance, increasing the need for reliable equipment, and may raise the cost of implementation. Sensors are subject to tampering, and preventative measures may put limitations on the hardware that can tied in. Cost may be difficult to reduce, and may take creativity to make usable from a financial standpoint.
- Opportunities – The idea would be an asset to anyone looking to market systems for power reduction.
- Threats – These systems already exist. Retrofitting on mass scales by government or necessity would require the development to be rushed.

Human-Device Interactions

When looking at an escalator, the everyday user sees nothing more than a set of moving steps, with a learned behavior on how to embark, ride, and disembark at the end of the trip. The habits vary, but on a simplistic level, this is the basic function and behaviors of an escalator system. When approaching the concept of an escalator from a design standpoint, the intricacies of its operation, and the resulting physiological responses to it, should be noted and used in improving design. Ergonomics for such a publicly used utility should be thoroughly researched and incorporated into design. A device should be adapted to human use, rather than humans adapting to using it. Improving the elevator not only means efficiency in the sense of power consumption, but ease of movement for the persons using it.

Power efficiency can be implemented on a human level. For instance, it is obvious to anyone that has seen an escalator running constantly in a mall that it could be more efficiently run. One method used currently to address power consumption in escalators is a voltage controller. This device senses the load on the motor and reduces the voltage when usage is low. In Figure 1, the installation in a Las Vegas casino is observed for periods of time with a controller bypassed and active.

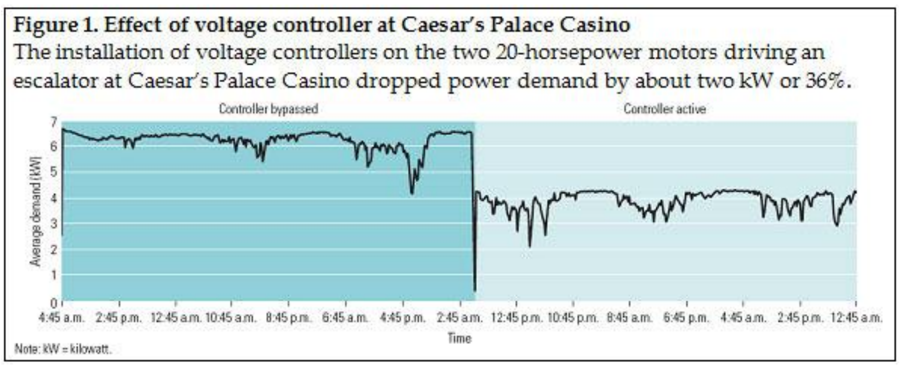
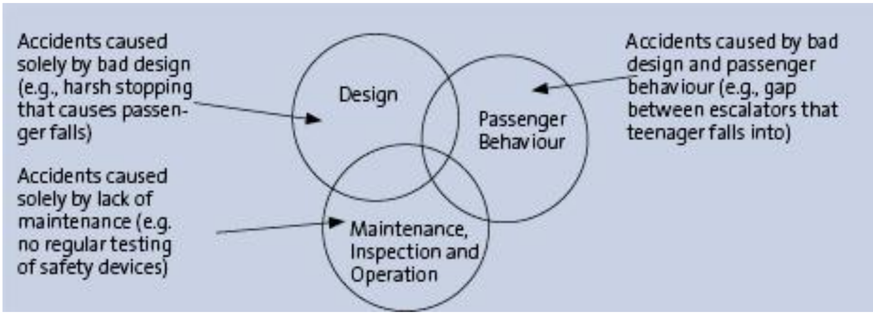


Figure 1- Source: Esource; data from Power Efficiency Corporation

When the escalators run idly by, this is low-load and unnecessary consumption. This model reduces it greatly, but further reduction is still possible by refining this approach. This method examines one input, and adjusts it output accordingly. But in large crowd and high use situations, the escalator should adapt to demand and move people more efficiently. This can be done using signage or voice commands, which can be modeled to human response and adapt intelligently to the needs of users. By using the various array of sensors available, from adapting to an oncoming users speed and moving them naturally at their pace, to using face recognition technology to judge demand and handle foot traffic much like stoplights handle cars, it is simple to retrofit, and design new systems based on the array of information available as inputs to models of use. Implementing microcontrollers is inexpensive, "smart" software is not unattainable, and would be overall beneficial in its reduction to the overall demand on the electrical grid.

The introduction of these smarter management systems will also improve safety. A Lift Report article from Issue 6/2006 called *Escalator Human Factors: Passenger Behaviour, Accidents and Design*, studied the common causes of injury from escalators:



An efficiency controller would reduce risks in all of these categories, as intelligent software and design can be added to prevent injury and alleviate it. Reduction in maintenance and wear of the system reduces failures and expenses associated with them. Design can be approached in conjunction with human behaviors to manage traffic safely and efficiently.

