Gait Controlled Treadmill

ECE 445 Project Proposal - TA: Anthony Caton
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1- Introduction

1.1- Objective

Currently, indoor running at treadmill plays a significant role at people's daily life. However, running at treadmill is not as safe as road running due to the inherent nature of a machine dictating the speed of people stride. Thus, it is an common behavior for gym patrons to hold on the rails of treadmill in order to get the sense of safety. Although there are tons of protective features on treadmill, including safety clip(used to break the circuit connection to the belt), several stop buttons and handrails, it is still very difficult to get rid of the fear of losing balance at the high-speed belt after long-term running. Specifically, the key issue triggering the sense of unsafety is the lack of natural speed control, which restrict runners to reach out to the control board to adjust the belt speed. However, after long-term running, if exhausted runners do not adjust the speed appropriately, it might be very dangerous when losing balance.

Our solution to this problem is to build the treadmill that automatically matches the gait of the runner. Upon start-up, the belt will have a slow initialization speed. The treadmill will then naturally control the belt speed according to runner's speed and position on the belt. Specifically, we divide the belt into three area: at the front area, the control system will increase the belt velocity; if the runner is at the rear area, the belt will slow down in response. The center of the belt will be the zero position, indicating the current speed is comfortable for runners. The system also adjusts the velocity of the belt based on the runner’s velocity relative to the belt, accelerating and decelerating in response to a difference. This natural speed control system will prevent unexpected injury because the system will increase the belt speed in pace with the runner which allows them to warm-up, and to not be forced to run at a predetermined pace, allowing for a run that feels more natural, and is safer.

1.2- Background

Historically indoor vs outdoor running has been a subject of debate on a variety of different fronts. Most evident is the fact that outdoor running tends to be considerably more challenging due to the forces that are needed to be generated by the runner to accommodate velocity changes. While the debate of whether one is more challenging or better than the other remains questionable, the fact that the two differ in execution is not up for debate. The evident presence of the electromechanical devices predicates the necessity for the user to tamper with these devices while moving. This being an evident deterrent to a hardcore outdoor runner may be part of the reason why so many exercise enthusiasts avoid the usage of a treadmill. Yet, despite this disparity among elite athletes vs the average runner this does not diminish the popularity of this piece of equipment. According to the Consumer Report Safety Commission, over 50 million Americans use a treadmill for activity needs [1]. This being the case, there is clearly a large interest in the treadmill as a viable piece of exercise equipment among the fitness community.

In addition to the popularity of the treadmill there is, more importantly, the risk of injury associated with its use. There are plethora of articles and information related to treadmill related injuries such as there being over 70,000 mechanical exercise based injuries between the years 2007 and 2011 [1]. While the numbers are not as high as say automobile related injuries, there is still reason for concern especially considering the easy access to young children. While there are a number of safety mechanisms embedded in the electromechanics of a current day treadmill, it does not eliminate the need for safety concerns.

1.3- High-Level Requirements

- Sensor sub-system must be very accurate and report the data in real time for quick adjustment of the belt speed
- Control system schema must eliminate latency on feedback within reasonable controllability (responsive)
- Motor should be able to rapidly approach normal human jogging speed (approximately 5mph) within 1 to 3 seconds based on user velocity and acceleration.
- System must stop within 1 to 3 seconds depending on current velocity when nothing is detected by sensors, when sensors detect that the user is standing still, or when the stop button is pressed.

2- Design

A traditional treadmill needs three central components to function: a power supply, a control unit, and a motor. Treadmills typically take in power via a wall outlet and pass it through an AC/DC converter that supplies the controls unit with 5V, and a variable amount to the motor based on input from the control unit. In the control unit, we process data from four different sources to produce a single output signal that will adjust the velocity of the motor. Finally the motor will take in a range of voltages from the power supply and drive the treadmill, whilst feeding back its current velocity data to the control unit.

