R2000

Mobilitate's Rehabilitative Exoskeleton for Legs

Meet the Team

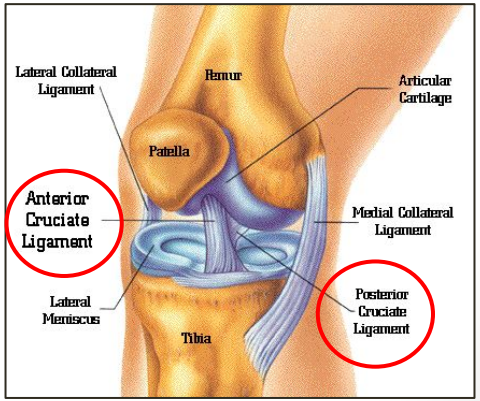
Ryan Villanueva
Electrical Lead
Chantal Osterman
Integration and Testing Lead
Jialiang(Kevin) Ou
Software Lead
Lucia Zhang
Design Lead

Presentation Overview

- Background, Motivation and Scope
- System Overview
- Market Analysis
- Project Logistics
- Conclusion

Motivation

- Approximately 1 million Canadians suffer leg injuries each year
- Reconstruction surgery is only required for Grade III tears in the ACL or PCL
- Study by Frobell suggests rehabilitation should be the first step
    - 60% of control group that delayed surgery no longer needed it

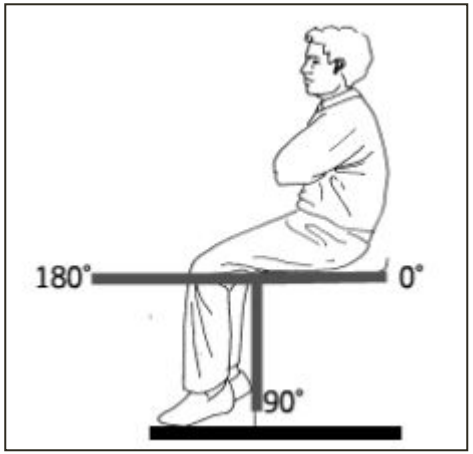


Motivation

- Provide means and motivation to exercise
- Health care money allocated towards surgery compensation can be used elsewhere
- Project integrates a number of different fields

What is the R2000?

- Rehabilitative exoskeleton for legs
- Provides 90 - 180° motion for stretching knees
- Allows rehabilitation at home
- Intuitive and user-friendly
- Can be used with some knee braces



