Vinh Hoang

Portfolio

M.S. Computer Science (Georgia Institute of Technology)
M.S. Mechanical Engineering (Columbia University)
B.S. Mechanical Engineering (University of California, Berkeley)

April 30, 2018
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Table of Contents

Career Summary and Goals:

I am a full-time student pursuing M.S. degree in Computer Science at Georgia Institute of technology (graduating in May 2018). I also have an M.S. degree from Columbia University and B.S. from University of California at Berkeley in mechanical design and robotics.

I have 3 year working experience in embedded system and design. I have won multiple awards and scholarship during my professional and academic career:

- Naval Nuclear Laboratory Team Design Award (2016)
- Toyota Motor Corporation Science Scholarship (2012-2013)
- Second Prize in UC Berkeley's Mechanical Design (2011)
- California's Regents Scholar (2009)
- 4th prize College Math Competition (2009)

During school, I have participated in multiple projects:

- Machine-learning projects to automate trading, detect malicious payload and employ polymorphic blending attack techniques to invade computer systems
- Python full-stack: web-based management tool that supports government agencies in managing resources.
- Java Spring full-stack: public transportation simulation system for Metropolitan Atlanta Rapid Transit Authority (MARTA).
- Many embedded system/robotic projects like Mind-Controlled Wheelchair, metal bending machine, and Braille ebook for the blinds.

I truly believe that with my strong background in engineering, my passion for technology, and my ability to learn, I would make a good fit. I enthusiastically look forward to putting my knowledge and experiences into practice, and I am confident that I would do outstanding work. I enclose my resume for your convenience, and please do not hesitate to contact me with any question, as I would appreciate a chance to meet you in person.

Sincerely yours,
Vinh.

Vinh Hoang

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https://github.com/vh2225

EDUCATION

Georgia Institute of Technology (GPA 3.9/4.0) — *Atlanta, GA*
Master of Science, Computer Science — Jan 2017 – May 2018

- Related coursework: Database Design, Computer Networks, Software Dev Process, Computability & Algorithms, Info Security, Network Security, Software Analysis & Test, Machine Learning for Trading, Software Architecture & Design, Human-Computer Interaction.

Columbia University (GPA 3.4/4.0) — *New York, NY*
Master of Science, Mechanical Engineering — Sep 2012 – Dec 2013

- Related coursework: Finite Element Method, Computational Geometry, Robotics, and Embedded System.
- Awards: Toyota Motor Corporation Science Scholarship

University of California, Berkeley (GPA 3.4/4.0) — *Berkeley, CA*
Bachelor of Science, Mechanical Engineering — Sep 2007 – Dec 2011

- Related coursework: Mechatronics Design, Microprocessor System, Engineering Analysis.
- Awards: University of California's Regents Scholar, Second Prize in UC Berkeley's Mechanical Design, 4th prize College Math Competition.

PROJECTS

- Trading robot: apply machine technique Q-learner to trade stocks.
- Algorithmic trading: using panda and numpy to apply value investing concepts to automated trading.
- Java spring and hibernate public transportation web application.
- ML-based IDS: Training & Evading Machine Learning based Intrusion detection system:
  apply machine learning to detecting malicious payload and employ polymorphic techniques to bypass the IDS
- Emergency Resource Management System (DBMS) information management tool built with
  Python, Bottle (micro-web-framework), Amazon Web Services (AWS) RDS Postgres and EC2, Bootstrap Front End
- Mind Controlled Wheelchair (2nd prize @ UC Berkeley, https://www.youtube.com/watch?v=HhD3DMjdKys)
- Embedded system: Metal-bending machine, wall-climbing robot, brail-eBook, etc.

WORK EXPERIENCE

Naval Nuclear Laboratory (Knoll Atomic Power Laboratory) - Bechtel Corp. — *Niskayuna, NY*
Hardware Engineer – Nuclear Submarine Simulation. — Jan 2015 – Jan 2017

- Led several design projects to prototype nuclear equipment in the submarine engine room.
- Won the 2016 Naval Nuclear Laboratory Team Design Award with the steam engine valve simulator.
- Initiated development projects to create an immersive virtual reality environment for training using VR equipment and Unity game engine.

Transit Wireless – New York City Subway — *New York, NY*
Design and Analysis Engineer — Jan 2014 – Jan 2015

- Developed the layout of a communications system in more than 120 subway stations and the main data center.
- Conducted stress analysis on equipment using Ansys to validate the equipment designs.

Columbia University, School of Engineering — *New York, NY*
Teaching Assistant in Advance Thermo-dynamics / FEA — Sept 2012 – Jan 2013

- Analyzed thermodynamics effects on turbine blades using Ansys/Abacus, theoretical FEA models (using MATLAB), and physical experiments.
- Delivered weekly tutorials and problem sections to 47 students.

UC Berkeley's Machine Shop *Berkeley, CA*
Teaching Assistant in Manufacturing Aug 2010 – Jan 2012

- Provided excellent assistance, technical training, and customer service to students and faculty.
- Implemented G-code programming and MasterCAM to automated and improved manufacturing process.

RELEVANT SKILLS & QUALIFICATIONS

- Programming Languages: Python, Java , JS, HTML, CSS, SQL, MATLAB/Simulink, LabVIEW
- Embedded software: Motion control, Robotics, PLC.
- Quality Assurance: Six Sigma – Green Belt.
- US Citizen

Text-only Résumé

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Machine Learning for Trading – Manual Strategy using panda/numpy

<u>Details:</u> All 4 parts below trade only JPM stock. Part 1, 2, and 3 use in sample period (01/01/2008 – 12/31/2009). Part 4 uses out sample period (01/01/2010 – 12/31/2011). Please see attached python files for the code details. The python files can generate pdfs of plots that are used in this report.

<u>Part 1: Technical Indicators (20 points):</u> Describe each indicator you use in sufficient detail that someone else could reproduce it. You should also provide a compelling description regarding why that indicator might work and how it could be used. You should also provide one or more charts that convey how each indicator works in a compelling way.

I used 5 indicators for this part: Price / Simple Moving Average (price/SMA), Bollinger bands, Relative Strength Index (RSI), Momentum, and Moving average convergence divergence (MACD).

1. Price / Simple Moving Average

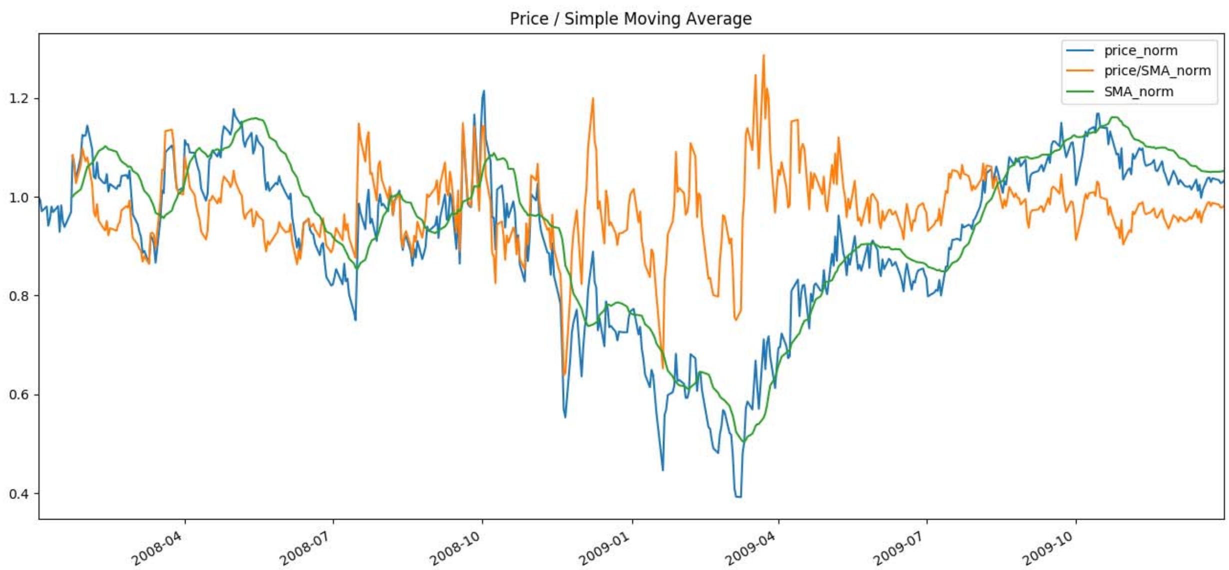


Figure 1.1: Price / Simple Moving Average, normalized data

a. Description: SMA is the unweighted rolling mean of the window period. SMA is a useful indicator in that it essentially smooths out the price values and can be viewed as a proxy for value. Price/SMA ratio is a more useful criteria, since it can be used to determined the buy/sell signal.
b. How to reproduce (formulas): SMA can be calculated by calculating rolling mean (using pd.rolling_mean) over a lookback period (I used 15 days for this). The price and the SMA would be normalized, then used to calculate the ratio. Price/SMA = price[t] / price[t-n:t].mean().
c. How it works and how it can be used: a value of price/SMA > 1 indicates that stock is trading above SMA (overvalued, sell signal). A number < 1 indicates the opposite (undervalued, buy signal).

2. Bollinger bands

Figure 1.2: Bollinger bands

a. Bollinger bands %
b. top and bottom bands with the close adjusted price
c. top and bottom bands with the close adjusted price normalized

a. Description: Bollinger Bands are another way to utilize SMA, but it takes volatility into account. The related indicators BB%, the top and bottom bands indicates the position of the price relative to previous trades.
b. How to reproduce (formulas): Bollinger Bands are often set at 20 days period. In this part, I used 15 days for the charts. We need to calculate the top and the bottom bands as Figure 1.2 b and c above. Top band = SMA + 2 * rolling std. Bottom band = SMA – 2 * rolling std. BB% = (price - bottom band)/ (top band - bottom band).
c. How it works and how it can be used: the top band indicates an overbought market. The Bottom band indicates an oversold market. BB% equals 1 at the top band, and 0 at the bottom band. That makes it an easier indicator to use for buy/sell signal.

3. RSI

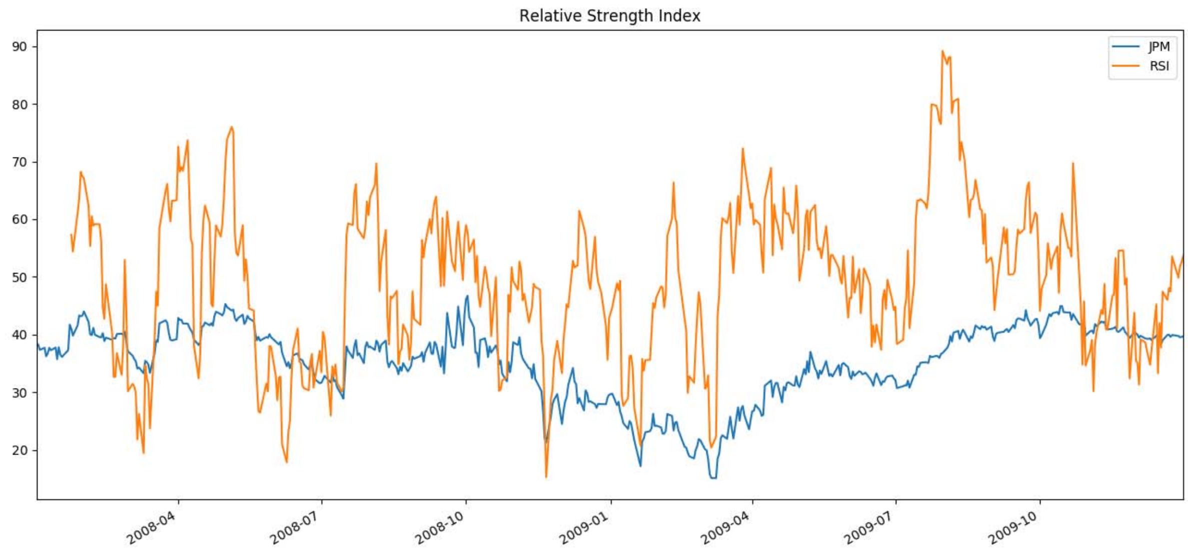


Figure 1.3: RSI and adjusted closed price of JPM

a. Description: RSI is an momentum indicator, which indicates the speed and change of price movements. $0 < RSI < 100$. It is a ratio of the average gains and the average losses over a period.
b. How to reproduce (formulas): as default, I used 15 days window for RSI. We create an array of all daily gains and an array of all daily losses. Then we take rolling mean of each array. Then we can find RS = rolling mean gain / rolling mean lost. RSI = 100 – (100 / (1+RS)).
c. How it works and how it can be used: an RSI over 70 indicates overbought and under 30 indicates oversold.

4. Momentum

Figure 1.4: Momentum, normalized price, and buy/sell signals (vertical lines) using crossover with the y=0 line (green for long and red for short entry points).

a. Description: momentum indicates the rising/falling rate of stock price during a period. Momentum is one of the easiest indicator to use and calculate.
b. How to reproduce (formulas): I use 20 days period for momentum in this part. Momentum[t] = (price[t]/price[t-n]) -1.
c. How it works and how it can be used: value > 0 indicates uptrend, and <0 indicates downtrend. I also calculate the crossover point with 0 to clearly demonstrate the buy/sell signal.

5. MACD

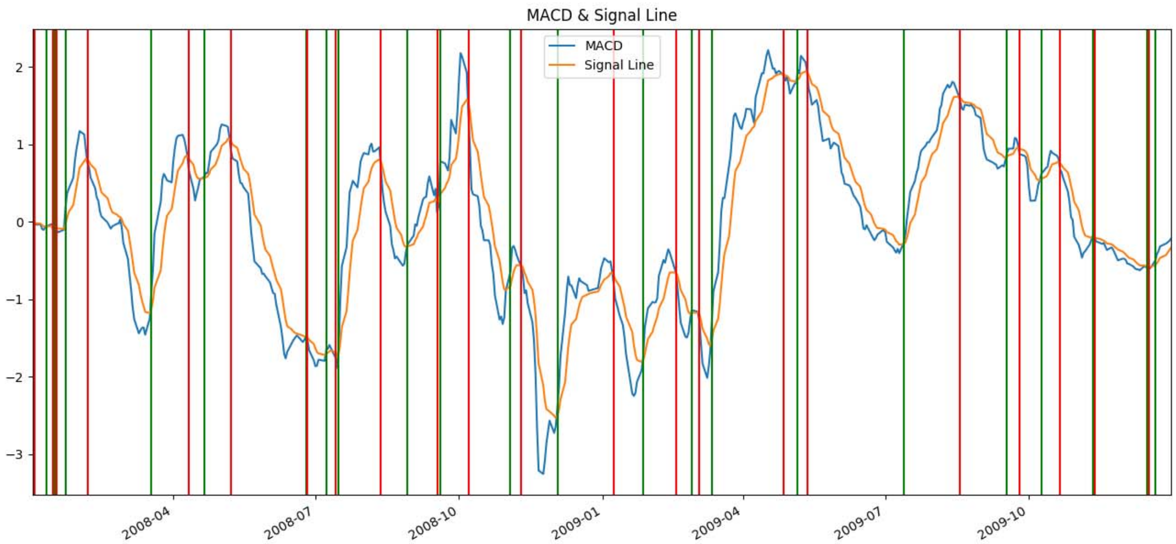


Figure 1.5: MACD (12-26 day period), signal line (9 day period), and buy/sell signals (vertical lines) using crossover between them (green for long and red for short entry points).

a. Description: MACD is a trend following momentum indicator, that indicates the relationship between 2 moving averages (the default setting is 12 and 26 day periods, the signal line is at 9 day period).
b. How to reproduce (formulas): We compute the 26 and 12 day exponential moving averages (using the built-in pd.ewma in panda). After that, we subtract the 26 day EMA from the 12 day to get the MACD line. We then calculate the signal line using 9 day period (using the built-in pd.ewma in panda). After that, we can use np.where to find the crossover.
c. How it works and how it can be used: MACD line moves above the signal line indicates a buying signal. MACD line moves below the signal line indicates a selling signal. I also plot the crossover point with green line for buy and red line for sell.

Part 2: Best Possible Strategy (20 points): describe how you created it and any assumptions you had to make to make it work. Provide a chart that illustrates its performance versus the benchmark.