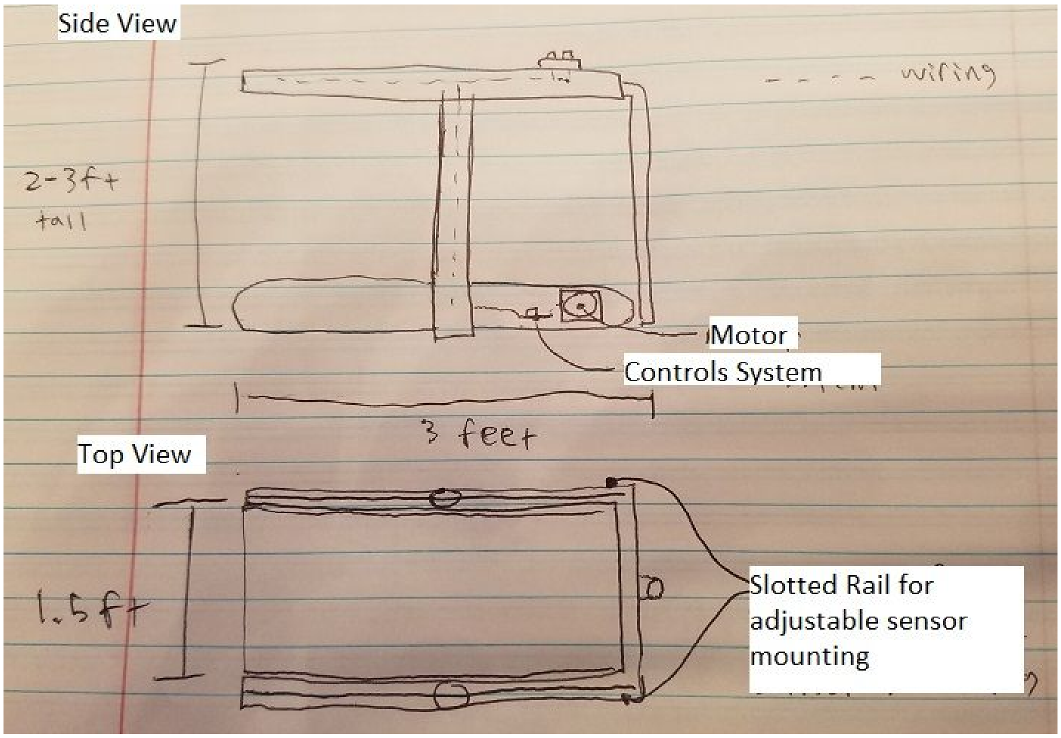

Figure 1, Physical Diagram

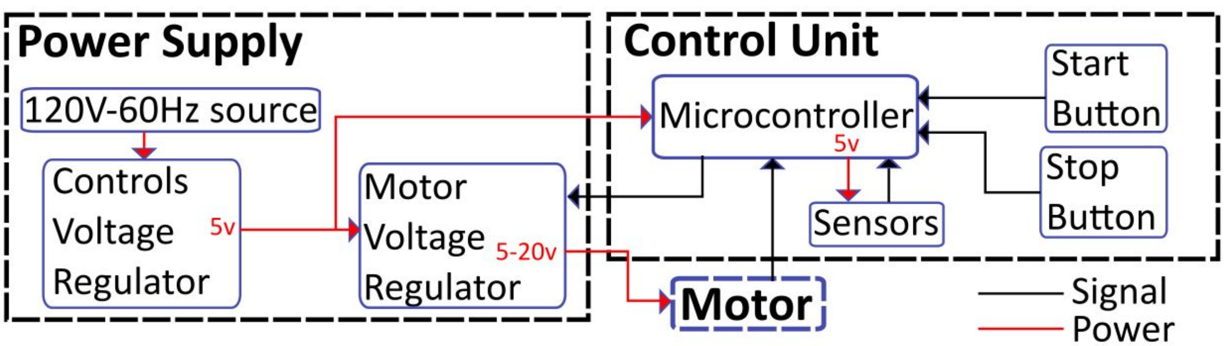

Figure 2, Block Diagram

2.1- Power Supply

The power supply will take power from a wall outlet, which is a 120v, 60Hz AC Source, and output 5v to power the control unit, and 5-20v to power the motor.