References:

http://www.lift-report.de/index.php/news/455/380/Escalator-Human-Factors-Passenger-Behaviour-Accidents-and-Design

http://www.hp-research.com/files/papers/humanfactors/Ayres-Schmidt-escalator-paper.pdf

http://www.hvs.com/article/4113/taming-the-escalating-cost-of-escalators-with-reduced

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<u>Escalator Power Consumption</u>

In these days, people are constantly trying to reduce power usage and make the machines we use daily become more energy efficient. Many are looking into renewable energy such as solar or wind power to save energy and ultimately money. An example of a machine that can be a figurehead for conserving power is an escalator. Escalators are used everywhere in the world around us, from malls to hotels to airports. Escalators are great when there are plenty of people using them, but what about the times when the demand is not nearly as much? Many malls turn off some escalators during non-peak hours…but is that really the most efficient option? According to the Power Efficiency Corporation, the average shopping mall escalator (with a 7.5 horsepower motor and rises 15 feet) when used for 14 hours a day, six days a week uses about 7500 KW hours of power in a year[1]. Below is a table of such data.

[1] How much energy do escalators use? Nina Shen Rastogi. Slate Magazine. http://www.slate.com/id/2262690/

Kind of Escalator?	Motor Power	Escalator Height	Power Usage
Shopping Mall	7.5 HP	15	7500 kW hours
Hotel	20 HP	20	31000 kW hours
Airport/Subway	40 HP	35	60000 kW hours

From this data, one can imagine how much power is being used by escalators in the United States. It is estimated that there are over 30,000 escalators in the United States alone[2]. During non-peak hours, escalators that are running are wasting electricity unless it has a constant flow of traffic on and off it.

Even when the escalator is running, it is probably using more power than necessary to run. An escalator is at full capacity when each step has 150-300 lbs of weight on it[3], and most often are escalators are not at full capacity. If the escalator was able to adjust the power output for the current riders, it could make a drastic improvement on power efficiency and cost. The escalator efficiency controller would be able to adjust the power being used to the amount of people currently on the escalator.

What about the times when the escalator is running while no one is on it? In order to save electricity even more, an escalator efficiency controller would be able to shut off the escalator when no one is on it. This would result in plenty of energy savings over the long haul. A recent European study estimated that installing such a device on Europe's escalators would cut electricity use by 28 percent[4]. Instead of turning off a set of escalators during non-peak hours and make shoppers annoyed, an escalator efficiency controller would keep everyone happy. Shoppers can use the escalators at their leisure, and companies do not need to worry about wasted energy.

References:

http://www.washingtonpost.com/wp-dyn/content/article/2010/11/29/AR2010112904996.html
http://e4project.eu

Hardware Requirements

For this project we will need to integrate electrical hardware to control the electric motor running the escalator. Aside from the electric motor, and some wiring to tie it into a power source, there are no real electrical components. This makes the integration of controlling hardware simple. For control of the motor we will need a microprocessor and supporting components. We will also need sensors to enable

[2] Escalator. New World Encyclopedia. http://www.newworldencyclopedia.org/entry/Escalator
[3] How much energy do escalators use?
[4] The Green Lantern: Are escalators more energy-efficient than elevators?

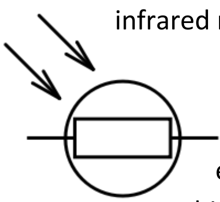
the system to know when there are people approaching the escalator. Through a combination of these components in an electrical schematic, a control unit will provide all of these capabilities.

Sensor – A few different sensor options are available for this product. One option would be to use weight sensing technology, another would be motion sensing, and finally break beam technology.

Weight sensors – Commonly referred to a load sensor, these devices measure the force on the device by a user or action. It is easy to implement and simple to understand. Using a switch the device is activated when the switch is depressed or released, depending on the application. Using formulae it is possible for some devices to determine how much force is being placed on the device. This is unneeded for this application. A switch works by depressing a mechanical arm or button which opens or closes an electronic connection. This  is known as a SPST switch, single pole – single throw switch.

Motion sensors – One form of motion sensing uses a simple form of radar technology to detect movement within its range. Using radio or electromagnetic waves a radar system sends out signals and waits for any to bounce back off something moving into the area of the sensor. It combines a transmitter and a receiver. It is similar to a bat sending out a sound wave, which returns in a certain amount of time, indicating the distance of the object and its size. When a wave hits an object it bounces off in many directions, also known as scattering.