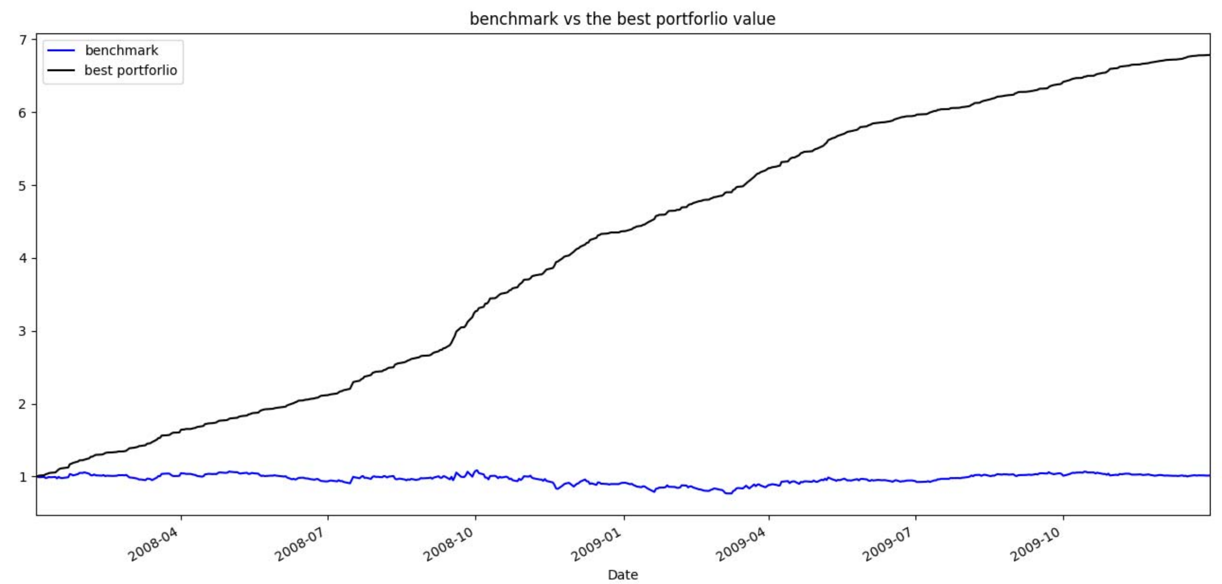


Figure 2: benchmark vs best strategy for the default in-sample period (01/01/2008 – 12/31/2009)

	cr	adr	sddr	sr	final val	normalized final val
benchmark	0.0122999	0.000168	0.017004	0.156918	101230.0	1.0123
best portfolio	5.7861	0.003816	0.004547	13.322769	678610.0	6.7861

(Cumulative return, Average daily return, Standard deviation of daily returns, Sharpe ratio, Final value, and normalized final value for the benchmark and the best strategy)

1. Description: This portfolio is to show the upper bound of the performance.

2. How to create: this portfolio is built by "peak into the future". There are 3 daily state for the portfolio (short: -1000 shares, long: +1000 shares, and nothing: 0). When the next day price is higer, the portforlio would be at long state. When the next day is lower, the portfolio would be at short state. We can do this in 1 line, since the portfolio can only be at 1 of 3 states (state = 1000*(price<price.shift(-1)) - 1000(price>price.shift(-1))). Then base on the daily state, we can create the order dataframe by calculate the difference in state across 1 day. The order dataframe would be fed to marketsimcode.py (modified from project 3) to output the daily portfolio value. We then normalize the data using the normalize function that I created. Then we plot the data.

3. Assumptions: we can see the next day price. The commission and impact are both 0.

Machine Learning for Trading – Automatic trading with Q learner

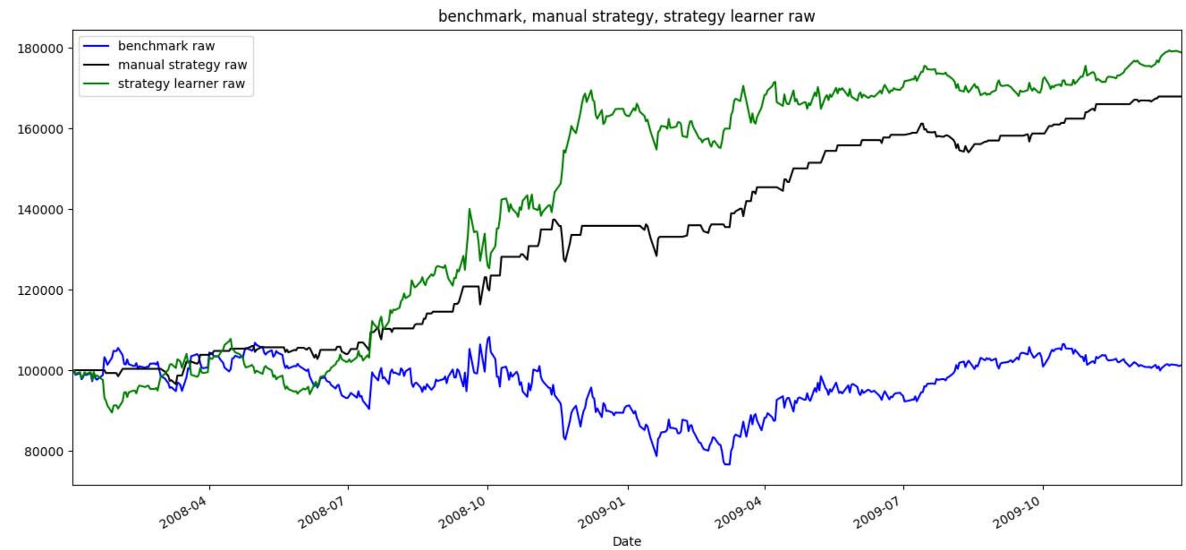
Details: All parts below trade only JPM stock. Strategy learner use qlearner and train in-sample period (01/01/2008 – 12/31/2009) then test on out-sample period (01/01/2010 – 12/31/2011). Both experiments were done on in-sample testing as instructed. Please see attached python files for the code details. The python files can generate pdfs of plots that are used in this report.

Part 1: Describe the steps you took to frame the trading problem as a learning problem for your learner:
- Indicators to use: price/SMA, Bollinger bands, Relative Strength Index (RSI) by default for all parts, except experiment 1 (part 2)

First, we need to draft a model for this problem:
This resemble the robot navigation problem, but in this case, the field is continous (hint that we need to discretize the data) . We can reuse the Q_learner from the previous project. This can be model with Q_learner and tuple (s,a,s',r)
s: current state
a: action a
s': next state after performing action a
r: reward from (s,a)
At first lance, we have 3 positions: (short: -1000 shares, none: 0 share, long: +1000 share). From those 3 positions, we can perform 5 actions (-2000, -1000, 0, 1000, 2000). However, if we have a reason to short or long, we would be comfortable doing that for maximum amount of share, so we can group the action into 3 groups similar to positions (short, hold, long). We use 3 indicators and 3 positions, so I will use 3000 states matrix to train the learner.

Now we can start ustilizing code from the preivous projects:
- Initial QLearner with 3000 states and 3 actions
- Use code from Indicators.py to calculate all indicators, and discretize them using pd.qcut
(there are code for all 5 indicators included in StrategyLearner.py: price/SMA, Bollinger bands, Relative Strength Index (RSI), momentum, and MACD, please see detail for each test to see what indicator was used)
- Combine indicators and the current position for state variable
- Calculate the reward for each action. Impact would affect reward at every trading move.
- Call Q_learner and query with state and reward until the data converge (or reach max 1000 iterations)
- Follow similar steps to build the testPolicy trade dataframe.

Part 2: Experiment 1 (without impact) in-sample:



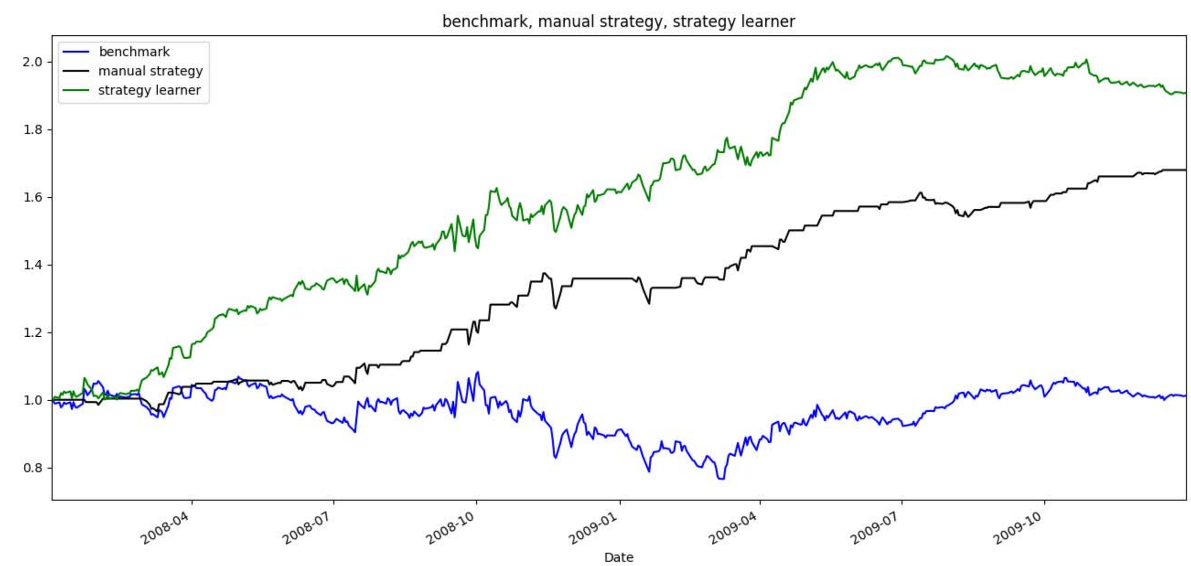


Figure 1: Manual rule-based trader vs stragegy learner for the in-sample period (01/01/2008 – 12/31/2009) without impact

a. raw data b. normalized data

	cr	adr	sddr	sr	final val	normalized final val
benchmark	0.012299	0.0001680	0.017004366	0.156918406	101230.0	1.0123
manual trader	0.679000	0.0010592	0.007860589	2.1391767	167900.0	1.679

stragegy trader	0.788400	0.0012255	0.011987831	0.91673260	178840.0	1.7884

(Cumulative return, Average daily return, Standard deviation of daily returns, Sharpe ratio, Final value, and normalized final value for the benchmark and the manual strategy for in-sample)

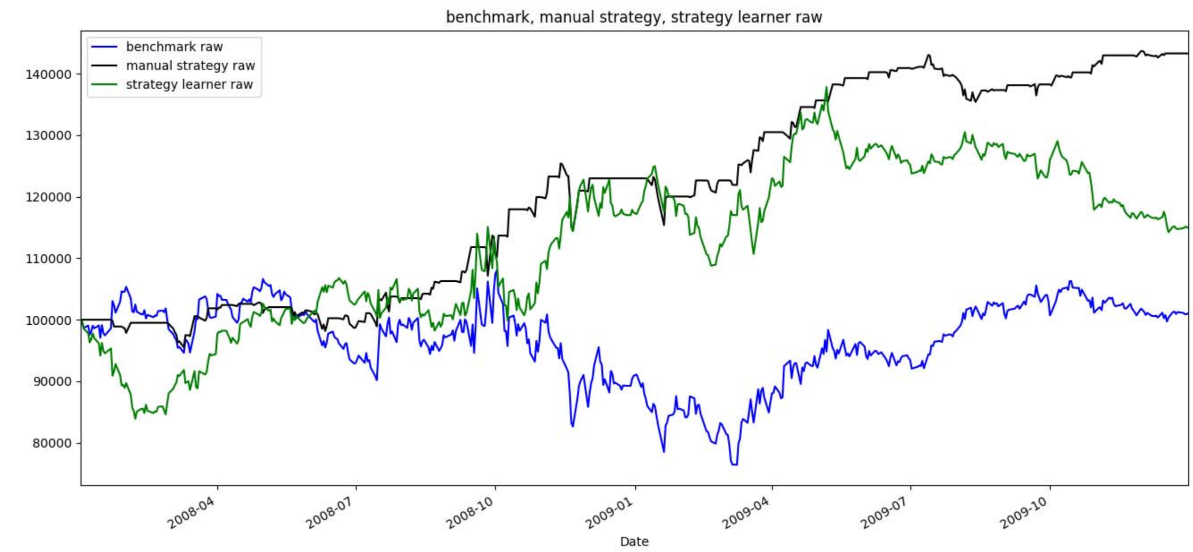
1. Details: For this experiment, we use 'JPM' data from 1/1/2008 to 12/31/2009 to train the strategy learner (which is a wrapper for the qlearner), then we plot and calculate the performance in the same period (with impact = 0.0). All data and plots were generated by experiment1.py
   - Indicators to use: Bollinger bands, Relative Strength Index (RSI), momentum, and MACD like in ManualStrategy. Follow steps below to change the indicators used:
   - Line 27, StrategyLearner.py, change num_states to 30000, since we are using 4 indicator + position
   - Line 87 and 181, StrategyLearner.py: change ind_state = BBp + RSI*10 + momentum*100 + MACD*1000
   - Line 105, 120, 185, StrategyLearner.py: change the weight of cur, replace "cur*1000" with "cur*10000"
   - Check commission and impact == 0 on line 19 in experiment1.py and line 39-40 in ManualStrategy
   - Run experiment1.py as usual
2. Result: stragegy trader outperform manual trader, which already yields significantly higher return than the benchmark.
3. Would you expect this relative result every time with in-sample data? This result should not be expected every time, since the manual trader already performed very well. Besides, due to assumptions and simplications we made in part 1, the learner is not fully model the stock price in this period. The machine-learning trading model will need some fine-tuning and a more complex model. The 3 indicators might not be adaquate to predict the future price.

<u>Part 3: Experiment 2: impact</u>

Details: For this experiment, we use 'JPM' data from 1/1/2008 to 12/31/2009 to train the strategy learner (which is a wrapper for the qlearner), then we plot and calculate the performance in the same period (with impact stated in 3a and 3b below). All data and plots were generated by experiment1.py and experiment2.py
<u>3a. Repeat experiment 1 above with impact = 0.005</u>

- Check commission==0 and impact == 0.005 on line 19 in experiment1.py and line 39-40 in ManualStrategy.py

<u>Hypothesis:</u> not like manual trader, strategy trader model already have trading cost taking into account, so we would predict stragegy trader to perform significantly better than manual trader.



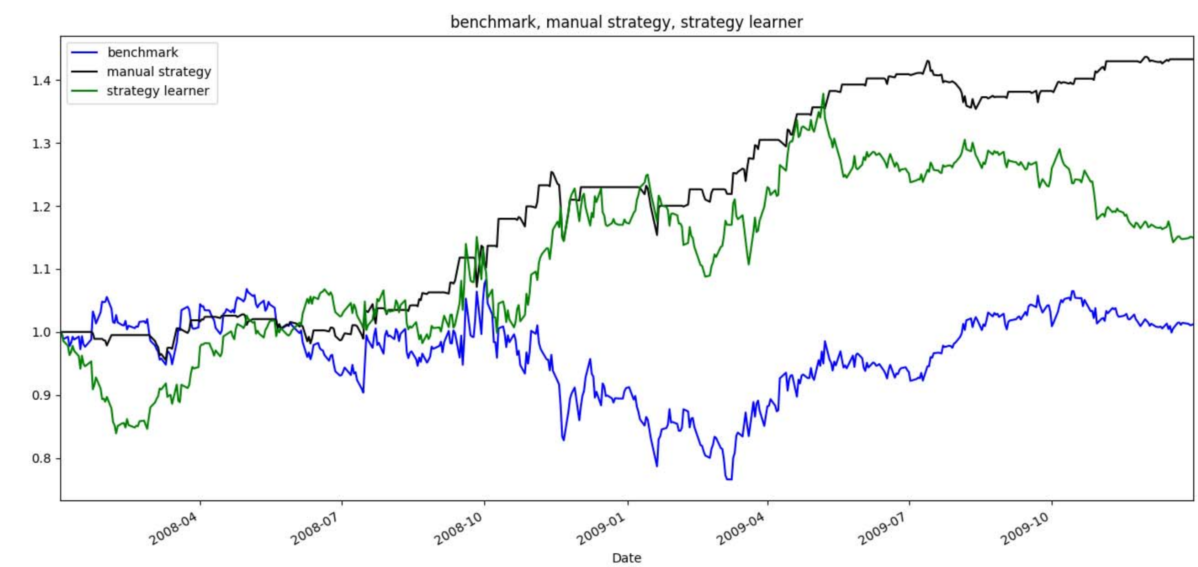


Figure 2: Manual rule-based trader vs stragegy learner for the in-sample period (01/01/2008 – 12/31/2009) with impact

a. raw data b. normalized data

	cr	adr	sddr	sr	final val	normalized final val
benchmark	0.01232	0.0001687	0.01703942	0.1571908	101037.6	1.01232
manual trader	0.43296	0.0007479	0.00827735	1.4343844	143296.0	1.43296
stragegy trader	0.14943	0.0003793	0.01436892	0.4191321	114943.0	1.14943

(Cumulative return, Average daily return, Standard deviation of daily returns, Sharpe ratio, Final value, and normalized final value for the benchmark and the manual strategy for out-sample)

3b. In-sample testing with impact = 0.005 vs 0.01:

- Indicators to use: price/SMA, Bollinger bands, Relative Strength Index (RSI) as all other parts except part2. Follow steps below to change the indicators used:
- Line 27, StrategyLearner.py: change num_states to 3000, since we are using 3 indicators + position
- Line 87 and 181, StrategyLearner.py: change ind_state = SMA_ratio + BBp*10 + RSI*100
- Line 105, 120, 185, StrategyLearner.py: change the weight of cur to "cur*1000"
- Run experiment2.py as usual

Hypothesis: strategy trader model already have trading cost taking into account, so we would expect to get a decent performance.

