

Preliminary Proposal
Accessible Manufacturing Equipment
Team 2
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Sponsored by
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Executive Summary

This project is a reengineering effort to improve upon an already functioning, handicap accessible ribbon cutting machine. The critical customer requirements include making the machine's processes faster and more precise, implementing an easy to revise programming interface, and solving heat and over current problems within the motor drives. To attain these requirements the current motor drive will be replaced with one that has better control, and operating characteristics. Also, the programming interface will be updated so that an unfamiliar user will be able to quickly make timing and other machine process adjustments.

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Introduction

In 2008 a group of engineering students from MSU designed a machine that allowed a physically disabled worker to cut, pleated cloth ribbons used for making awards. There are currently two major problems with the machine. First, the machine in its current state uses stepper motors to drive one of the most important machine processes of pulling the cloth to a correct length to be cut. The stepper motors currently lead to inaccuracy in the cut, and they cause heat dissipation problems within the control system. The second problem is the programming interface is currently written in C and only a user who is familiar with the machine and language of C can make adjustments to the machine. The machine needs to have a programming interface that is easy to use so that locals near the machine can maintain the machine.

Customer Requirements

The stepper motors lead to inaccuracy due to the high torque requirements demanded of them. This high torque demand has also led to high current problems that are the source of heat dissipation issues. It has been hypothesized that high startup torque is the reason for the inconsistency and inaccuracy in the cuts made by the machine. The Lettuce Duit Corporation has specified that the final design should be capable of cutting with a tenth of an inch precision. The final motor drive should feature a variable speed control, and have a higher maximum speed of operation than the current system.

The current programming interface is written entirely in C and adjustments can only be made with access to a PIC programmer. The customer has specified that the final design must have a programming interface that a High School student with basic knowledge of robotics and programming could understand and modify the code as necessary.

Other customer specifications include the production of a new and concise schematic of the system. Code that either features documentation or a document detailing the machine's program. The current movable clamp doesn't always release the cut ribbon which causes the system to jam on the next iteration. The current system features a fan that is used to blow away the cut ribbon but this is an inconsistent solution. The final design is to have a reliable solution to this problem.

Since the project is intended to aid disabled persons it has been requested that the machine be completed one week before design. This is so David, the handicapped primary operator of the machine, can become familiar with the new machine for the purpose of demonstrating the machine on design day,

Background

The requested new interface for programming the machine is to be based on Lego's NXT-G programming environment, or National Instrument's Labview. Labview and Lego partnered to create the NXT-G environment so both solutions are similar. Using either programming environment would require the use of hardware purchased from the software supplier to provide the input/output interface for the rest of the design. For this reason the Lego NXT brick has been chosen as the microcontroller to be used in the final design. This is because the Lego NXT brick is compatible with the NXT-G software and is also compatible with Labview software designed

specifically to expand the Lego programming environment.