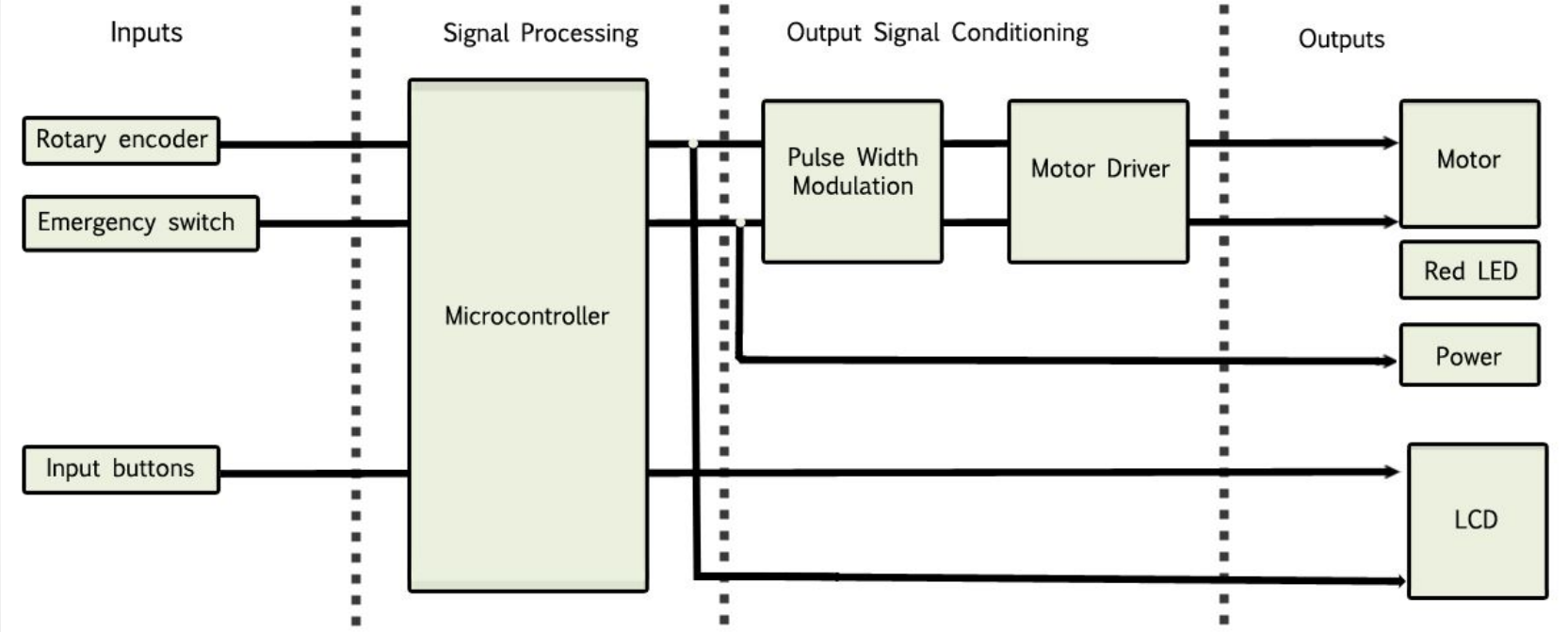
Changes in Scope

- Positional control was replaced with speed and directional control due to last-minute issues
  - Product uses a different motor driver
- Due to the size of the motor:
  - Only one exercise is available
  - Portability was sacrificed

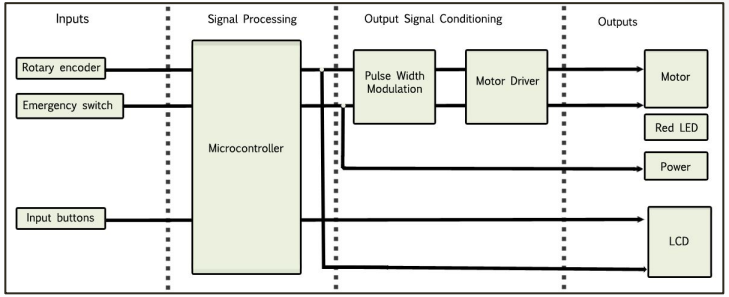
Presentation Overview

- Background and Motivation
- System Overview
    - Mechanics
    - Enclosures
    - Electronics
    - Software
- Market Analysis
- Project Logistics
- Conclusion

High-Level Diagram



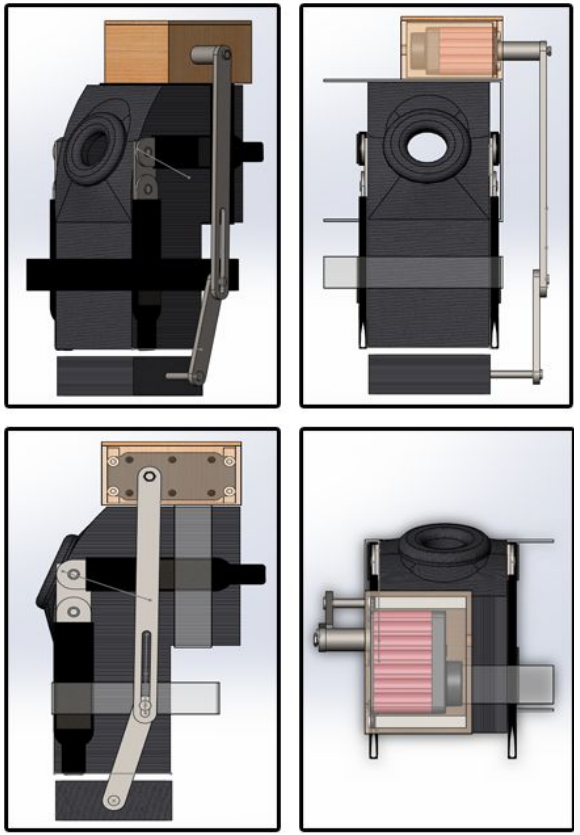
High-Level Diagram



- Input
  - User navigates through menus to input exercise information
  - Distance sensor detects obstacles within exercise area
- Signal processing
  - Arduino reads in data, translates to signals, and sends to driver and other components
- Output Signal Conditioning
  - Driver uses PWM signals to manipulate motor motion
- Output
  - Errors and progress are indicated through LCD, LED, and buzzer
  - Motor and rigid bar rotates until exercise is complete
  - Switching power off shuts down both UI and motor