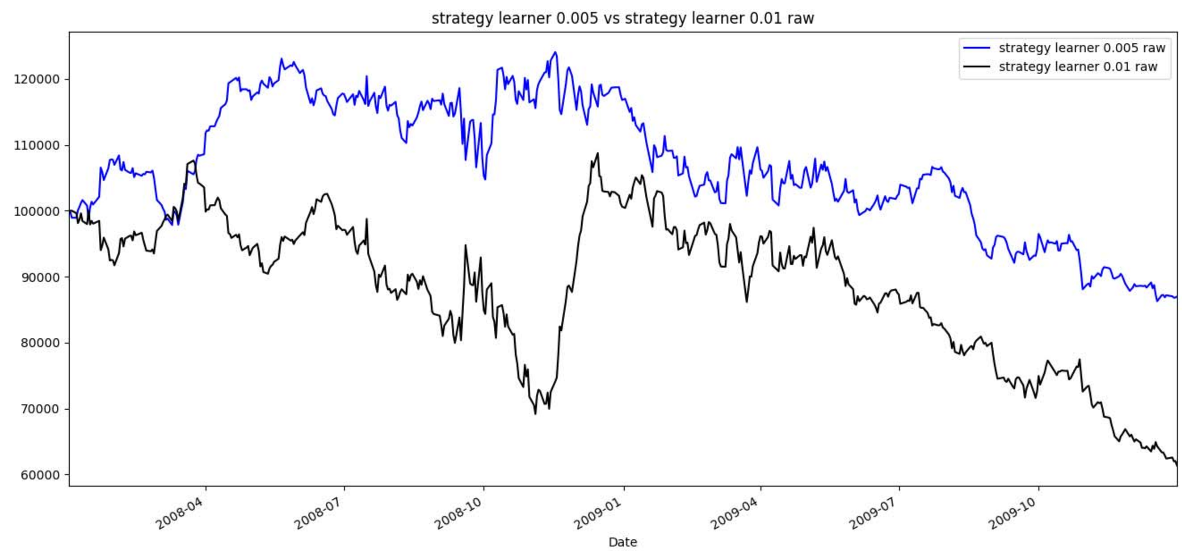


Figure 3: stragegy learner for the in-sample period (01/01/2008 – 12/31/2009)

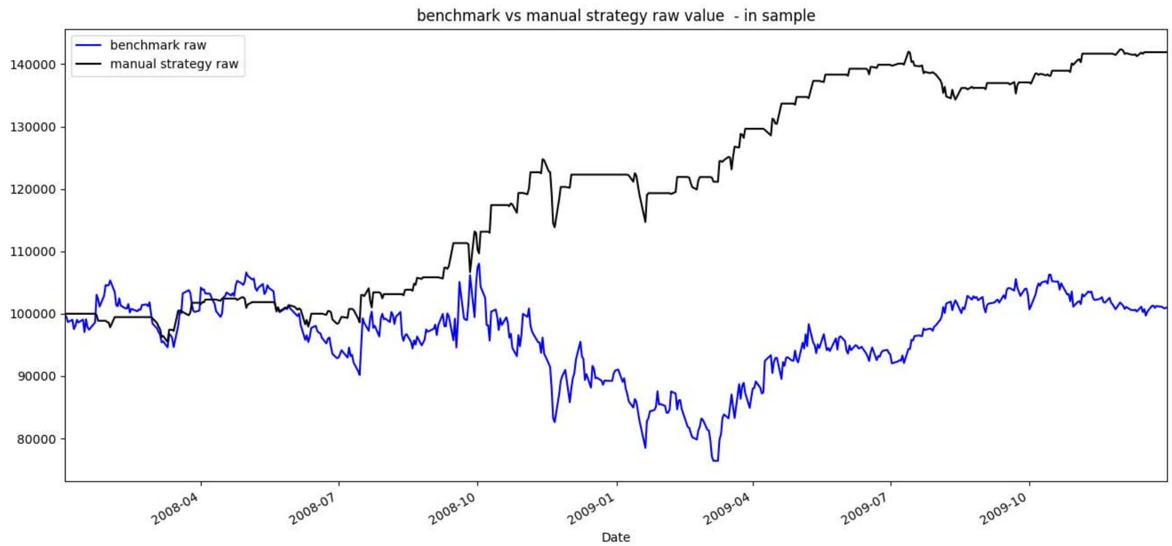
with impact 0.005 vs 0.01

a. raw data b. normalized data

Result:

The stock is traded very frequently since I used many indicators, and the impact is fairly high. Strategy trader continue to outperform the benchmark in 3a, but the return was significantly less. Due to assumptions and simplications we made in part 1, the learner is not fully model the stock price and the impact of trading cost. The machine-learning trading model will need some fine-tuning and a more complex model. The 3 indicators might not be adaquate to predict the future price.

Part 3: Manual Rule-Based Trader (50 points): describe how you combined your indicators to create an overall signal. How do you decide to enter and exit your positions and why? Why do you believe (or not) that this is an effective strategy? Provide a chart.



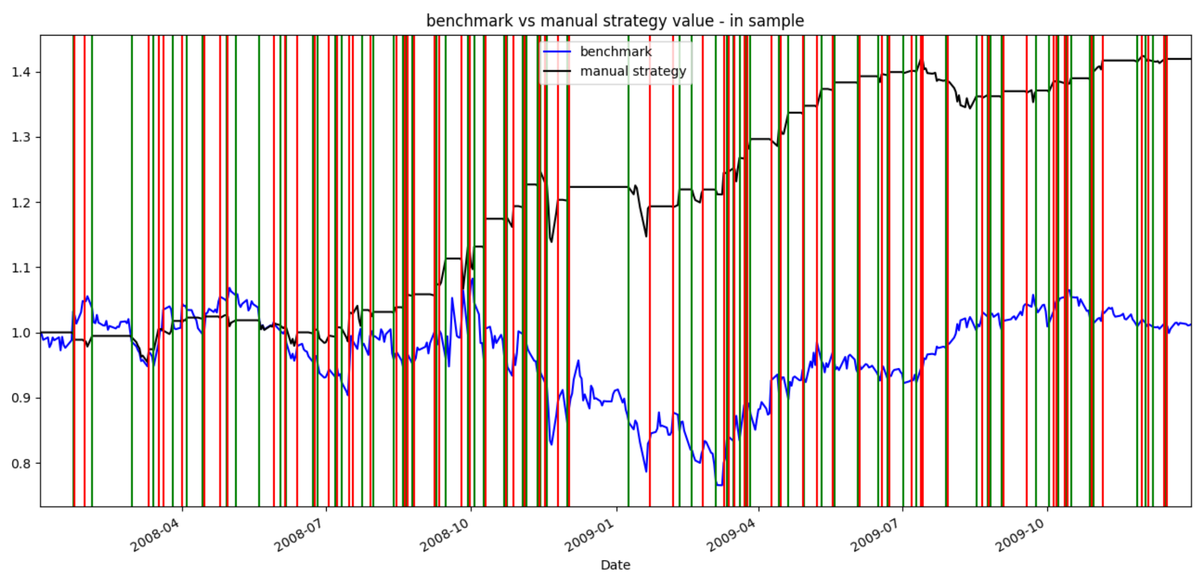


Figure 3: Manual rule-based trader for the default in-sample period (01/01/2008 – 12/31/2009)
a. raw data
b. normalized data and buy/sell signals (vertical lines) using a combination of indicators from part 1 (green for long and red for short entry points).

	cr	adr	sddr	sr	final val	normalized final val
benchmark	0.012324	0.000168	0.017041	0.157204	101027.7	1.012324

best portfolio	0.419228	0.000729	0.008303	1.393759	141922.8	1.419229

(Cumulative return, Average daily return, Standard deviation of daily returns, Sharpe ratio, Final value, and normalized final value for the benchmark and the manual strategy for in-sample)

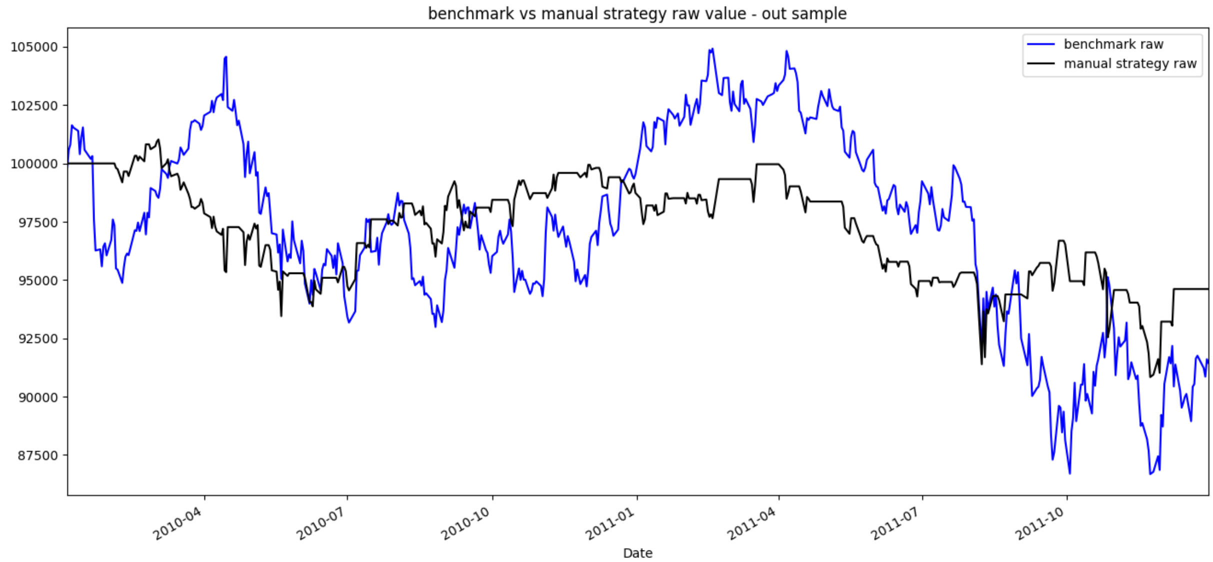
4. Indicators to use: Since both price/SMA and BB% are methods to trade using SMA, and BB% also take volatility into account. I decided to use only 4 indicators: Bollinger bands, Relative Strength Index (RSI), Momentum, and Moving average convergence divergence (MACD).

5. Signal formula and reason to use:
   I create 4 trigger column in the dataframe using the indicators. Each has 3 states: long = 1, short = -1, and nothing = 0 to signal the long/short entry points. All values that I decided to use are very common in the industry.
   a. BB%: long when BB% < 0.2 and short when BB% > 0.8
   b. RSI: long when RSI < 30 and short when RIS > 70
   c. Momentum: as mentioned in part 1, I use crossover with the y=0 line as signal
   d. MACD : as mentioned in part 1: I use crossoever between the MACD and the 9-day signal line to decide the long/short entry points

   Since MACD also reveal momentum, I decided to add weight into each indicator trigger to consider all technical aspect of the stock as fairly as possible . I comeup with a symple formula:
   stock trigger = 2*BB% trigger + 2*RSI trigger + MACD trigger + momentum trigger
   Then long when stock trigger > 2, and short when stock trigger < -2.
   I then decide the lookback window for each indicator. Since JPM is a little bit volatile, and moves up and down around the starting price, so I used a shorter momentum lookback window (14 days), and keep the rest at 20 days period to get a good amount of data for the indicators. The formula and period are mostly result of many trial-and-errors. However, I tried not to tweak the model extensively without a proper reason to avoid overfitting.

6. why this is an effective strategy: The strategy takes many technical aspects of the stock into account. The portfolio achieved a 41.9% gain compared to 1.2% of the benchmark. The stock is traded very frequently since I used many indicators, and the commission and impact is fairly high. Even though that has a huge impact on the performance. (The gain could have been 67.9%, and the final value would be 167900 otherwise), the formula is still a success in beating the benchmark by a very high percentage.

Part 4: Comparative Analysis (10 points)



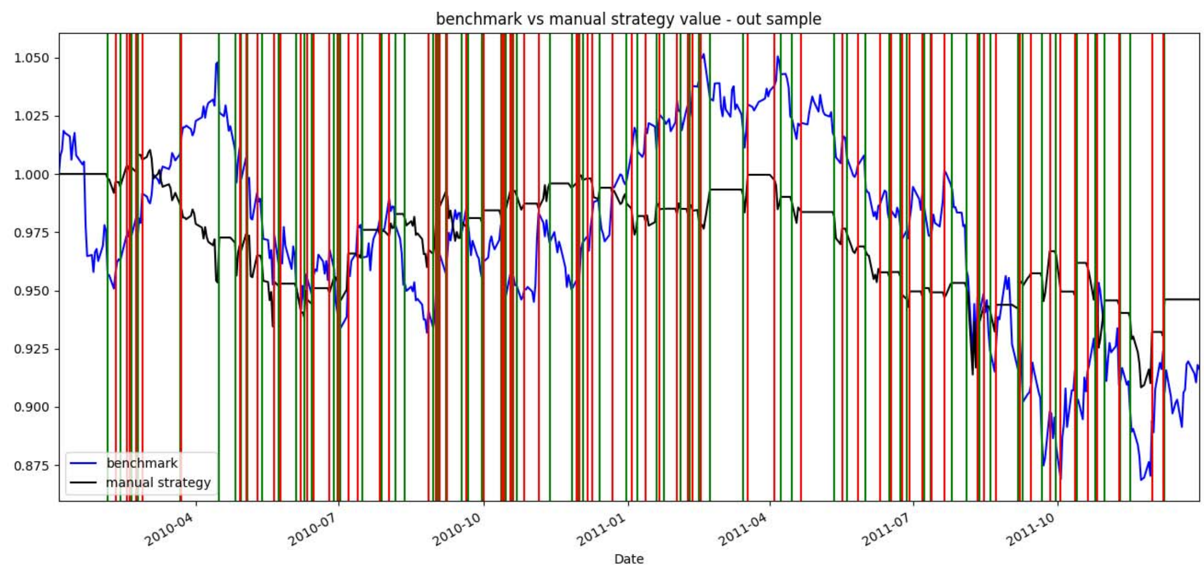


Figure 4: Manual rule-based trader for the default out-sample period (01/01/2010 – 12/31/2011)
a. raw data
b. normalized data and buy/sell signals (vertical lines) using a combination of indicators from part 1 (green for long and red for short entry points).

	cr	adr	sddr	sr	final val	normalized final val
benchmark	-0.083579	-0.000137	0.008500	-0.256656	91445.7	0.916421

best portfolio	-0.053868	-9.59612 e-05	0.005317	-0.286489	94613.2	0.946131

(Cumulative return, Average daily return, Standard deviation of daily returns, Sharpe ratio, Final value, and normalized final value for the benchmark and the manual strategy for out-sample)

1. Difference between this out sample here and the in sample in part 3: the formula still continue to have higher performance than the benchmark, but did not get a performance nearly as good as part 3. At the end of the out-sample period, we still lose money (-5.48% for out-sample compared to +41.9% for in-sample).

2. Is it effective and explanations: The formula is not effective for out-sample period. JPM price only increased 0.86% in this period, that is too small to cover the trading cost. The stock is traded very frequently since I used many indicators, and the commission and impact is fairly high (The gain could have been 22.49% and the final value would be 122490 otherwise). We need a strategy with lower trading frequency or find a broker with lower commission fee.

April 30, 2010

Design, Fabrication and Testing of a Wall Climbing Robot Using Suction Robotic Feet

Vinh Hoang, Ming Kit Lau, and Majid Khan

Abstract:

A miniature wall climbing robot equipped with two Suction robotic feet (SRF) is developed and tested. It is controlled autonomously by an Arduino microcontroller and a 6 volt power supply onboard. Each SRF contains a suction cup with a diameter of 40 mm, a pressure sensor, and a micro valve. The robot's motion is driven by two servo motors which are electronically linked and synchronized.

Introduction:
Autonomous robots, equipped with sensors, actuators and energy scavenging devices, are expected to use new walking, rolling, climbing, jumping and flying techniques. Such robots will lead to new future applications in unprecedented areas. However, for current needs in areas such as biomedical, aerospace, environmental and military systems, walking or autonomous robots are needed. Object manipulation and surveillance are crucial for many applications, and in many cases, require an ability to climb walls. Therefore, it is necessary to design a small mechanical system to attach to and move on flat and vertical surfaces to collect data and make decisions in different situations. Our wall-climbing robot is built from light weight material, and capable of climbing smooth surface.

Design concepts:
There are quite a few methods developing a wall-climbing robot, including wheel with suction system, robot body with fan suction, or a multi-legged robot with suction-cup. After developed and testing the prototypes, we decided that the 2 legged robot would be the most dynamic, power-efficiency, and simplest to control.