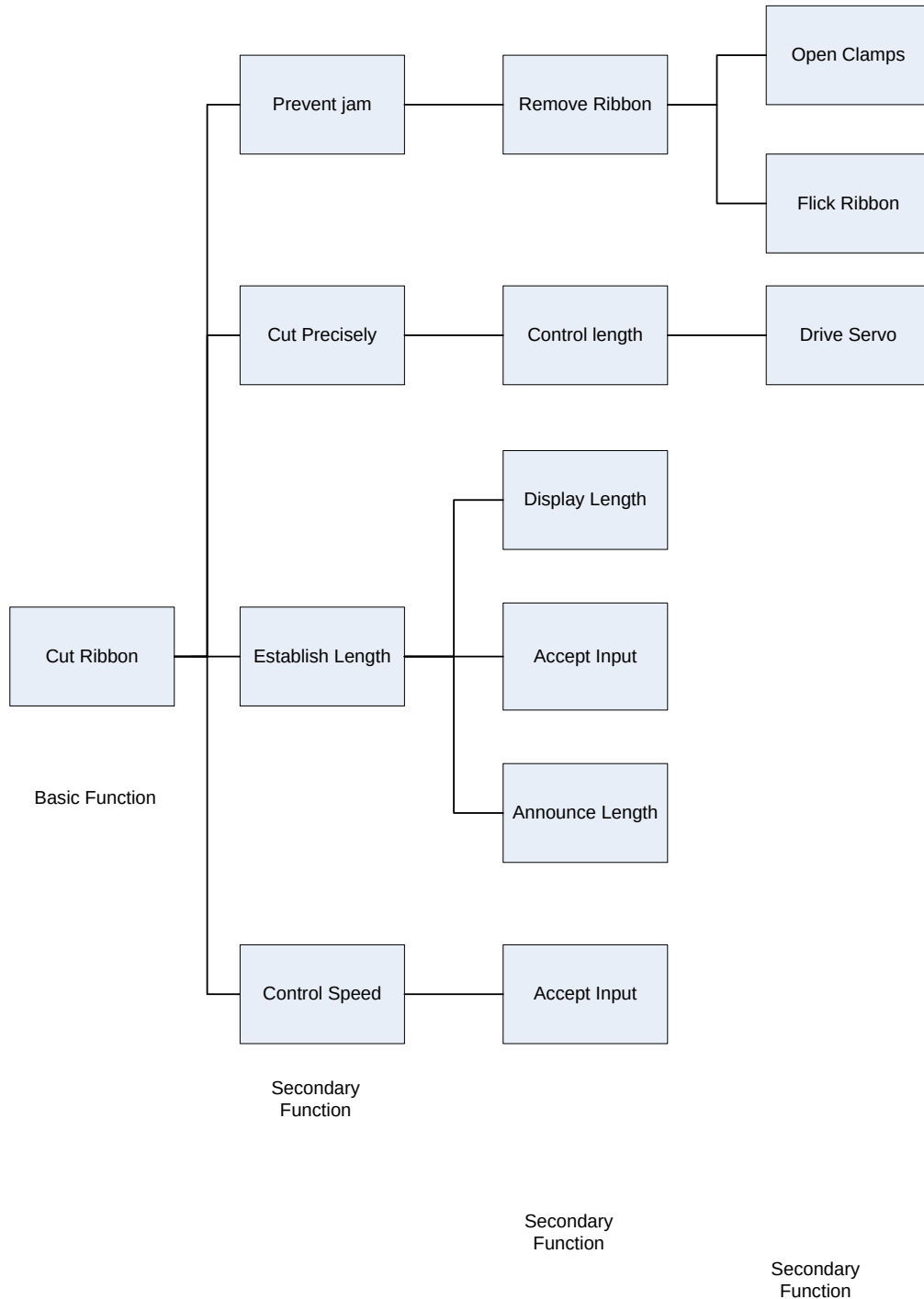
The current motor drive system uses two stepper motors operating in parallel. Initial experiments by the group have shown that the system has unnecessarily high friction resulting in the high torque requirement of the stepper motors. The current system has two plastic rollers that are in contact with the rotating bar used for closing the movable clamp. These plastic rollers are a source of friction that can be greatly reduced with their replacement with either a ceramic or steel roller. It is estimated that this improvement will lower torque requirements enough that a Lego Servo motor will be able to drive the movable clamp along its track. This solution will also remove the over current and heat dissipation problems associated with the stepper motors, while maintaining servo/stepper motor accuracy.

Objectives

Our primary objectives are to improve the accuracy of the ribbon cutter to within 1/10 of an inch, add a variable speed control, and increase the maximum speed of the movable clamp, as well as redesign the motor drives to prevent the heat buildup that plagues the current design. The machine must also be easily reprogrammed and maintained by high school students with a minimal robotics background.

Our secondary objectives are of significantly less importance than the primary ones. They improve the convenience of the machine but are not necessary for its operation. First, replace the original machine's blower fan with a flipper. This would clear any ribbon that sticks to the movable clamp and would not make a mess out of the already cut ribbons that the blower currently does. Also the machine's aesthetics must be improved. The sponsor wants to convince other engineering programs around the country to take up final engineering projects like ours in order to improve the quality of life for many more disabled people. If our project is successful it would be used as a model for future projects. To facilitate this, a polished looking final product should be delivered.