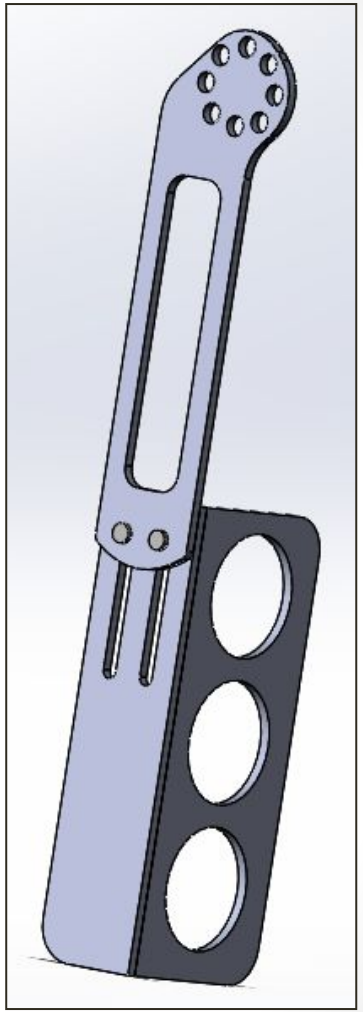
Mechanics

- Rigid bar needed to have adjustable length
- Must be attached to user comfortably
- Must be strong enough to lift leg
- Should ideally be minimal in design



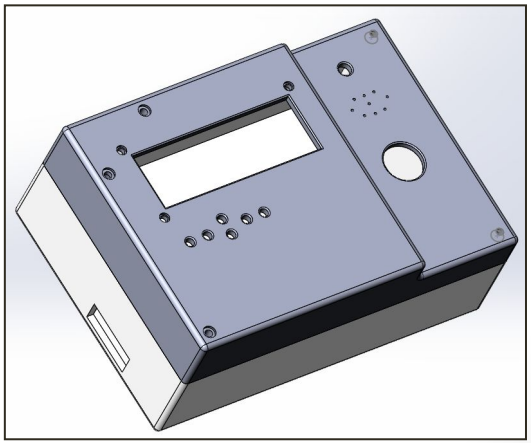
Mechanics

- Final design provides a scooping feature
- Holes provide weight reduction
- Does not require prismatic joint for dynamic length during motion
- Adjustable length up to 8cm

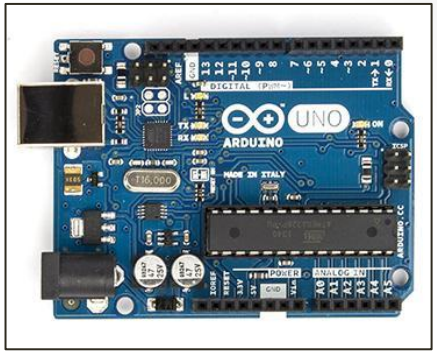


Enclosures

- Motor Enclosure and Mounting
  - Sturdy to avoid tipping and shifting during motion
- User Interface Enclosure
  - Houses Arduino, PCB, and misc components
  - Must be ergonomic and easy to use
  - Components should all be easily accessible



Electronics



- Arduino Microcontroller
  - Reads or sets the status of numerous electrical components, eg. LED, pushbuttons, etc.
  - Sends pulse-width modulated signal to motor driver

- Motor Driver
  - Receives signal from Arduino
  - Uses PWM value to determine position

Electronics

- Printed Circuit Board
  - Contains connections for all electrical components
  - Voltage divider determines remaining battery
  - Emergency switch cuts off power
- Distance Sensor
  - Detects obstacles and emits noise if there is danger

Electronics

- Servo Motor
  - Translates electrical energy into mechanical energy
  - Consists of motor, driver, gearbox, and position-sensor
  - High torque

Software

- All done on Arduino
- Two-level menus displayed on 16x2 LCD
  - Calibrate neutral position
  - Choose angle and repetitions for exercise
  - Test input components
  - Check battery level
  - Test low battery conditions
- Includes debouncing for buttons
- Built-in interrupt prevents PWM values from going out of range