2.1.1- 120v, 60Hz Source

The source of power for the system is simply a wall outlet, the only requirement of which is that it is a secure connection.

2.1.2- Controls Voltage Regulator

The controls voltage regulator will need to be an AC/DC adapter that steps down the wall outlet voltage.

Requirement: Must be able to convert a 120v AC signal to an approximately 5v DC signal, since the output signal must be able to power a microcontroller, we use an ATmega328p as an example.

2.1.3- Motor Voltage Regulator

The motor voltage regulator will need to be a DC/DC converter that steps up voltage from 5v to a range of other voltages (in our case up to 20v for our current motor) based on input from the microcontroller.

Requirement: Must be able to step up a 5v DC signal to a range of DC values between 5v and 20v.

2.2- Control Unit

The control unit will take in external user input and sensory data, then send an output signal to the motor unit in order to adjust to the input data.

2.2.1- Microcontroller

The microcontroller will be the heart of this unit, and will be where all of the input data is fed into, and where the output signal will originate from. We will most likely use an ATmega328p since we do not need much memory to perform the operations we will be making, and its price is cheap, which will allow us to put more money into the motor unit and sensors. The control board (possibly the MC2100 series) used to run the motor will need to be controlled by the PIC microcontroller. Generally a basic treadmill PWM signal is controlled by an adjustable potentiometer, but our microcontroller will instead utilize a CCP (capture compare PWM) set of libraries for easily adjustable PWM control. In addition, the sensors will need to be interfaced with the control unit as an input signal to the CCP modules in order to adjust the PWM signal to the control board, which will adjust the voltage output to the DC motor, which in turn will adjust the speed determined by the position control system algorithm.

Requirement: Must be able to process and temporarily store data for up to 1 millisecond from up to 4 separate locational sensors, a velocity sensor, and 2 buttons, then be able to be programmed to output a range of voltage values based on this input data.

2.2.2- Sensors

The sensors will be vital to the function of our system. In order to most accurately get a measurement on the position of our user, we will test a number of configurations and type of sensors, namely ultrasonic and Lidar sensors, then determine which configuration is most suitable based on if the configuration can keep track of distance within 95% accuracy, and for under approximately $20. To test these configurations and sensor types, we will have an rc car run the length of the treadmill at a constant velocity, then compare the values read from the sensors from any given time to what the actual value was. Research on sensors in our price range suggests that we'll likely need to supply them with 5v to keep them running.

We will use testing qualifications to determine the best combination of the number of sensors, their position of the number of sensors in use. The sensor testing procedure will be broken down into two subcategories (lumped as one test per sequence). The first subcategory of testing will be to determine the number of sensors to use per positional test. We determined that the proposed number of sensors to use will be 1, 2, or 4. One sensor can be used to determine if the tracking gives proper velocity/positional readings within the predetermined error acceptance range while the additional 2 or 3 will test will help determine if there is any additional information on tracking that can be obtained by increasing the amount of incoming sensory data.

The second subcategory of testing functions is in conjunction with the first test subcategory. With it we will determine positional efficacy of the sensors. The test for all combinations of sensors will be tested by varying the positioning, angling, and distances apart from other sensors. Depending on the positioning there may be the possibility of two different control schema to determine tread velocity.

Requirement: Sensor must be able to track the distance of a user with 95% accuracy, at a range of up to 6 feet, across a width of 3 feet. Accuracy is determined by velocity and position tracking while the tread is not in motion. We only wish to determine velocity and position tracking without the added dynamic movement associated with the tread movement. Position tracking will be measured by tracking the relative position to the sensors at various points on the tread and reading the measurements in comparison with physically measured values. Velocity will be the sensor velocity measurement compared with the rc car velocity readings (likely tracked with a tachometer). Each condition will be compared by way of error percentage ((measured value - experimental)/measured value)*100).