Another type of motion sensor is an infrared sensor. Objects that emit heat, such as humans, generate infrared radiation. Infrared radiation exists in the electromagnetic spectrum, not visible to the human eye. Pyroelectric systems make use of this infrared radiation. When exposed to heat the sensor's crystalline material generates an electrical charge. Using a FET the charge can be measured, and a filter window is used to eliminate the detectable radiation outside the range of what a human emits. Using two sensing elements enables the device to eliminate constants such as temperature changes and sunlight. When a human passes into the area of the device, one element is activated and the second element is activated separately, indicating motion. The device uses a Fresnel lens, which is sensitive to infrared radiation, to activate the elements.



Finally, break beam technology can be used to sense motion. One part of the device emits a beam, laser/light emitting diode, which is received by another element, usually a phototransistor or photoresistor. The emitter can send out many things including light and laser beams. When an object passes between the emitter and the receiver the connection is broken. This absence of light increases the resistance in of the device, decreasing current flow through the resistor. This decrease in current causes the code to realize an object is in the way. Therefore, motion through the beam causes the recognition of motion and the subsequent indication to the microprocessor.

The next portion of the device is the microprocessor. This device enables a user to embed code into the system that controls different aspects of its operation. This is the central processing unit in the system. A microprocessor uses I/O ports to attach other devices such as the needed motion sensor apparatus. Using code, the device is able to bring together all the components to create a system. It is located in one microchip, or integrated circuit. They use bits, to communicate with itself and other devices. The device can also be connected into a DAQ which enables the device to use its computing to create voltages capable of running the electric motors for the escalator. Soldering these devices into a PCB will create a system that can be coded to do a certain job. For this project the device will take input from the sensor to turn the electric motor on and off.

References:

http://en.wikipedia.org/wiki/Photoresistor

http://en.wikipedia.org/wiki/Microprocessor

http://en.wikipedia.org/wiki/Radar

http://home.howstuffworks.com/home-improvement/household-safety/security/question238.htm

http://en.wikipedia.org/wiki/Switch

http://www.google.com/patents?hl=en&lr=&vid=USPATAPP12856846&id=EfTwAAAAEBAJ&oi=fnd&dq=escalator+electronics&printsec=abstract#v=onepage&q=escalator%20electronics&f=false

http://www.google.com/patents?hl=en&lr=&vid=USPAT5168202&id=IDcdAAAAEBAJ&oi=fnd&dq=microprocessor+controlling+an+electric+motor&printsec=abstract#v=onepage&q=microprocessor%20controlling%20an%20electric%20motor&f=false

http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4503770

http://journals.lww.com/acsm-msse/Abstract/2004/05000/Motion_Sensor_Accuracy_under_Controlled_and.25.aspx

http://www.glolab.com/pirparts/infrared.html

Microcontroller Implementation

Microcontrollers can turn a simple closed source device into an open sourced more interactive device. What is a closed source device? A closed source device is one that cannot deviate from how it is programmed. However, a closed source device can become an open sourced device by the addition of a microcontroller. Take a microwave oven for example. A user is able to press buttons to choose the time and temperature of the oven. There are also a few preset settings for various types of food. Now say a consumer wants to utilize an intermediate temperature that is not set on the microwave. He cannot change the settings that are already put in place. The solution to this is a microcontroller. A programmable microcontroller can be programmed and implemented to modify the temperature that is already set and override the preset program.

In order to implement this, one must have some knowledge of the workings of the existing device hardware and software along with how they interact with the overall device. A person cannot simply disconnect to random wires and connect them to a microcontroller and expect it to work. The person must be able to identify what in the device switches between the preset temperatures. Then they must break the circuit so that the signal will be fed into the microcontroller and translated into the desired output. The user must also somehow modify the user interface to reflect and control the output.

People modify existing devices to make them more user friendly and this is very common. One example of such a modification is an iPhone controlled RC car. One person decided to modify the controller for a remote controlled car in order to utilize an iPhone. The person unscrewed the controller and soldered 6 wires to a breadboard. The person then downloaded a webserver to the microcontroller and attached it to the breadboard. This allowed the microcontroller to receive signals from the iPhone and control the car as the user saw fit.

Another example of a microcontroller being utilized was with a freezer. In this case, the user had a freezer whose compressor was broken. Due to this defect, the temperature could not be maintained. In order to fix this problem, the user removed the device controlling the compressor. In place of this, he used a microcontroller and took the input and output signals that were originally controlled by the device, and assigned them to a microprocessor which was then connected to a digital display. This could now be modified to whatever temperature

Much like these projects, the escalator efficiency module needs to break the circuit within the existing escalator controls. This would be routed to a chip and a receiver which would, like the iPhone RC car, have a server. The inputs of the server would then be sent through the chip and trigger the program producing a desired output. Now instead of a escalator that simply has on and off switch, the escalator is now controlled by a program.