Presentation Overview

- Background and Motivation
- System Overview
- Market Analysis
    - Intended Audience
    - Similar Products in Market
- Project Logistics
- Conclusion

Intended Audience

- People with knee injuries
    - awaiting surgery
    - recently underwent surgery
- Young adult to seniors
- Height: 150cm - 170cm
- Weight: Up to 73kg

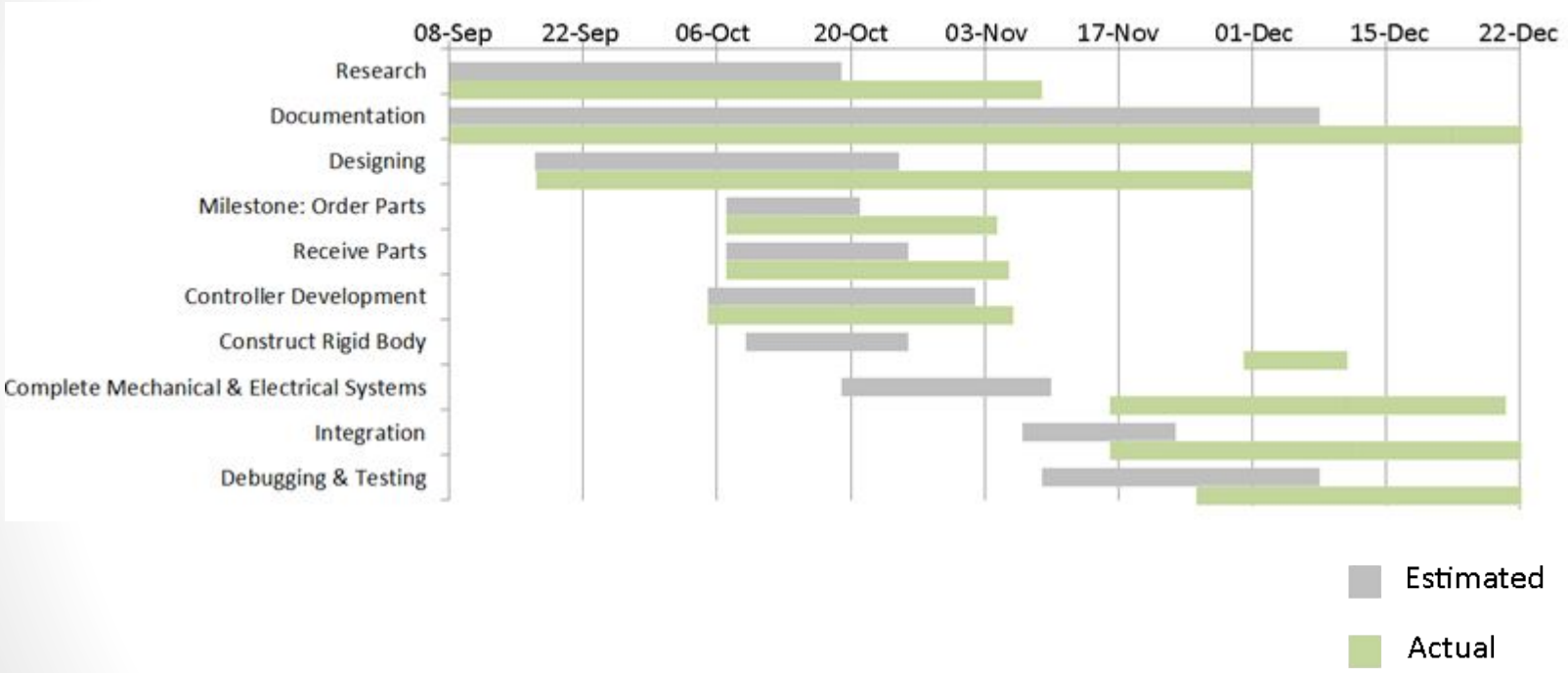
Similar Products in Market

- Hybrid Assistive Limb (HAL)
  - Only rented
  - Only available to medical institutions and welfare facilities in Germany and Japan
- ReWalk
  - Aids users to walk
  - Can be used at home
  - Costs $69,500