Figure 1: first leg prototype using stepper motor to drive customized suction cups

Figure 2: second leg prototype using solenoids to drive customized suction cups

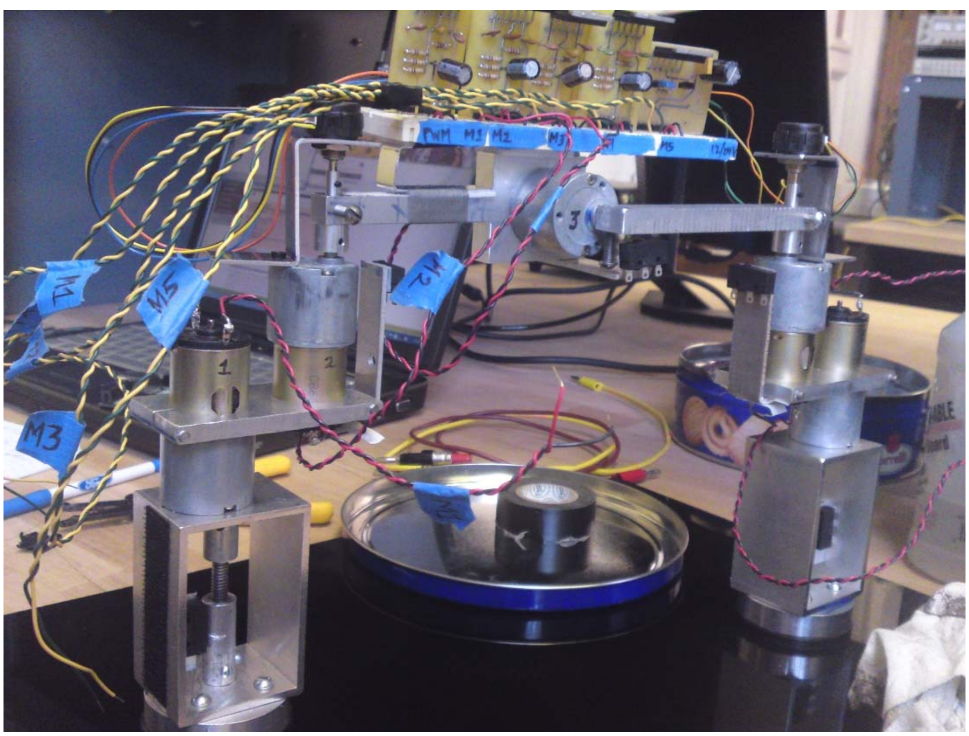


Figure 3: First finalized prototype.

The first finalized prototype was fairly working, but required a lot of power due to heavy material used in the manufacturing process and bulky looking design, so we had to come up with the totally new approach (using polycarbonate plastic and adding a micro air pump).

Suction Robotic Feet:

The SRF presented in this paper was re-designed specifically to work in conjunction with this robot. It features a compact size that enables it to be implemented as a single unit, and can be easily removed or serviced.

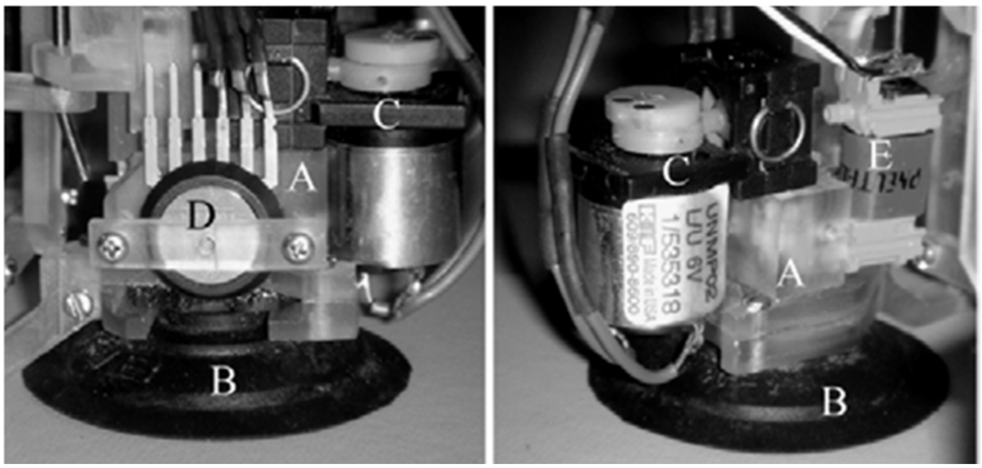


Figure 4: completed SRF: mounting block (A), suction cup (B), micro-pump (C), pressure sensor (D), and micro-valve (E).

A pressure sensor, which is mounted on the side of the SRF, monitors the pressure inside the suction cup. Using a current of 45 mA, it was possible to achieve a pressure of approximately 77 torr inside the suction cup. The SRF is also equipped with a 3V micro-valve that is solenoid actuated. When the SRF is ready to be lifted, the valve creates a leak for air to enter the suction cup. Use of the valve enables faster suction cycles, which contributes to a faster walking speed.

Robotic Body:

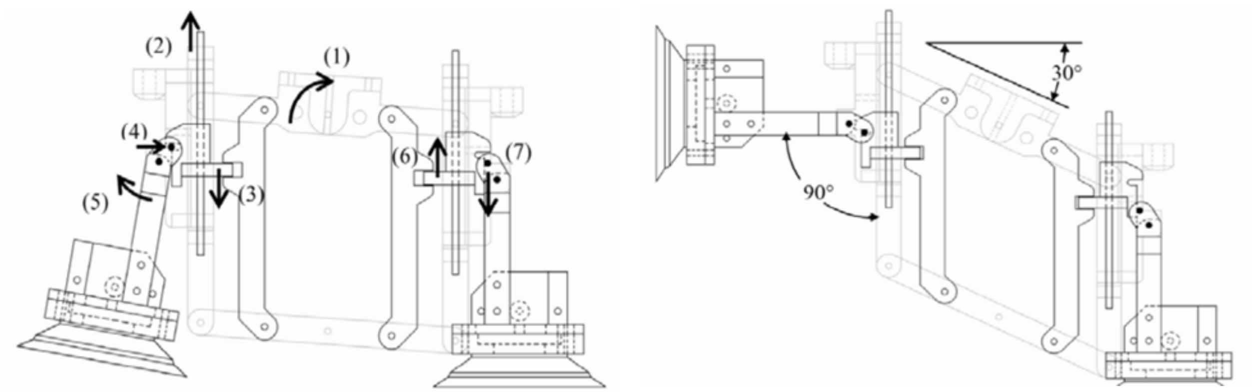


Figure 5: leg movement

In addition to walking forward, this robot is designed to transition between two perpendicular surfaces. Fig. 5 shows diagrams of the mechanics involved in raising and lowering the robot's legs and transitioning from a horizontal to a vertical surface. Note that the leg assemblies in these diagrams are tilted outward 90.

Control:

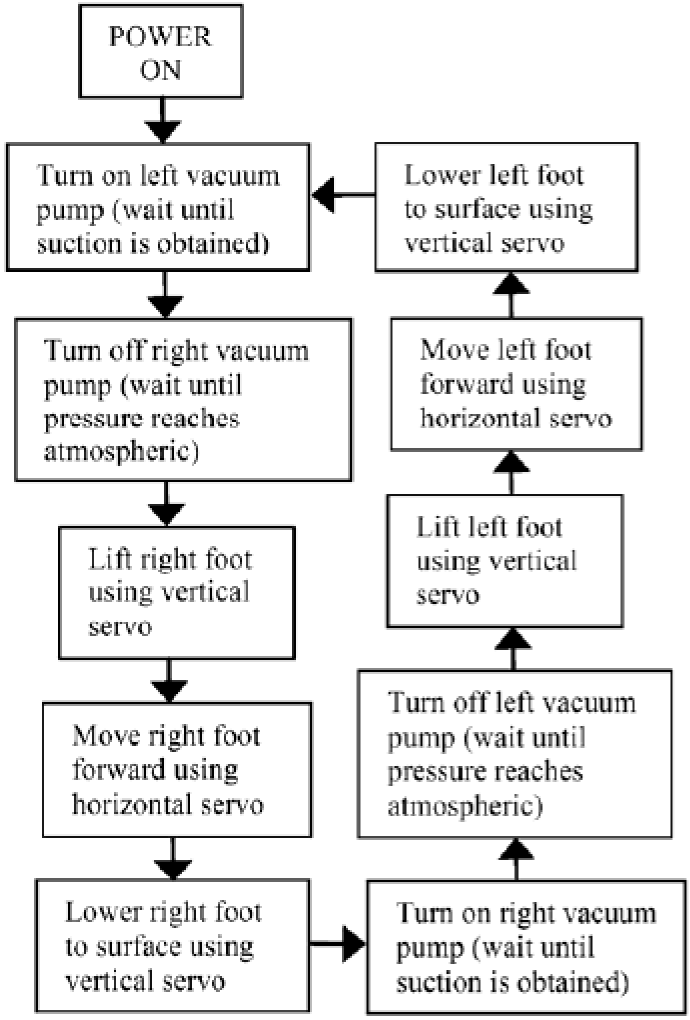


Figure 6: control flow chart

The robot was designed such that both servo motors and both SRFs can be controlled by a single, central circuit board. This configuration was chosen to minimize the number of electronic components, reduce the total weight of the control system, and to make the overall design more compact. The controller and associated electronic components are mounted on a printed circuit board attached behind one of the servo. Fig. 6 shows the sequence of actions that the microcontroller is programmed to take when the robot walks in a straight-line path.

Testing, Result, and Discussion:
The robot was first tested on a horizontal smooth plastic surface. Following the walking sequence shown in Fig. 6, the robot was programmed to continuously take steps in a straight-line path. Some trouble was noted when the robot attempted to place a foot down onto the horizontal surface.

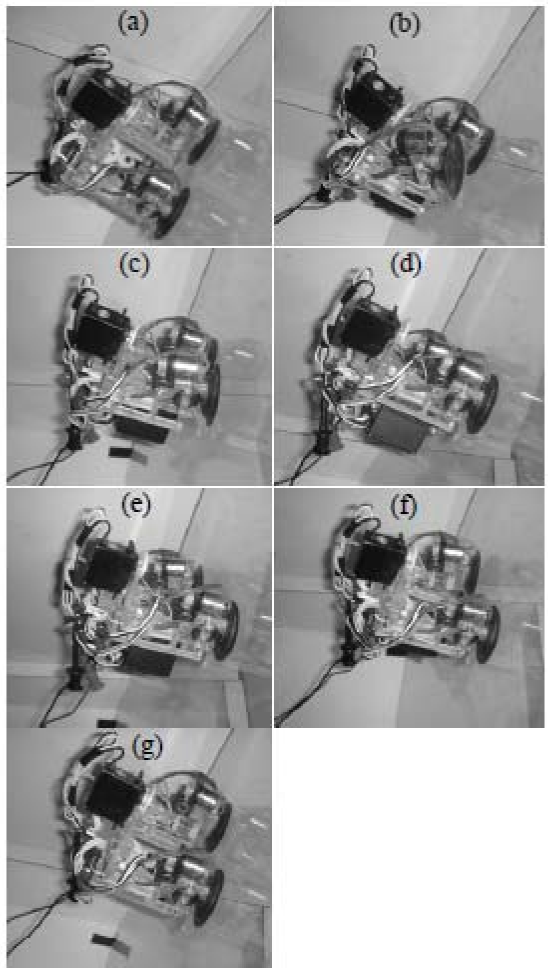


Figure 7: Sequential views of the robot climbing a 70-degree inclined plastic surface.

A recurrent problem when running the robot was the deformation of the polycarbonate frame as it moved. Due to the complexity of the frame design, space tolerances in the multiple joints connecting the members tended to magnify the deformations. Ideally, the robot should be able to walk without the aid of braces mounted behind the suction cups. In the finished robot, however, these braces were found to be necessary, and they improved the robot's walking capability on horizontal and inclined surfaces.

Work is still being done to improve the robot's climbing capability on smooth surfaces of all orientations. Further areas of testing will determine performance qualities including maximum walking speed of the robot at various wall angles, maximum load-carrying capacity, and total current consumption as a function of time.

CONCLUSIONS

A miniature wall climbing robot equipped with two smart robotic feet has been designed and tested. Each SRF contains a suction cup with a diameter of 40 mm, a vacuum pump, a pressure sensor, and a micro valve. The robot is currently capable of walking on a horizontal smooth surface and an inclined surface that is angled up to 70 degrees. Two servo motors are used to drive the robot's motion, and are controlled by a Arduino microcontroller.

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R. Mukherjee, N. Xi, and L. Tammala (Michigan State University)

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Neural-Controlled Wheelchair

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Steven Lin
Chatura Abeyratne

Introduction

Motor wheelchairs are commonly used nowadays, especially for the elderly and the handicaps. However, handicapped people are challenged in maneuvering their wheelchair. A number of elderly and paralyzed people are incapable of precisely with their hands to control a wheelchair and are mandated to purchase liability insurance for damage and injuries caused by using motor wheelchairs. On the other hand, a lot of studies and developments have demonstrated the feasibility of controlling objects through neuro-signals. With an integration of this technology, dependency of user's physical condition of current motor wheelchairs can be reduced. A neuro-controlled wheelchair could potentially help users to overcome the precision difficulty in operating wheelchairs.

By obtaining the neural signals from skin surface of the user's forehead and by translate to wheelchair control signals, a wheelchair can be operated from free will. Brain signals is precisely identified that the actual output is the same as the desired output of the user's mind. Instead of provide a physical command, users only "think" to control the wheelchair. This revolutionary controlling method will benefit people with paralyzed body and with missing body parts. The neuro-controlled wheelchair will tremendously improve user's quality of life by providing the degree of independency and mobility which ordinary people have taken for granted.

Figure 1: Final Design

Executive Summary

Current wheelchair users are mainly elderly and disabled people. Their reaction time from a dynamic environment is generally longer. Likewise, current wheelchair generally has a 1-2 second system lag. These two lags make users difficult to control their wheelchair precisely especially in indoor conditions.

While current wheelchair users are suffered from hitting obstacles, current wheelchair suppliers are yet satisfied to solve this issue. Our mission is to improve the mobility and independency of motor wheelchair users by implementing EEG brain wave control and feedback control on the wheelchair. To achieve that our project aim to demonstrate a marketable and operational wheelchair controlled solely from neural signals. Wheelchairs which are controlled neurally open a new door for paralyzed patients. Our prototype will potentially enable people with extreme disabilities such as people who are paralyzed below neck and people who lost legs and arms in war or in accidents can use this wheelchair to travel. It will ultimately improve their quality of life and help them live a better and a happier life. We will find an affordable solution that can be applicable to any electric wheelchair.

The OCZ Neural Impulse Actuator (NIA) streams bio potentials into the computer and witness real-time feedback through the software will result new experience. User will enter a virtual world where abstractions like keyboard commands are replaced by intentions converted into tensions and translated into command structures. NIA control can cut the system reaction time by 50%, and it could be the major improvement for normal wheelchair user.

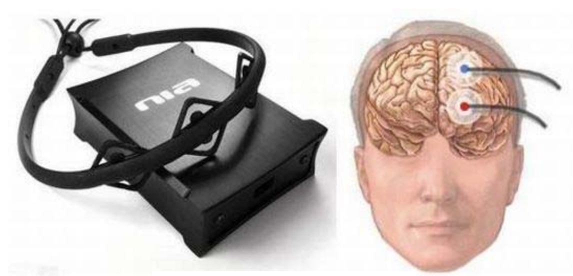


Figure 2: OCZ NIA

The input signals received will go through the NIA interface to the computer and it will send signals to the arduino which will actuate the motors through the wheelchair’s built-in controller. 4 signal combinations are required to generate 4 basic directional movements. It can be done with 2 deferential input signals. The 4 basic controls are left, right, forward and backwards. As we proceed with the project we expect to our prototype can prevent hitting obstacles by implementing distance sensors and feedback system.

Our team has chosen an array of hardware to suit our mission. OCZ's Neural Impulse Actuator (nia) is affordable, portable brain signal detector with sufficient sensitivity for our prototype. The Emotiv EPOC neuro headset, which is the first generation of the new interface human-computer interaction, is also available in the market. It is more sensitive with more functionality, but the price is unsuitable as an integrating part of a power wheelchair. For programming language we use C and labview. For microcontroller, we use the Arduino board, an open-source electronics prototyping compact and versatile evaluation platform based on flexible, easy-to-use hardware and software. For further developments, we will use ultrasonic sensors to detect obstacles.

Concept Generation

In our concept generation process, we followed a systematic approach. We began by brainstorming a couple project ideas among the group. We thought of self balancing skateboard, EEG controlled RC car, single wheeled all direction skate. Finally, after looking at several videos about different type of wheelchair controlling methods, we came up with our mind-controlled wheelchair. Then we clarified our objective, which to improve the easiness of wheelchair control for paralyzed and elderly wheelchair user. We listed the issues and problems with current power wheelchairs have and checked if our project would really help the user end. We came up with the concept of brainwave control. The idea is not to rely on any physical muscles to control the wheelchair, which will tremendously improve the usability of the wheelchair and the independency of wheelchair user.

To ensure our vision fits the need of the user end, we interviewed 3 motor wheelchair users for their opinions. The feedback was very positive. They were excited to try a prototype like this. From these short interviews, we notice their difficulty in precise wheelchair control, typically issues with hitting walls indoors, ground objects and people. Wheelchair users are actually mandated to purchase liability insurance to cover any damages they made. We had a discussion of how to improve the safety and control accuracy, and we came up with the concept of obstacle rejection using feedback control with distance sensors. We first came up with the infrared distance sensors. However, we figured the point sensing properties is not desirable for our application, so we came up with ultrasonic distance sensors.