FAST Diagram



Conceptual Design Descriptions

Our top three designs are: an all LEGO MINDSTORMS solution, a solution based on two PIC Microchip 18F4520 microprocessors, and a hybrid solution taking the best out of both the LEGO and the PIC design.

Lego Solution

The LEGO MINDSTORMS NXT solution has a great deal to offer in simplicity and ease of maintenance. Because all of the parts are standard LEGO motors and sensors if they break they can be easily replaced with another standard part. Also because the RCPD has contacts in a high school LEGO robotics team near where the machine will be deployed, there will be experts available to maintain the machine after the final product has been delivered. The coding will also be greatly simplified by the LEGO programming interface as LEGO NXT bricks are programmed using a simple GUI.

In this solution the movable clamps would be driven with LEGO servomotors. These motors are not very strong so they would need to be run in parallel. Initial testing suggests that three will be required to give us the mechanical power needed. These servos are also accurate to 1° of rotation. This will yield accuracy much higher than the minimum specification required by the customer. The other motors on the machine would also be replaced with LEGO motors. The buttons set in the NXT brick would be used to set the cutting length, reducing the number of I/O ports needed. There is an audio system and video display built into the NXT brick but they are much smaller than the current user interface system. This means that the LEGO solution will be harder for the visually disabled to use. This solution easily accomplishes both of our secondary goals as well as our primary goals. A flipper would be easy to add using a LEGO system and the parts are already designed to look appealing. Unfortunately the cost of the LEGO NXT bricks is \$145 and the project would require at least two of them because the NXT brick had only three outputs and four inputs. In addition, all of the new motors and sensors will add up to another \$150. Adding another NXT brick also adds to the complexity, making it harder for the LEGO robotics club to maintain.

Simplified and well documented C code solution

Another option is to use the same PIC microprocessors that the machine currently uses and rewrite the code so it is easy to read and modify. By commenting and changing the code so that all the variables are well labeled the code can be simplified. A section could be added near the top of the code where any variables or constants most likely be changed, so that they can be found without searching the rest of the code. This should allow even very inexperienced C programmers to read the code and modify it. The speed and accuracy problems would be solved by using a DC motor with a PID controller. The DC motor would be large enough to replace both stepper motors, making the machine more robust. The PID controller would allow for precise control of the position of the motor, and allow for feedback to the rest of the system eliminating the need for timing loops in favor of an event driven program. This would make the program more efficient by eliminating waste time in between machine processes. The flipper could be implemented with a simple DC motor.

This design has much simpler I/O as the PICs can have more than 40 I/O ports while the LEGO has only four inputs and three outputs. This design is also much cheaper than the LEGO solution. The PICs cost about \$2 each and sensors can be bought as discrete components, lowering their price. This would also provide the opportunity to choose any DC motor, allowing for a higher maximum speed than could be obtained using LEGO NXT.

Hybrid Solution

The hybrid solution is a combination of the best features of the LEGO and PIC solutions.

The PIC will maintain control of the display and the audio system. A Lego NXT brick will be used to control the movable clamp drive system and the cam motors, as well as the cutter motor. This design adds the precision of the LEGO servo motors as well as the programmability of the LEGO MINDSTORMS NXT interface. Also the current large visual display and more powerful speaker system currently driven by a PIC microprocessor will be kept.