Presentation Overview

- Background and Motivation
- System Overview
- Market Analysis
- Project Logistics
    - Development Timeline
    - Costs and Materials
    - Funding
- Conclusion

Timeline


08-Sep
22-Sep
06-Oct
20-Oct
03-Nov
17-Nov
01-Dec
15-Dec
22-Dec
Research
Documentation
Designing
Milestone: Order Parts
Receive Parts
Controller Development
Construct Rigid Body
Complete Mechanical & Electrical Systems
Integration
Debugging & Testing
Estimated
Actual

Costs and Materials

Component	Estimated Cost ($CAD)	Actual Cost ($CAD)
Servo Motor and Driver	482	509.16
Motor Enclosure & Mounting	N/A	Donated
Arduino	Borrowed	Borrowed
LCD Shield	35	33.60
Rigid Bar	40	364
UI Enclosure	N/A	90
Battery	40	Borrowed
Distance Sensor	20	12.32
Misc	140	Borrowed
Contingency	151.40	N/A
Total	908.40	1009.08

Costs and Materials

- Rigid Bar
  - Aluminium alloy
  - Screws, nuts, washers
- Motor Enclosure
  - Hardboard
  - Joist angles, screws, nuts, washers
- UI Enclosure
  - 3D printed

Funding

- $400 from ESSEF
- Mobilitate Members
- Wighton Fund

Presentation Overview

- Background and Motivation
- System Overview
- Market Analysis
- Project Logistics
- Conclusion
    - Future Plans
    - What We Learned
    - Special Thanks

Future Plans

- Complete the project with positional feedback
- Smaller size of motor
    - Create our own gearbox
- Focus on portability
- Better UI and motor enclosures
- Support multiple rehabilitative exercises

What We Learned

- Arduino programming and interfacing
- Introduction to orthopaedic biomechanics
- Different methods of motor control
- Proper design algorithms
- Importance of documentation
- Networking
- Sometimes trial and error is the way to go

Conclusion

- Learned a lot about integration of components
- Do not underestimate project scope
- End product did not align with initial goals
  - But final product still functional

Special Thanks

- Professor Steve Whitmore
- Professor Andrew Rawicz
- Lukas-Karim Merhi
- Sohail Sangha
- Yaser Roshan
- Professor Shahram Payandeh

References

[1] M.A. Wind (2011). *Ligament Injuries of the Knee* (Online). Available: http://www.keyweb14.com/drmichaelwind/wp-content/uploads/2011/12/knee-surgery1.gif

[2] J.Billette, T.Janz. (2011, June 28). *Injuries in Canada: Insights from the Canadian Community Health Survey* [Online]. Available: http://www.statcan.gc.ca/pub/82-624-x/2011001/article/11506-eng.htm

[3] WebMD. (2015). *Knee Ligament Injuries: PCL, LCL, MCL, and ACL* [Online]. Available: http://www.webmd.com/fitness-exercise/guide/knee-ligament-injuries?page=2

[4] R. Frobell et al. "A Randomized Trial of Treatment for Acute Anterior Cruciate Ligament Tears". *N Engl J Med*, 363., 331-342, July 2010.

[5] Assist Ireland. (2015). Choosing A Chair And Chair Accessories [Online]. Available: http://www.assistireland.ie/eng/Information/Information_Sheets/Choosing_a_Chair_and_Chair_Accessories.html, last accessed October 12, 2015

[6] *Getting Started with Arduino on Windows* [Online]. Available: https://www.arduino.cc/en/Guide/Windows

[7] Jaycon Systems. *Pololu JRK 21V3 USB Motor Controller With Feedback (Fully Assembled)* (Online). Available: http://www.jayconsystems.com/pololu-jrk-21v3-usb-motor-controller-with-feedback-fully-assembled.html

[8] Robotshop. *Torxis i00600 12V High Torque Servo Motor* (Online). Available: http://www.robotshop.com/ca/en/invenscience-torxis-i00600-12v-high-torque-servo-motor.html

[9] Cyberdyne (2015). *HAL for Living Support (Single Joint Type)* (Online). Available: http://www.cyberdyne.jp/english/products/SingleJoint.html

[10] CBS News (2014). *First patient takes ReWalk robotic exoskeleton home* (Online). Available: http://www.cbsnews.com/news/first-patient-takes-rewalk-robotic-exoskeleton-home/

Questions?

Demo