Concept Selection

In concept selection, we choose our project concepts by the application of the end product. We don't want to spend 4 months of time and effort on something that has no benefit to the society. We believe that the EEG-Wheelchair project would help disabled people to be mobilized and independent. Therefore, we have focused our energy on the wheelchair concept early on and came up with a range of sub-concepts. We put all the sub-concepts into a concept selection matrix with detailed descriptions, advantages and disadvantages. We also combined the concept scoring matrices method in our table, scored the concepts in a scale of ten. With this visual tool, we came to a conclusion objectively and quickly.

We have introduced the 3 concepts of brain waves detection, Alpha wave, Beta wave, muscle signals and specific band of Beta wave associated to lateral eye movement. Alpha brain waves are typically 8-12Hz and Beta brain waves are over 12Hz. These detections are very fast and precise. However, it is hard to control and has lots of noise. They require training of about a month. On the other hand, muscle signals concept is easier to learn and use. User can pick up easily. However, the lag is significant and it interferes with daily activities. Finally, specific band of Beta wave associated to lateral eye moving concept is also fast and precise. It is also easy to pick up as people move their eyes every minute. However it interferences our daily activities and may induce danger as observation activity may be inhabited while controlling. To minimize the training time without sacrificing precision and response time, we combine the concepts. We will use muscle and lateral eye movement signals for binary control as they are the easiest for users to pick up.

In microcontroller selection, we had a tough choice between Arduino board and Luminary board. The Arduino board has lots of online recourses which we can reference while coding. However, the board works in 8-bit in which its workload is limited. The feasibility of LabVIEW is low as additional C programming is required. The luminary board can take 32 bit data and can be directly programmed by LabVIEW. However, the team is not familiar with the board. Finally, Arduino board is chosen due to its rich, accessible recourse base and easiness to program.

Figure 3: Ping Sensor

As for sensors, we have chosen ultrasonic distance sensors over infrared ones. The selection is based on the fact that infrared sensors are point sensors, which will provide blind spots in sensing an object. Ultrasonic sensors are more expensive and with less specification, yet wide area of detection outweighs the others.

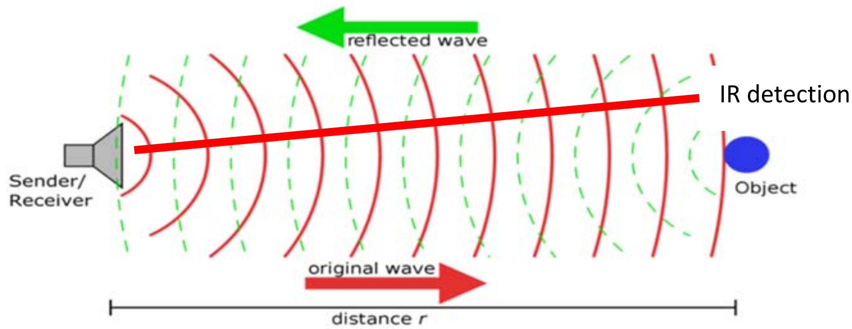


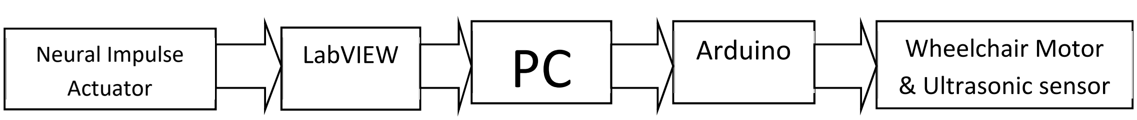
Figure 4: Ultrasonic sensor

Concept Description

Our final concept is to use EEG to control the wheelchair. With ultrasonic distance sensors and feedback control, the wheelchair will prevent itself from hitting obstacle. We will direct the wheelchair using muscle signals and lateral eye movement signals. All the neural signals are passed on to the computer to analyze and process. LabVIEW maps and filters the signals from NIA. Then the computer communicates with the microcontroller through serial ucb protocol and microcontroller adjusts their output voltage accordingly. The voltage generated from arduino is read by the wheelchair controller and our desire motion is performed. Finally, feedback control is implemented in microcontroller with ultrasonic distance sensor so that a command override will be activated when the wheelchair is too close to the obstacle.

Manufacturing Plan

The goal of this project is to prototype a wheelchair controlled by brain signals. The neural sensor will be connected to the Arduino board through a PC. Our plan is to bypass the joystick of the wheelchair. We will control the wheelchair through manipulate the control signals from Arduino Board processed from LabVIEW. The ultimate wheelchair will also be able to respond to an obstacle. So, whenever an obstacle occurs in the front or the back, the wheelchair prohibit in moving to the direction. This will be accomplished by implementing an ultrasonic sensor in front and rear of the wheelchair.



The manufacturing resp Figure 5: Manufacturing plan ded into the following:

Circuit division

Chathu and Felix are primarily responsible for the circuit design while receiving support from Steve. The plan is going to design the circuit using RC filters and H bridges. Eventually, the RC low pass filter is implemented to get the correct output voltage from the joystick of the wheelchair.

Neural Impulse Actuator division

Vinh, Steven and Enrika are responsible for the brainwave detection. Due to uncertainty of brainwave mechanism, this division will research on EEG control, brainwave signal analysis, precision enhancement and detection algorithm design. This division is supporting throughout the whole semester.

Programming division

Steve and Felix responsible for the Arduino and computer programming section of the project. Felix is programming on LabVIEW while Steve is programming on arduino. This division had achieved PWM signal output, computer keyboard input, signal pattern filtering and serial communication coding. This division also support in terms of GUI and other coding portion.

Design and Machining Division

A small unit needs to be fabricated to mount the circuit, Arduino board, and the ultrasonic sensor. In our team, the machining expert is Vinh. He is solely responsible for part machining and Felix will share the CAD designing responsibility. This division will design and machine the part for computer stand, Arduino board, circuit board, and the sensor.

Testing and Analysis division

Felix and Steve are accountable for testing and analysis of the project. They will design testing methods, analyze the results and modify our current design. This division will also receive support from all the team members.

Documentation and Website design division

Enrika and Chatu are responsible for all the updates and documentations of test results. She is also primarily responsible for the design and updates of the project website.

Team dynamics and progress division

Felix is primarily responsible for team dynamics. Steven is accountable for the meeting arrangements and budgeting. Felix is accountable for keeping track of the team progress, communication, and efficiency. They are working to make sure our team delivers all the tasks on time.

Parameters Analysis

Reaction Time:

LabVIEW output loop time: 0.05s

Arduino output loop time: 0.05s

Labview sampling frequency: 500Hz

Wheelchair reaction time: 0.1s

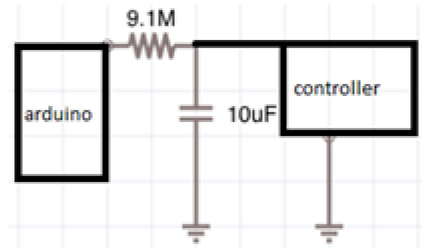


Figure 6: RC filter

Low pass RC filter:

PWM frequency f = 500 Hz

With R = 9.1 MOhm; C=10 µF; Time constant τ = RC = 91s

Charging time (from 2.45V to 3V): 0.5s

Cutoff Frequency f_c = 1/2πτ

= 1.748x 10-3 Hz

Low pass filters are implemented to our PWM output signals to generate analog signals. The above setup maximizes the speed and outputs the exact voltage we want to mimic from the wheelchair's joystick, which contains 4 inductors. As the Cutoff frequency is well below the PWM frequency, the square wave signals will be filtered and averaged to an analog voltage signal, which will transmit to the controller.

Ultrasonic sensors:

Detecting range: [2 cm, 300 cm]

Distance = time/2 * 340 (meters)

Arduino board will send out 10 µs High (5v) signal to ultrasonic sensor. The sensor will send out 8 ultrasonic waves (40 kHz) and trigger the Arduino to start counting time. When the sensor receives the echo, the Arduino will stop counting.

Controller Joystick output signal
Mean Voltage = 2.5v
Neutral Voltage = 2.4-2.5V
High coupling voltage = 3.5V
Low coupling voltage = 1.5V


Figure 7: Joystick

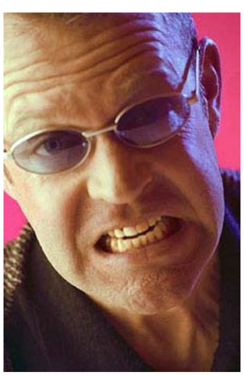
The joystick output signals are 2 pair of opposite coupling plots. The middle stick is polarizing by a DC current attached on the joystick. The movement is then detected through induced current by four inductor cord facing to the joystick.

Pin	Function	Min	Max	Neutral Voltage
1	5V			
2	Ground			
3	Increase go forward	1.01	3.64	2.44V
4	Increase go backward	1.25	3.9	2.48V
5	Increase turn clockwise	0.981	3.88	2.65V
6	Increase turn anticlockwise	1.02	3.93	2.44V

Language:
Processing with 5Hz frame rate is used for arduino UNO microcontroller. LabVIEW is used for signal sampling, processing and filtering.

Final Design

Input



Final design will collect inputs from the OCZ NIA headband. Customer's facial muscle signals will be converted to specific letters on the keyboard. As an example, the user wants to go forward he would apply tension to his jaws. Depending on how long user holds this muscle signal intensity above certain level, the wheelchair will continue to go forward, stop. If user wants to go backward, they need to hold their facial muscle in mid-intensity. To turn right or left, user moves their eyeballs from center to side and back to center. Then, the wheelchair will continuously rotating unless a new command is applied. Turning commands would just cancel rotation but Movement commands would initial motion immediately. Combinations of muscle tension signals and glance eye movement signals would generate Forward Left, Forward Right, Backward Left and Backward Right accordingly.

Signal Processing and Filtering

Labview is sampling at about 4 times faster than the NIA output. It will then count the number of positive samples respected to 4 basic corresponding directions and compile a history of sample pattern. After that, count rate filter is used to eliminate noise and pattern filter is used to filter incorrect rotation directions signals. For pattern filtering, alternating rotation signal pattern are filtered. Clean signal is then passed to arduino through encoded character serial communication.

Output

We have bypassed the input pins from the joystick to the controller of the wheelchair. These pins are connected to OUTPUT pins of the Arduino through a low pass filter. There are also 4 corresponding inputs to the analog input pins of the Arduino. These input signals will be accepting a string array. Depending on how long the string array is, a corresponding PWM signal will be generated and give out to the controller. Since the PWM signal is passed through a low-pass filter before connecting to the controller, it will only be a DC signal. For every action of the controller, two wires of the controller are amended.

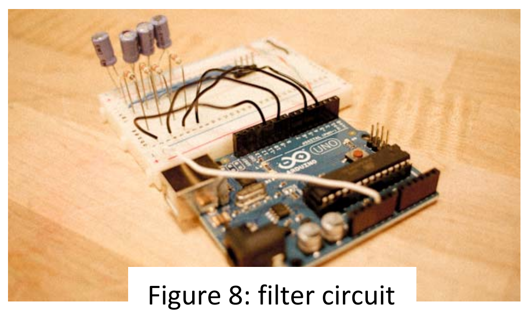


Figure 8: filter circuit

Wire #	Action
1	Forward/Reverse signal
2	Forward/reverse mirror signal
3	Left/Right signal
4	Left/Right mirror signal

Obstacle Prevention

Two ultrasonic sensors were implemented to sense objects in each direction. Distance data is read by Arduino microcontroller. If the critical distance has reached, a stop function initiates and overrides user's current command. Wheelchair will be stopped and motion further towards the obstacle is prohibited.

Problem analysis

Our project has been challenging over the whole semester. We have encountered numerous issues. The simpler solution, however, is always a better solution to our problem.

Our initial approach was to implement a system that is purely operable on brain signals. OCZ claims that the nia has the ability to recognize alpha and beta waves of the brain. However, after weeks of trails and research, we were unable replicate alpha and beta waves consistently from our brain. Therefore we move to an easy regenerated muscle control signals and beta wave associated with lateral eye movement. These two signals are easy to replicate in our brain as everyone have been practiced every day.

Replication of joystick was not expected to be a hard task. Most of the joysticks apply a well known mechanism either resistive potential divider or variable resistor. However, our joystick is an electro-magnetic coupled potential divider. Thus, measurements we have been recording did not match our theoretical expectation. For example, the individual natural voltage of each channel is off almost by 0.1 in 1 volt range. Moreover, the precision and accuracy of the instruments in the lab are un-calibrated. Thus, False result returns even correct values are inputted. With calibrated usb power supply, precise microcontroller pwm signals and suitable low pass filter, we eventually able to replicate a stable coupled DC signal more stable than the joystick.

In terms of coding, we were just using arduino for all the function. However, the sampling rate is unsatisfactory and filters are hard to implement. Moreover, the low speed serial communication slow down the whole reaction time of the wheelchair. Therefore, we made a hard decision, recoding whole set of function in Labview. Labview is a good tool to process signals in a designated amount of time. However, coding in labview would also means to code the protocol on the usb serial communication with arduino. With 2 weeks of work day after nights, 75% of the string are completely received on the arduino hand and the communication speed remains slow. Finally we encoded our pwn signal as a character. As the length of string is reduced to 1, speed and robustness of data transimition has improved greatly.

Manufacturing and Test Results

The first step to insure that our wheelchair is functional is to run numerous amounts of trial runs. We invited our friends to try the OCZ Nia headband and recorded all inputs received by the wheelchair and recorded which movements they were attempting to create at specific times. By doing so, we are able to apply filters using LabVIEW to establish a better control for the user. Once we believed that our project was fully functional, we attempted to move around through narrow corridors and through doors. The initial attempt for these maneuvers failed but it was due to the lack of experience with the wheelchair. After a couple of more tries, we were able to maneuver the wheelchair very smoothly. We were able to go wherever we desired. Another aspect of our design that worked flawlessly is the ultrasonic sensors we placed in the front and back of the wheelchair. The sensors allowed us to safely conduct trial experiments and move through tight spaces without collision. The wheelchair moved with precision and was safe for everybody to try, which were amongst the main objectives of our project. Overall, everything works better than we could have hoped.

To adjust the signal filters correctly, we have save all history of the EEG signals of all significant tests. We analyze the signal pattern as well as the count rate for each of the commands. In a sampling rate of 500Hz, count rates less than 4 are filtered. For pattern filtering, alternating rotation signal pattern are filtered.

In reaction time testing, we found a satisfactory reaction time if the system loop time is less than 0.1 seconds. To achieve that, we have analyzed the process time for each component. Computing loop time for computers and arduino can be easily adjusted, yet no loop can go faster than 0.003 seconds. For some of low performance laptops, the minimum loop time are up to 0.2 seconds. As for usb serial communication, we have abandoned the feedback of sensor reading from arduino to computer as two ways communication doubles the loop time. Moreover, we encoded pwm output values into a single character so that time for a computer arduino read is minimized. Finally we achieved a total reaction time from EEG, computer and arduino end for 0.05 seconds. Adding motor respond time and circuit saturation time, our wheelchair has a total of 0.2 seconds reaction time.

Discussion

In our mission statement, we aim to provide a solution to current wheelchair users who are physically incapable to control a motor wheelchair precisely. Integrated with EEG sensing device, a prototype have successfully made where users can control without moving any muscles of below their head. Moreover, almost any user can learn and control the 4 basic directions in 10 minutes. Although the degree of adaptation varies, we believe that any user can be skilled in controlling our wheelchair in 3 hours. In terms of safety, one of the concern of the current motor wheelchair is that user ran into people. Tested by over 40 beta users in the expo, our wheelchair has never run into any people. The great success in prototype testing brings a strong demand of the curious ordinance.

Throughout our development of prototype, we have been targeted our primarily user to paralyzed and elderly people. Interestingly, due to the joy on “mind controlling”, people are interested in our prototype as a vehicle which can “take your tired body home after a long day”. As described in manufacturing analysis, our prototype has a comparable cost to current motor wheelchair. This additional demand could increase the production scale and eventually reduce the retail price of our wheelchair. Handicapped users can be benefited financially.

The success of our prototype is a result of the effort of all the team members. We have been conscious of our progress. All of the subtasks have finished within a week from our schedule. Our team was not as efficient at the beginning of the semester. We have divided the role of each team member. Yet, not all members have an active task to work on, as a role like machining and CAD designing barely has anything in our project. Freed members tried to work on random tasks which some members have been working on. Later, as members are busy for midterms in the middle of the semester, we switched to dynamic roles that everyone can pick up the work from the detailed updates. We have updated every single achievement, file and problems that one has encountered over emails. This change in communication and structure of division of labor has massively improved our team performance.

With the effort of our team, we have successfully demonstrated our solution through the prototype. There are several aspects can be improved and further developed. Firstly, we should implement a non-physical kill switch. In our current prototype, we are able to terminate the wheelchair through the physical power button. Yet pressing the button contradicts with our purpose of mind-controlling. User should have a way to terminate all actions with their mind. Then, they can terminate the motion of wheelchair when user wants to interact with the environment and people. Second, speed control should be implemented in the detection and output algorithm. Our wheelchair can move in a range of 0.1mph to 6.5mph. User should able to adjust their speed accordingly for indoor and outdoor environments. Thirdly, for obstacle prevention, there are some blinded pints where wheelchair cannot detect. Two ultrasonic sensors should be implemented at the edge of the wheelchair. Moreover, since the time for deceleration varies with the current speed of wheelchair, the critical obstacle distance, which trigger the override “stop” action, should also varies with wheelchair’s speed. Finally, the reaction time can be improved by switching cable choices. Our reaction time of the wheelchair is roughly 0.2 seconds. Computation loop time is 0.05 seconds and the reaction time of the motor voltage change take another 0.05 seconds. In our testing, an acceptable reaction time should not be more than 0.2 seconds. Our team had tried to increase sample rate and reduce the loop time. However, the speed of USB communication is incapable for any faster. If we could switch to Ethernet cables, our reaction time can be almost halved. The extra time will also create room for computation of more features. With these improvements, our prototype will be ready for production.