Solution Selection Matrix

Engineering Criteria	Importance	Possible Solutions										
● = 9 (Strong) ○ = 3 (Moderate) Δ = 1 (Weak)		Lego Servo Motor	DC Motor	LEGO Mindstorms	LabVIEW	RobotC	C++ Code	Connectors	Safety Guards	New Cutter	New Controller Box	Flipper
Speed of Operation	5	○	●							Δ		Δ
Accuracy and Precision	5	●	○							Δ		
Safety	4								●	○		
Aesthetics	2							●			○	●
Revisable Software	5			●	○	Δ	Δ					
Noise	2	Δ	Δ							●		
Compatibility	3	●	Δ									
Mechanical Maintenance	3							Δ				
Maturity of Technology	4			Δ	○	○	○					
Robustness	4	○	●	Δ	○	○	●					●
TOTALS		101	101	53	39	29	53	21	36	40	6	59

Proposed Design Solution

Hardware

The proposed design solution is hybrid between the current system and the LEGO NXT

robotics system. The stepper motors will be replaced with three 9v servo motor that have been purchased along with the LEGO NXT brick. The servo motors will allow for the program to execute cuts down to 1° of rotation. This corresponds to accuracy to within .26mm. The stepper will have to be removed from the system and the brackets rearranged to accommodate the three servomotors.

The plastic roller on the movable clamp open/close bar will be replaced with brass ones. The spring that forces the movable clamp assembly to make contact with its cam will also be replaced for one with a lower spring constant. This will hopefully reduce the friction along the movable clamp assembly enough that the servomotors will be able to move the system more quickly and accurately.

The design will be using I2C communication buses to expand the number inputs and outputs available on the NXT. To do this I2C circuits will be using the PCF8574 I/O expansion IC. There will be two of these circuits used. One will handle the interface between the current length input buttons, the set and reset buttons, and potentiometer will be designed to give the system variable speed control.

A buck circuit will also have to be built to reduce the 12V supply down to 9V this will be used to power the NXT brick which in turn will power the servomotors.

Since the I2C bus can only deliver very limited power. MOSFETs will be used to turn on and off the windshield wiper motors. These motors operate at 12V.

The current 7-segment display and audio system will remain. These two functions will remain programmed to one of the PIC microcontrollers. It is felt that once these two systems are operating no further adjustments will need to be made by future users.

The current fan blower systems will be removed and replaced with a small DC motor that will also be interfaced through the I2C bus. This small motor will be attached to a small rod that will be used to flick loose pieces of ribbon from the machine.

Software

The current timing loops that open and close the stationary and movable clamp, and move the cutter will be replaced with event driven programming within the NXT. These events will correspond to sensors alerting the NXT brick that the previous event has resolved and it now time to move on. This will have the effect of removing wasted time that previously existed.

Communication over the I2C bus will accomplished through downloadable programming blocks that are available through LEGO.

The variable speed control will be implemented by adjusting the power supplied to the servomotors. The potentiometer will be used as the user input to control this. All other processes of the machine will left independent of the variable speed control since all processes, such as opening clamps aren't expected to alter user experience significantly.

Build Methodology

The first components that must be built are the I2C interface circuits, buck circuit, improved movable clamp, and the brackets that will be used to support the three servo motors. These two components are independent of each other. The reason for these components taking priority is so that tests can be conducted on the servomotors, and so that interfacing between the NXT brick and all components on the I2C bus can begin.

Once the I2C bus is operational the next step will be to design all supporting circuits for interfacing the sensors, and windshield wiper motors with I2C bus, as well as provide power to components that require it.

The final step will be to program the NXT brick to automatically carry out all processes. Testing will also be conducted to ensure that the new system meets all critical customer requirements and expectations.

Evaluation

Two tests have already been conducted to benchmark the performance of the completed system. The current machine is capable of making 100 cuts in 7 minutes 50s. The accuracy of the cuts varies up to an eighth inch. The final design will be required to best the current machine speed, and meet the design requirement of accuracy to within a tenth of an inch.

The objective of meeting programming simplicity will be met by the use of LEGO NXT-G. The complexity of the end program will be a result of the limitations of the programming language.

The machine should be generally considered more aesthetically pleasing.

Risk Analysis

With the decision to select the LEGO hybrid solution, some challenges become apparent. The LEGO NXT Brick only provides the user with only three output ports and four input ports. Due to the number of motors in our system that need to be controlled, this limitation of the input and output ports has to be overcome. There will be at least six motors in the final system; therefore, three output ports from the brick will not be enough to control all the motors. This particular concern has been discussed and the best approach to overcome this issue has been discovered. The I²C buses for serial communication can be implemented in the circuit design to increase the number of input and output ports of the LEGO NXT Brick. Thus, the constraint of having the most of three motors to control can be resolved, and is considered a low risk.