2.2.3- Start Button

The start button is a simple user interface for the sake of safety and ease of use.

Requirement: Must be able to send a signal to the microcontroller within .25s of being pressed for the sake of user comfort and convenience.

2.2.4- Stop Button

The stop button is a method for the user to stop the treadmill at their own convenience or in the event of an emergency occurring.

Requirement: The stop button must be able to send its signal within 1ms of being pressed for the sake of safety.

2.3- Motor

The motor will take in voltage values from the supply unit, and respond accordingly in a timely manner, whilst also providing data related to its current rotational speed to the microcontroller.

Using a Minertia small size DC p-series (P09S) servo motor we will not need to use a driver. The motor will be rated at a max voltage of 23.8V with a max torque of .5N*M at approximately 4000rpm. We wish to use a high RPM low voltage motor as they tend to be cheaper and it is relatively easy to control the speed of them.

Requirement: Motor must be able to begin adjusting to a range of input voltages within a timeframe of less than 10ms, or the lag to such voltage changes must be constant such that it can be accounted for in our control system.

2.4- Risk Analysis

Overall the block that poses the greatest risk to the completion of our project is the sensors block. Getting accurate readings from laser and ultrasonic sensors can be very hard. In addition, if the sensor readings are inaccurate or unreliable, that cascades down through every other system, since the control system requires that information be precise in order to function at all. This issue is also exacerbated by the fact that none of our team members have much experience using sensors of these nature. The only other system that would pose a major risk is the microcontroller, but two of our three group members have experience with controls, so the risk of failing due to the sensors is greater than failure due to the microcontroller.

3- Ethics and Safety

Treadmills pose a number of safety and ethical risks. The most readily apparent risk is the fact that people can easily get hurt on a treadmill, violating IEE code of ethics #1: ”to hold paramount the safety, health, and welfare of the public [...]” and #9: “to avoid injuring others [...]” [2]. On a typical treadmill people must match the speed of the treadmill, if the speed is too quick for them they will lose their footing and fall. The objective of our design is to help alleviate this issue by designing a prototype treadmill that will match the speed of the user, rather than forcing the user to match the speed of the tread. However in the event that a fall still occurs, we will ensure that safety rails to help catch the user and an emergency stop button is installed to help prevent it. In addition we will use our sensors to automatically stop the treadmill if it is sensed that the user is at a standstill or is no longer in view of the sensors. In addition, the testing procedure would be incredibly dangerous if we were to use a live subject, so for this reason we have opted to use a scaled down treadmill and an RC car to do testing, since no live subject will be needed that way.

Treadmills are also very large and difficult to move around, and since we will be making ours in a an environment shared by our peers, this could be seen as violation of IEEE code of ethics #10: “to assist colleagues and co-workers in their professional development [...]” [2], since we would be disrupting the work environment of our peers and possibly inhibiting their ability to do their work properly. As such we have decided to use a scaled down model of a treadmill to prototype our design, since this would greatly reduce the footprint we have in the shared workspace. However, scaling down the treadmill may pose a problem with both IEEE code of ethics #1 and #9 as stated above, and in IEEE code of ethics #3: “to be honest and realistic in stating claims or estimates based on available data” [2]. This breach in ethics is caused by the fact that a treadmill at a smaller size such as this may not scale up to a human size and function correctly still, which means that if we scale it up without testing, it may bring harm to someone, and if we lie about the test results or the scalability of our system on a conceptual level, we would be violating those codes. As such we have decided to use an algorithm that uses positional tracking and velocity measurement to drive our control system, as that is a more linearly scalable system than if we were to use pressure or force detection.

References

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