In the future, environment sensation can be further integrated to our wheelchair. With implement of GPS, and outdoor and indoor maps, our prototype can develop an auto pilot feature, which can send user to their destination automatically. Moreover, indoor map integration also help to avoid the blind event that sensors cannot pick up obstacles with empty bottom like tables.

Conclusion

Our focus of this prototyping project is to increase the usability of wheelchairs by eliminating the demand of a physical hand. Users are currently required to have a pair of fully functional hands in order to precisely control a wheelchair available in the market. Our prototype wheelchair allows inputs through the brainwave signals. This concept will let people who are paralyzed below neck or people who doesn't have arms use the wheelchair freely and precisely.

To achieve our mission, we have modified our initial design. On Sensing side, we chose muscle signal and lateral eye motion signal instead of pure alpha and beta waves. In programming, we have combined processing and LabVIEW coding to control the wheelchair. The strength of LabVIEW signal processing provides a cleaner output for turning. The simplicity of processing code maintains the speed of arduino microcontroller. With the integration of ultrasonic sensor and feedback control in arguing, our wheelchair is prevented from hitting object in the front and back.

Tested by over 40 people, new users are control the wheelchair in 15-20 minutes for basic level of accuracy. Further accuracy control would take about 3-4 hours. The robustness and ease of control of our prototype are over our expectation. If our prototype were commercialized, a brand new, convenient method of commute is presented to all people who want to do nothing but to travel to their destination.

Appendix

Specifications

EEG Device:	OCZ-NIA
Computer	Laptop
Microcontroller:	Arduino
Software:	LabVIEW/Processing
Sensors:	4 x Sonar Range Sensors

Wheelchair:	Pride Jet 2 Motorized Wheelchair
Drive Wheels	14” pneumatic tires
Rear Wheels	8”
Anti-Tip Wheels	6” front-mounted
Maximum speed	4.5mph
Brakes	electronic, regenerative disc brakes
Ground Clearance	3”
Turning Radius	19.5”
Length x Width	38” x 23.5”
Drive train	2 motor, mid-wheel drive
Battery	2 x 12V 55 AH, NF-22
Range per charge	20 miles/charges
Battery weight	24lbs each
Base weight	96 lbs
Seat Weight	36.5 lbs
Total Weight	208 lbs

Reference

Las Vegas Consumer Electronic Show 2009

- Mindflex (demonstrate usage of brain wave to lift up a ball)
- OCZ Nia (use as a game controller)
- http://www.cesweb.org

NIA-OCZ Technology

- http://gear.ocztechnology.com/products/description/OCZ_Neural_Impulse_Actuator/index.html
- http://www.ocztechnology.com/nia-game-controller.html
- http://www.ocztechnologyforum.com

Toyota

- http://www.sciencedaily.com/releases/2009/06/090629101848

YouTube Video

- http://www.youtube-nocookie.com/watch?v=O-WSzzYhOV4

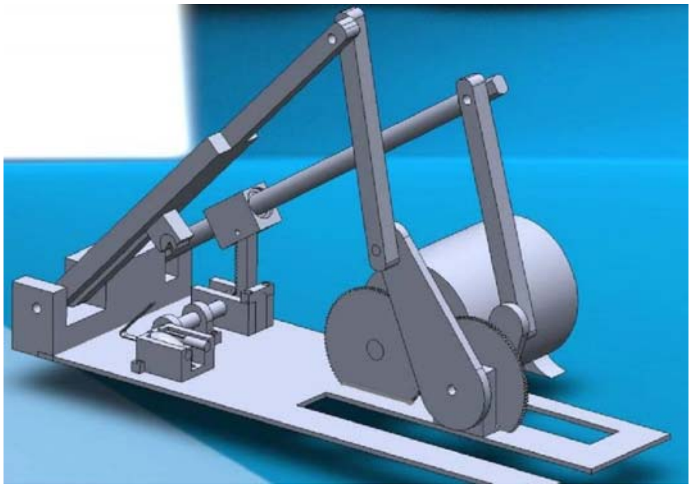
Processing

- http://www.processing.org

Arduino

- http://www.arduino.org

The Metal-bending device
a.k.a "The Boss"



Dean Arthur
Vinh Hoang
Andres Lara
Sumeet Singh
Cindy Xinzi Wang

ME130 Final Project
Professor Ken Youssefi

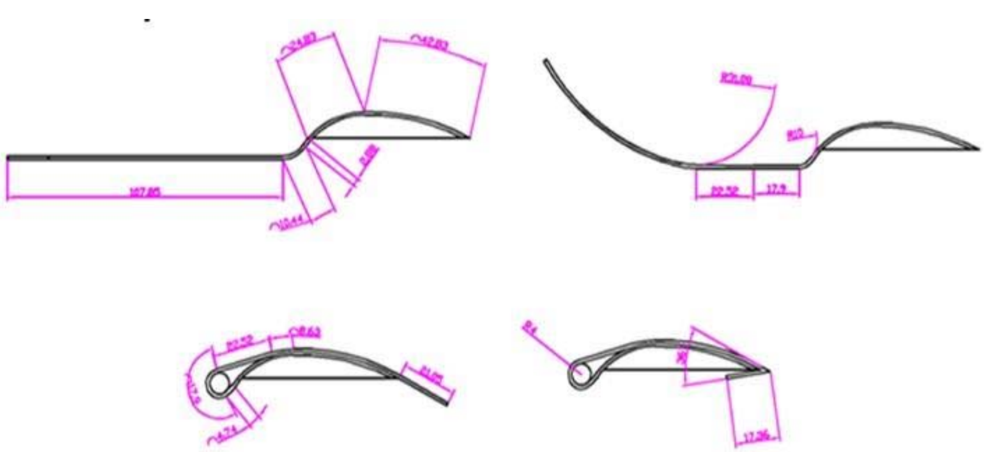
12/08/2011

Background

The idea for our project originated with a novelty bottle opener that was hand-made from a spoon by our group member Dean. He presented us his seemingly simple final product during the idea generation phase at the beginning of the semester. We were all amazed by how interesting the idea was and decided to make a machine that can manufacture this spoon/bottle opener for our semester-long project. Unlike other groups whose mechanism *is* the final product, our mechanism *makes* the final product.

Our spoon bottle-opener qualifies more as a novelty than a mass-marketable consumer product. A very similar analogy to our mechanism is the penny pressing machine, which can be seen ubiquitously in many tourist attractions all over the globe. The end result is a flattened penny souvenir, which serves no practical purpose. Using our machine, tourists can watch the spoon bend in front of their eyes, waiting anxiously to try out their new bottle-opener.

A positive effect stemming from our project is the idea of recycling. Instead of producing new products, we transform one product into another, which reduces material and energy consumption, and helps in waste management.



Task Assignment

Our team consisted of five members. Dean originally came up with the idea of the spoon bottle-opener. We then began working together to design a mechanism that could bend a spoon in such a specific manner. During our weekly Friday meetings, we discussed project progress and any new conceptual ideas. Building began somewhere in mid to late October. By the November 1st final design review, our CAD drawings were good enough so that we were able to build most of our mechanism the entire month of November, with Dean in the machine shop 5 days of the week, Vinh and Andy present on average 3 of 5 days, and Sumeet and Cindy contributing whenever their schedules permitted.

Our project was split up into the following parts and assignments:

- CAD Drawings
    - Sumeet and Dean, with support from the rest
- Building
    - Dean, Vinh, Andy, Sumeet, with support from Cindy
- Final Report and Poster
    - Cindy and Andy, with support from the rest

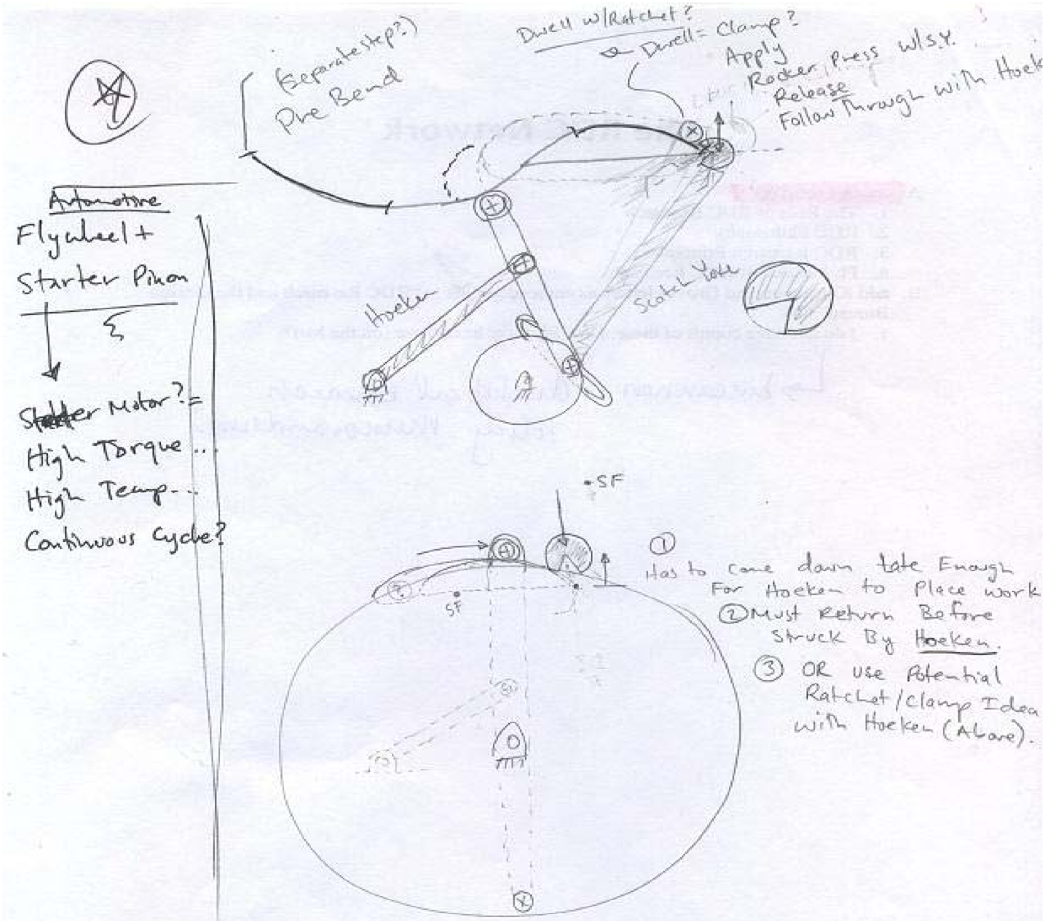
Specifications

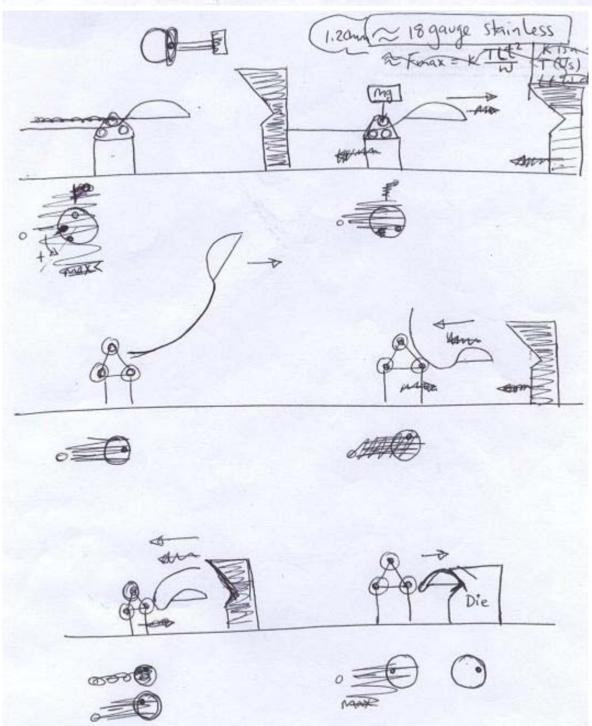
Design Concept: Convert an ordinary teaspoon into a functional bottle opener.

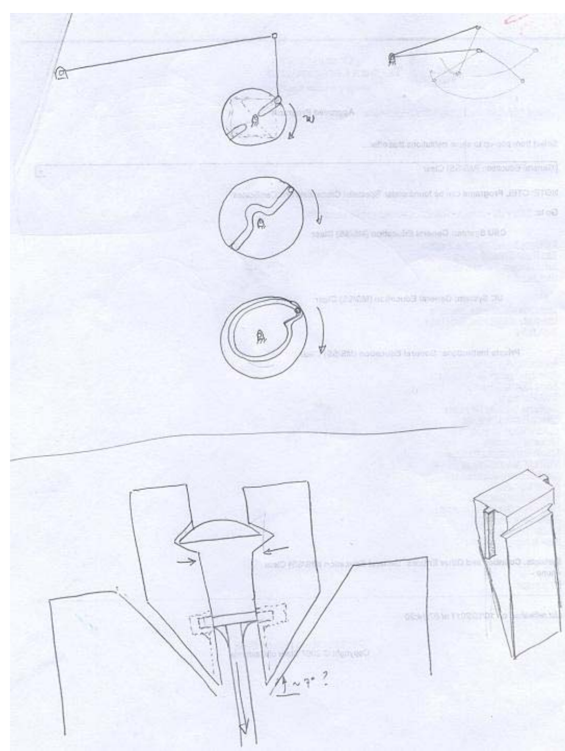
Design Specifications:
• Size: 26” x 8” x 24” (LxWxH)
• Weight: 60 lbs.
• Material: Cast Iron Frame with hardened steel tooling and fasteners
• Material Finish: Powder coated (bright color)
• Power Source: (1) Gear Reduction of 286:1, 600 in-lb output Motor
• Mechanism Timing: 10 seconds per cycle
• Mechanism Enclosure: .25” thick Lexan with access port for loading/unloading of spoon
• Safety Features: Access port kill switch and external emergency kill switch
• Personalization: Logo and serial number embossing on each item produced by mechanism
• Additional Requirements: “Go-No Go” Gauge for appropriate selection of spoon size

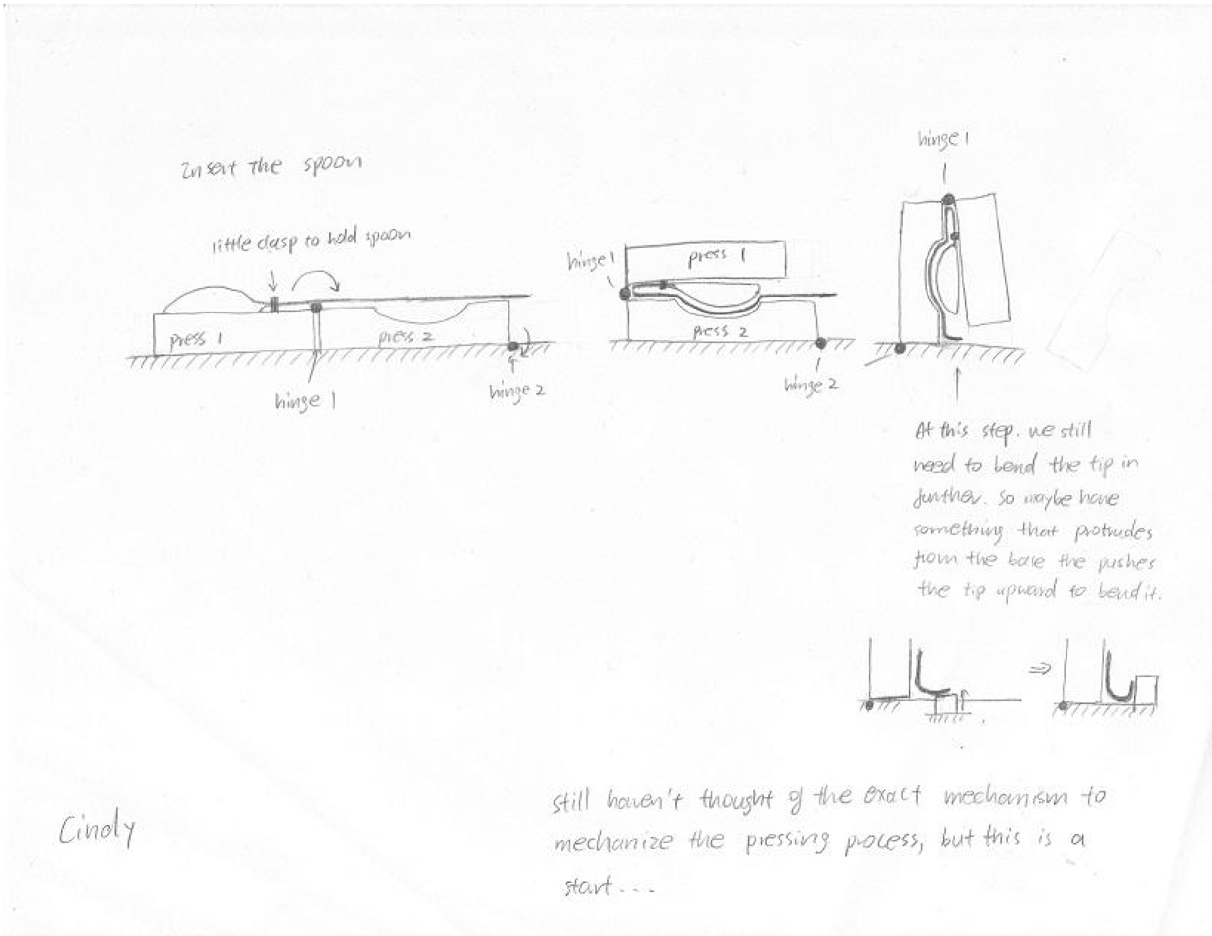
Conceptual Designs

Prior to developing our current design, we played around with various ideas. This, of course, was before we had calculated any required forces or dimensions. The following four images show some of these initial concepts:


Dwell w/Ratchet?
Dwell = Clamp?
Apply
Rocker Press w/S.Y.
Release
Follow Through with Hoek
(Separate step?)
Pre Bend
Automotive
Flywheel + Starter Pinon
Starter Motor? =
High Torque...
High Temp...
Continuous Cycle?
Hoeken
Scotch Yoke
SF
① Has to come down late Enough For Hoeken to Place work
② Must Return Before Struck By Hoeken.
③ OR use Potential Ratchet/Clamp Idea with Hoeken (Above).