Another challenge is the inability to create complex features in the NXT-G software. The LEGO Mindstorms software is a programming interface that is designed to emphasize the simplicity of the programming itself. This leads to a lack of complex features in the programming that might be helpful to improve the robustness of the whole system. For example, the LEGO Mindstorms does not provide the built-in PID Controller feature in its programming software tools. However, since LEGO servo motors are being utilized in the system, the precision and accuracy can be assured with the advantage of having 1-degree of accuracy in the rotation of the motor itself. In addition, the simplicity of the programming code has to be maintained based on the main objective of this project. The inability to program all necessary functions is considered a medium risk.

The last major challenge is the low overall power that can be provided by the LEGO servo motor. Initial testing suggests that operating three LEGO servo motors in parallel will provide enough power to move the movable clamp assembly at or greater speed than the current stepper motors. The risk that the LEGO servo motors will not be able to move the movable clamp assembly is considered low. However, the risk that the servomotors will not be able to

improve the current speed of the machine is considered a high risk. Therefore, the three servo motor assembly is to be mounted to the machine frame and tested as soon as possible so that alternative measures can be used if necessary.

Project Management Plan

The following section describes the technical tasks to be completed by each member of the group.

Nick will be responsible for the programming interface; this will include programming in the NXT-G interface and reprogramming of the current 18F4520 Microcontrollers. Once the programming is complete, he will run a series of tests to ensure that the program runs at the desired specifications and that all the cues are timed properly. In addition Nick will be implementing and programming the sensors; this includes all the push buttons and switches on the user interface.

Ralph will be in charge of researching and implementing the I²C Bus for communication between the PICs and the NXT Brick. Ralph will also be working with the drivers for the cutter and cam motors; this will include relaying the drivers through the PICs and to the NXT Brick via the I²C Bus. In addition to this he will be aiding Nick in all the programming.

Jon will be doing all work associated with the LEGO Servo Motors. This includes testing, implementation and design, and programming. He will also be assisting Ralph with the I²C Bus.

Li will be in charge of designing and adding the flipper to the machine as a replacement for the blower fan. He will be programming the LEGO NXT to run the DC Motor controller for the flipper. He will also be implementing the audio output of our user interface. Li will also be in charge of ordering parts for the project.

Felix will be designing and implementing the new cutter mechanism and programming it. The new cutter mechanism will still be controlled via one of the 18F4520 microcontrollers. In addition he will aid the other members as needed for their various tasks.

The proposed schedule identifies a feasible timeline for the completion of the project and all required deliverables. The project is scheduled for completion in early December.

A summary of the schedule is as follows:

	Completion Date
Pre-proposal	9/20/2010
Proposal	10/22/2010
Oral proposal presentation	10/18/2010
Student Technical Lecture	11/3/2010
Demonstration #1	11/1/2010
Electrical Interfacing	11/5/2010
Hardware Modifications	11/12/2010
Demonstration #2	11/15/2010

Programming Completed	11/18/2010
Project Completed	12/3/2010
Final Report	12/8/2010
Final Demonstration	12/10/2010

Budget

Quantity	Parts	Cost
1	Lego Mindstorm NXT 2.0	\$299.99
2	Bronze Rollers	\$3.02
1	New Cutter	\$30.00
1	Flipper	\$5.00
	Miscellaneous	\$10.00
	Total	\$348.01

The Lego Mindstorm NXT was provided by our sponsor. Since most of the hardware is being carried over from the previous project the cost Team 2 should be relatively low. The total cost to Team 2 is expected to be around \$50 total. This will cover the costs of the ICs used to integrate the Lego NXT with the rest of the system.

References

Gasperi, Michael, and Philippe Hurbain. *Extreme NXT Extending the LEGO MINDSTORMS NXT to the Next Level*. 2nd. New York: Apress L.P., 2009. eBook.