1.20mm ≈ 18 gauge stainless
Mg
Die





For one of our weekly meetings, measurements and calculations were done to obtain the minimum input force required to bend the spoon with the lever arm given from our pin placement. This was achieved through material mechanics analysis, calculating the amount of force needed to cause plastic deformation in a member with spoon dimensions and made of 1018 steel. Also, a fish scale was used to approximate the input force, by putting a spoon in a vice grip, attaching the fish scale to the end of it's arm, then applying and measuring force until the spoon arm was plastically deformed. With these numbers, design for our main design commenced. The following drawings show the progression of the design for our mechanism:

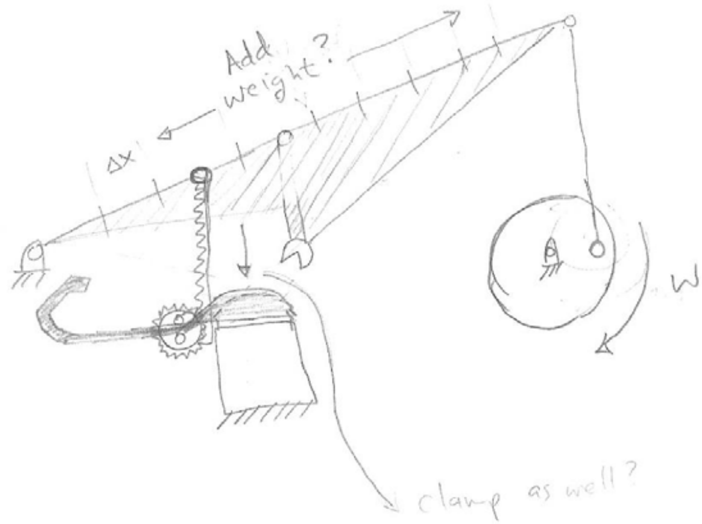


Figure 1. Our initial working design for our mechanism. Note that this design includes only one four-bar mechanism, while our actual design includes two separate four-bar processes.

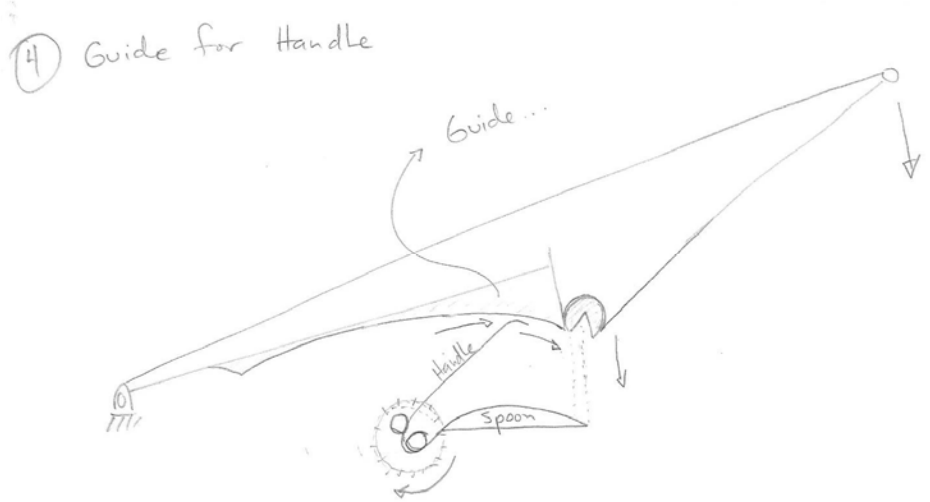


Figure 2. Initial ideas for bending over the spoon handle. We ended up only using the rotating pins.

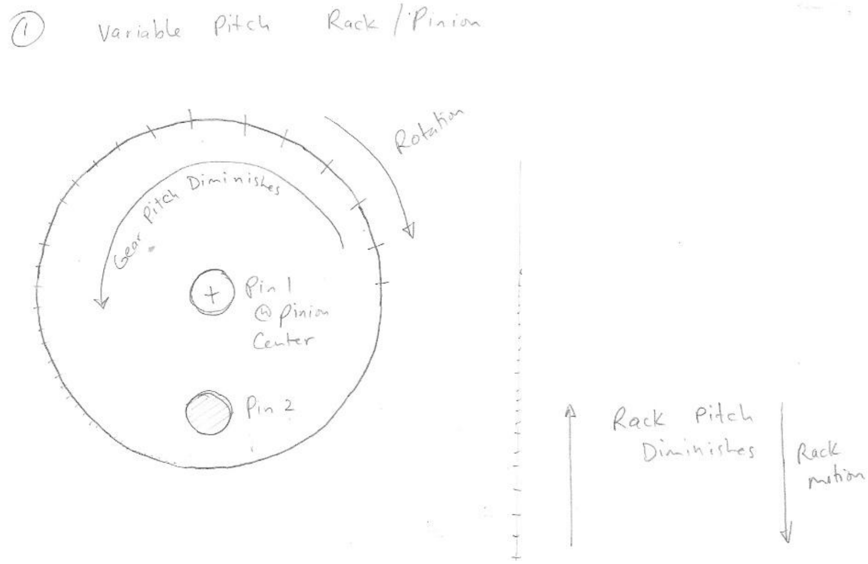
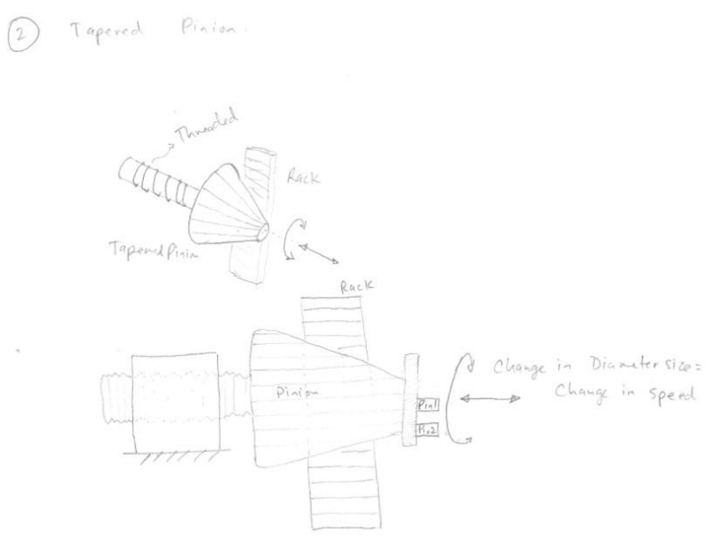
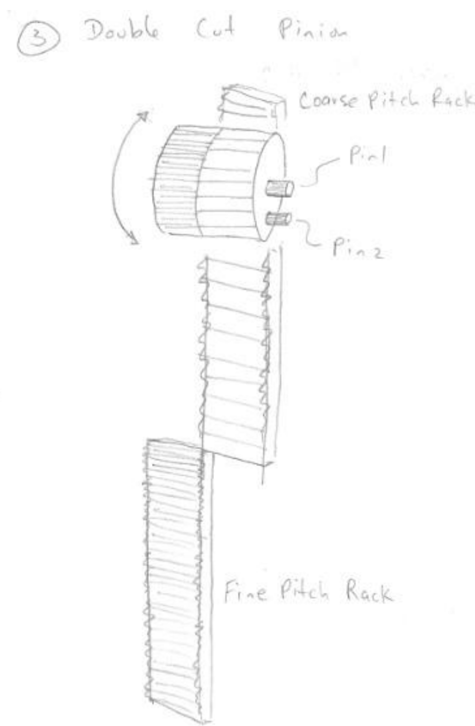


Figure 3. One initial design for our arm bender pin design. The variable gear teeth are an attempt to synchronize the bending and "pacman" processes.





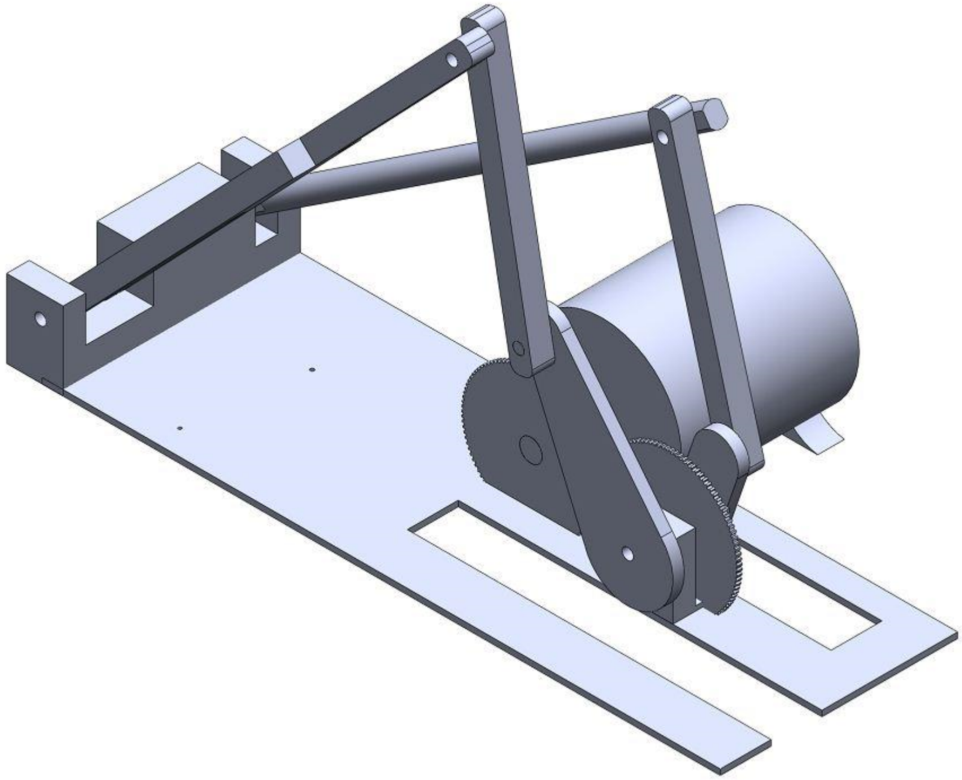
Figures 4 and 5. Other rack/pinion designs to synchronize bend and pacman processes.

At one very critical meeting, it was determined by Dean that, instead of using one four-bar mechanism to perform two different actions, we could easily mate two four-bar mechanisms to each other and complete these two actions. This novel idea dramatically simplified our design, and we immediately began to work on Solidworks to draft and test our design.

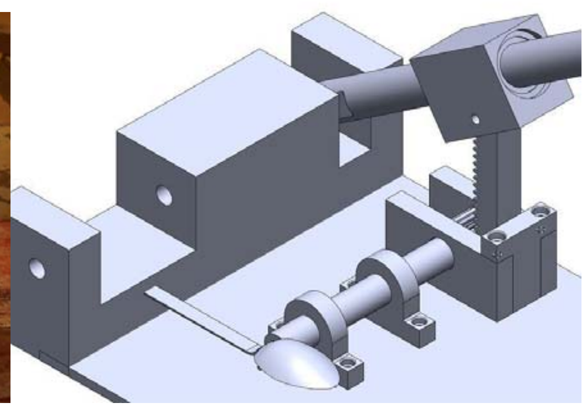
Introduction

There are four major components to our mechanism.

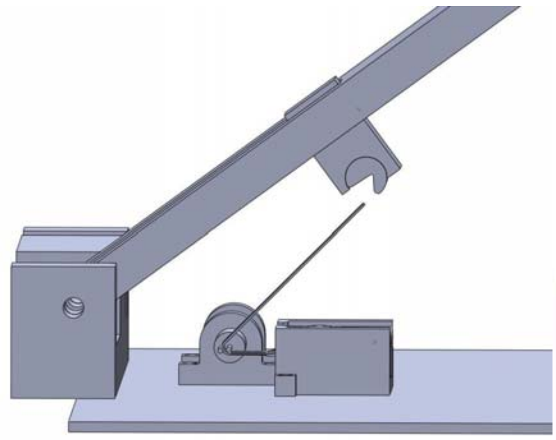
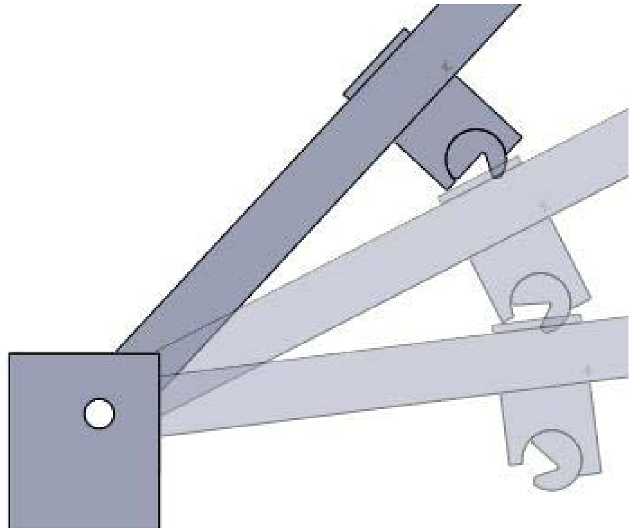
- **Grashoff Input.** Two four-bar Grashoff mechanisms, one connects to each side of the arm housing, granting them one-degree of freedom. The arms are driven by the input gear of the motor that is placed at the center of the arm housing. The four-bar in the back drives a rack and pinion to initialize the bending process. the four-bar in the front drives the “pacman”, an assistant forming tool that bends the spoon tip into place. Each four-bar linkage uses a different input arm radius, and are oriented 50 degrees from eachother. This produces separate timing for the rack/pinion and the pacman portion of the mechnism. The two four bars are joined together at the other end by a “pivot base”, which is connected to the base plate along with every other component.



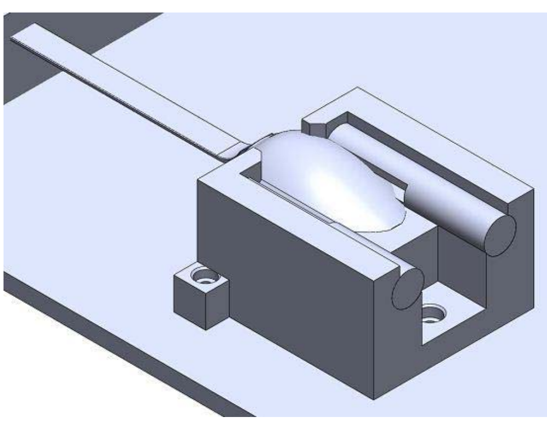
- **Rack and pinion pair** drives the handle bending process. The rack is mounted to a four-bar linkage via a linear bearing. The linear bearing was used to maintain perfect vertical alignment of the rack to reduce friction and jamming. As the rack is sliding down, it drives a pinion which drives an axle, which has two pins attached to the end. As the pins rotate, the spoon handle is bent 185 degrees clockwise, after which the pin will return to the starting position.



- **Pacman forming tool** will come down and make contact with the now bent spoon handle to push the handle tip into a locking position with bowl tip. The forming tool is called pacman because of its shape. The pacman is essentially a rocker that is free to rotate within the housing without falling out. When the handle tip comes in contact with the mouth of pacman, the pacman will come down and rotate to push the handle tip into place.

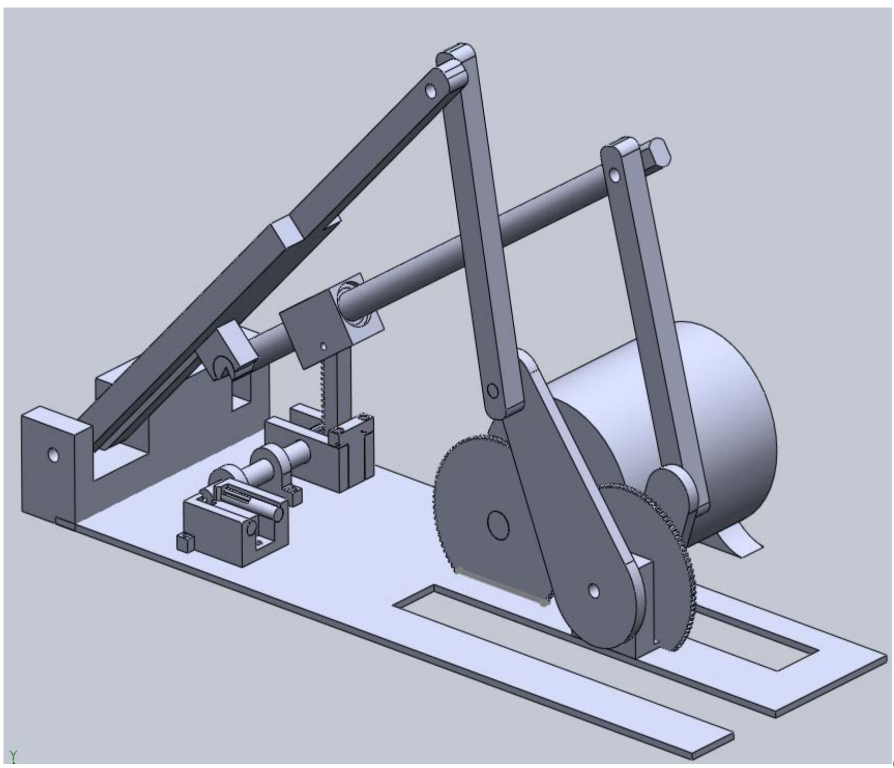



- **Clamp** essentially utilizes two pacman rods placed parallel to each other to lock the bowl of the spoon in place during the bending process. The clamp provides an upward normal force to counteract the downward force caused by the bending of the handle. It also prevents the spoon from wobbling side to side. The spoon can only be released from the clamp by vertically lifting it up.



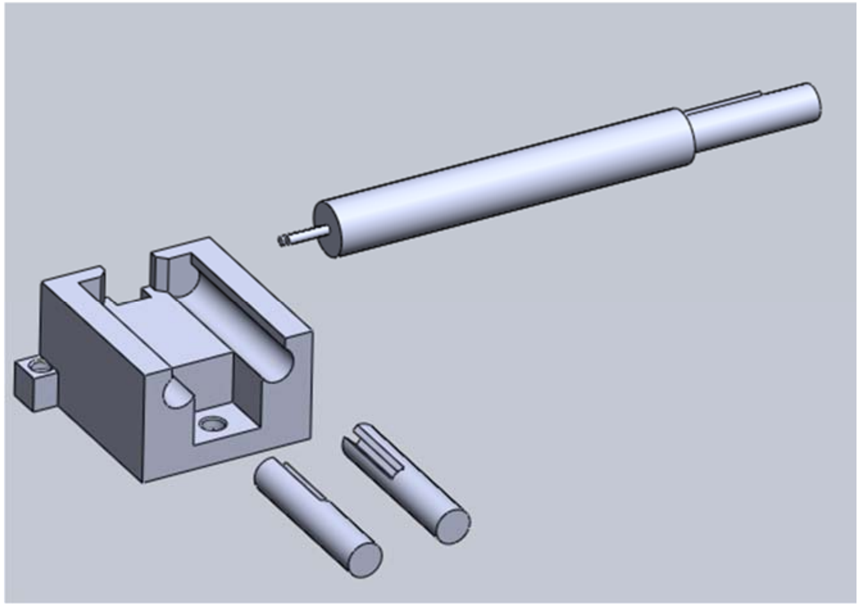

Drawings*

Full Assembly:

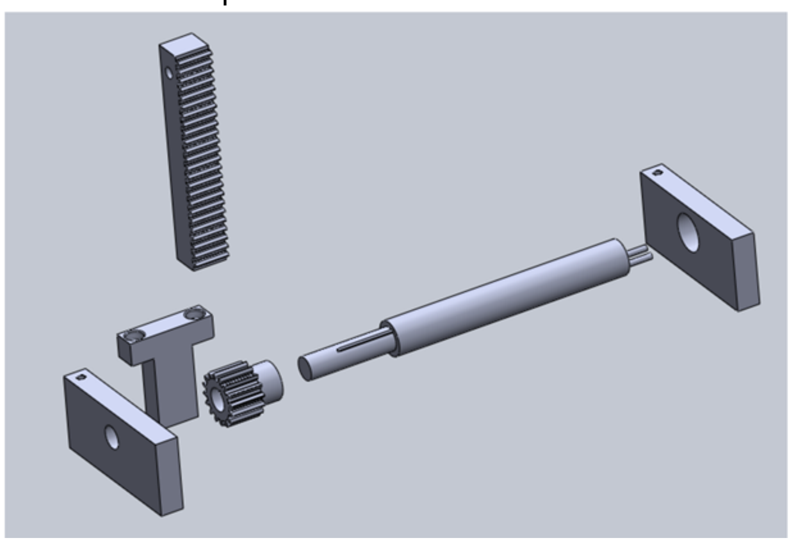


Exploded View:

Clamp

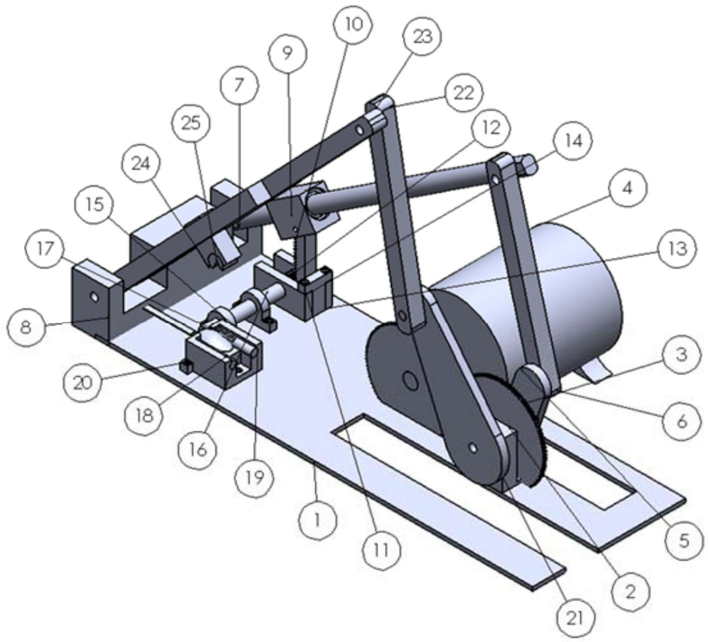


Exploded Rack and Pinion Setup View:



***For convenience, the remainder of the parts are located in the appendix.**

Bill of Materials



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Price
1	Base	Made, holds everything	1	$30
2	Grashoff Base	Made, connects to rack input and pacman input	1	$10
3	Gear	Bought, connects motor to mechanism	2	$15
4	Motor	Bought, outputs 50 ft*lb	1	$300
5	Rack Input	Made, part of rack and pinion four bar	1	$10
6	Rack Input Arm	Made, part of rack and pinion four bar	1	$5
7	Rack Arm	Made, part of rack and pinion four bar	1	$10
8	Pivot Base	Made, connects to rack arm and pacman arm	1	$5
9	Linear Bearing	Bought, accomodate the shifting between rack and rack arm	1	$35
10	Rack	Bought, mates with pinion	1	$20
11	Rack Guide	Made, part of rack and pinion housing	1	$1
12	Pinion with Keyhole	Bought, mates with rack	1	$15
13	Pinion Back	Made, part of rack and pinion housing	1	$2.5
14	Pinion Holder	Made, part of rack and pinion housing	1	$2.5
15	Axle Support	Made, supports the bending axle	2	$1
16	Axle With Key	Made, transfer pinion motion to rotate two pins which bend the spoon	1	$5
17	Spoon	Bought, to be bent	1	$0.2
18	Clamp Pin 1	Made, clamps spoon in place	1	$1.5
19	Clamp Pin 2	Made, clamps spoon in place	1	$1.5
20	Clamp Base	Made, houses the spoon bowl	1	$3
21	Pacman Input	Made, part of pacman four bar	1	$10
22	Pacman Input Arm	Made, part of pacman four bar	1	$5
23	Pacman Arm	Made, part of pacman four bar	1	$10
24	Pacman Housing	Made, holds pacman	1	$3
25	Pacman	Made, rotates and pushes spoon handle tip into place	1	$5
			Total	$506.2

Detailed Design

The following are the calculations performed in order to design our machine.

1015 Yield: $60\,300\ \#/in^2$
1020 Yield: $63\,700\ \#/in^2$

Safety Margin ⇒ $70\,000\ \#/in^2$

$$\sigma = \frac{My}{I_x}$$

$M = Fd$
y = distance to NA.
I_x = 2nd Moment

$I_x = \frac{bh^3}{12}$

$b \sim 10mm$
$h \sim 2mm$

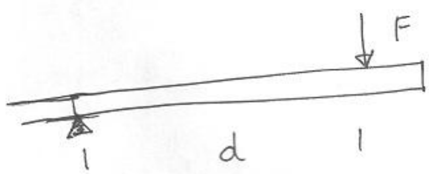
$$\frac{\sigma I_x}{dy} = F$$

$$\frac{(70{,}000\ \#/in^2)\left(\frac{(10mm)(2mm)^3}{12}\right)\left(\frac{1in}{25.4mm}\right)^4}{d\,(1mm)^*\left(\frac{1in}{25.4mm}\right)} = F^*$$

$$F = \frac{28.47\ \#\ in}{d\ in}$$

$$F^*\ (.5mm\ \text{Neutral Axis}) = \boxed{\frac{56.95\ \#\ in}{d}}$$

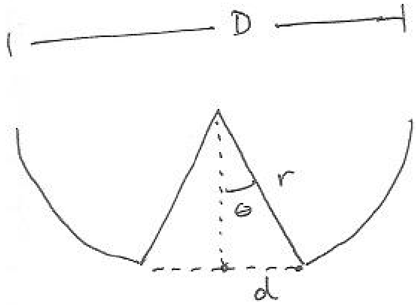
Assumptions:
NA @ Center
$M = Fd$
$\sigma = 70000\ \#/in^2$



Calculations 1. This figure shows the yield strength of the spoon. From these figures, the spoon handle had to have a force equal to approximately 29 lb per lever arm inch, in order to yield.

(2)

Pacman



$D = 1''$

$r = .5''$

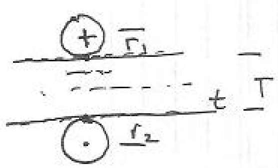
$\theta = 15^\circ$

$r \sin\theta = d$

$\boxed{d = .5 \sin(15^\circ) = .13''}$

$$F_{pc} = \frac{28.47\ \#\ in}{.13\ in} = 220\ \#$$

Pins



$r_1 = r_2 = 4mm$

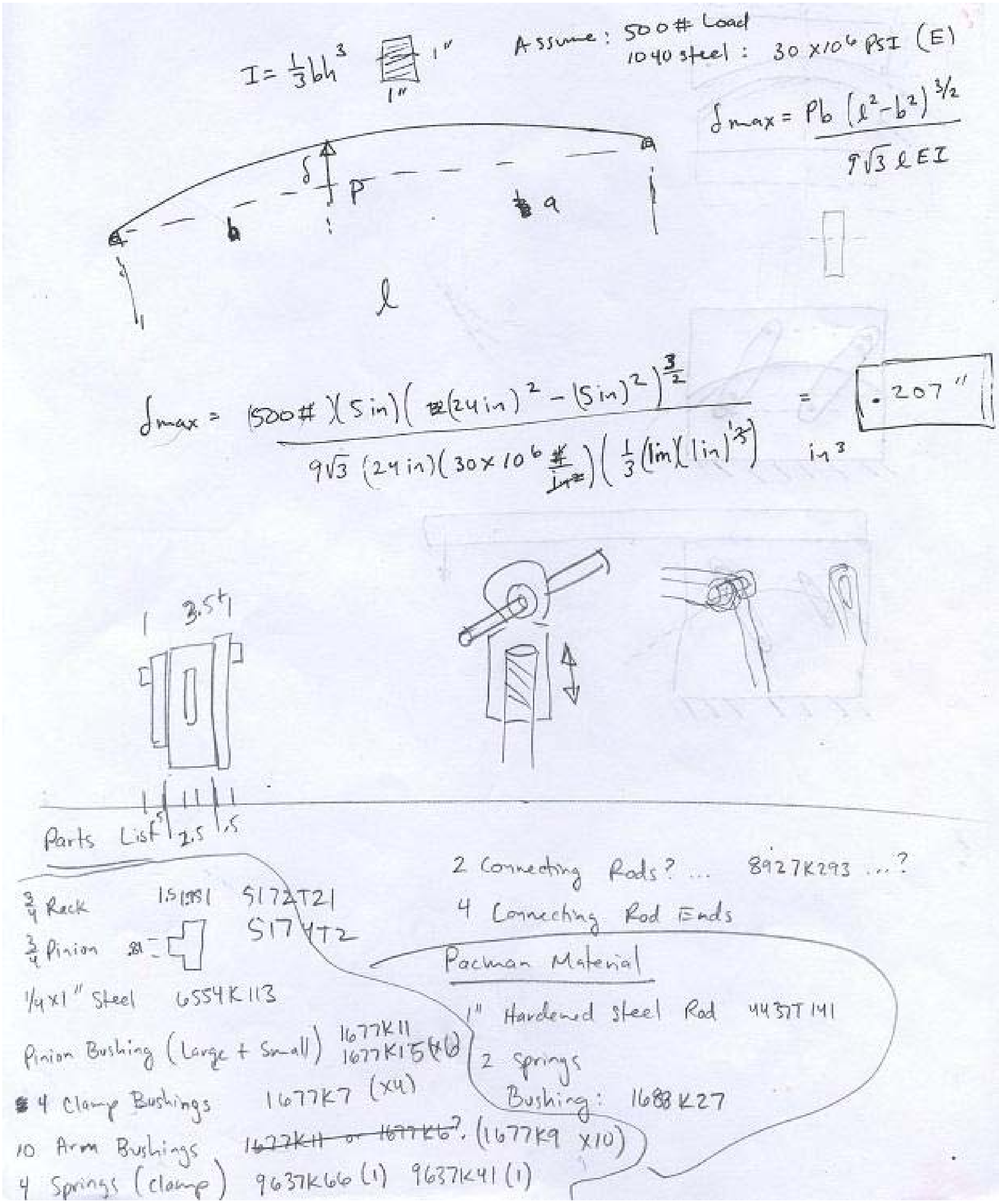
$T = 2mm$

$t = 1mm$

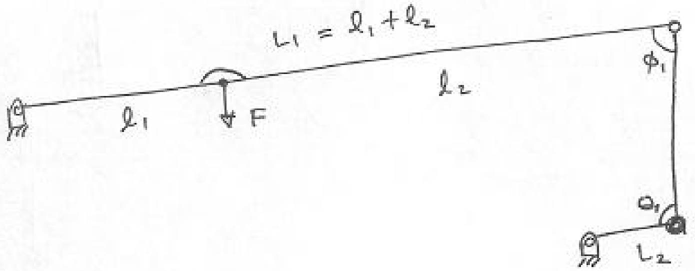
$$F_p = \frac{28.47\ \#\ in}{(2mm)\left(\frac{1\ in}{25.4\ mm}\right)} = 362\ \#$$

$$= 723\ \#^*$$

Calculations 2. These calculations show our range of resistance force given a lever arm of 2mm. Therefore, depending on where your neutral axis is located, the resistance ranged from 362 lb to 723 lb. When determining this value empirically using the fish scale, the resistance force averaged out to 720 lb. However, because our experimentation methods were not very robust, we chose a value of 500 lb for our design. This figure also shows the amount of force needed at the “pacman” end of our device to be able to bend in the “tooth” for our bottle opener.



Calculations 3. This figure shows the deflection analysis for our mechanism. Because our members and pins were made of steel, we did not have to worry about any deflection. However, to be safe, in the worst case scenario for a resistance force of 500 lb, our longest member, 25", would only bend .207".



MA: $\dfrac{L_1 \sin \phi_1}{l_1 \sin \theta_1}$ $\longrightarrow$ Try to approach 90° @ ϕ_1
Try to approach 0° @ θ_1

MA: $\left(\dfrac{r_{in}}{r_{out}}\right)\left(\dfrac{\omega_{in}}{\omega_{out}}\right)$

<u>Rack / Pinion</u> (Assume $\phi \approx 90°$, $\theta \approx 5°$ @ max) input...

$l_1 = 5''$

$L_1 = 24''$

MA: $= \dfrac{24 \sin(90°)}{5 \sin(5°)} = 55:1$

Plus we gain @ Gear...

F_1, d, h, F_2

$F_1 d = F_2 h = \tau$

$\dfrac{F_1 d}{h} = F_2$ $\rightarrow$ $F_2 >$ Than F_1 ...
@ 55:1

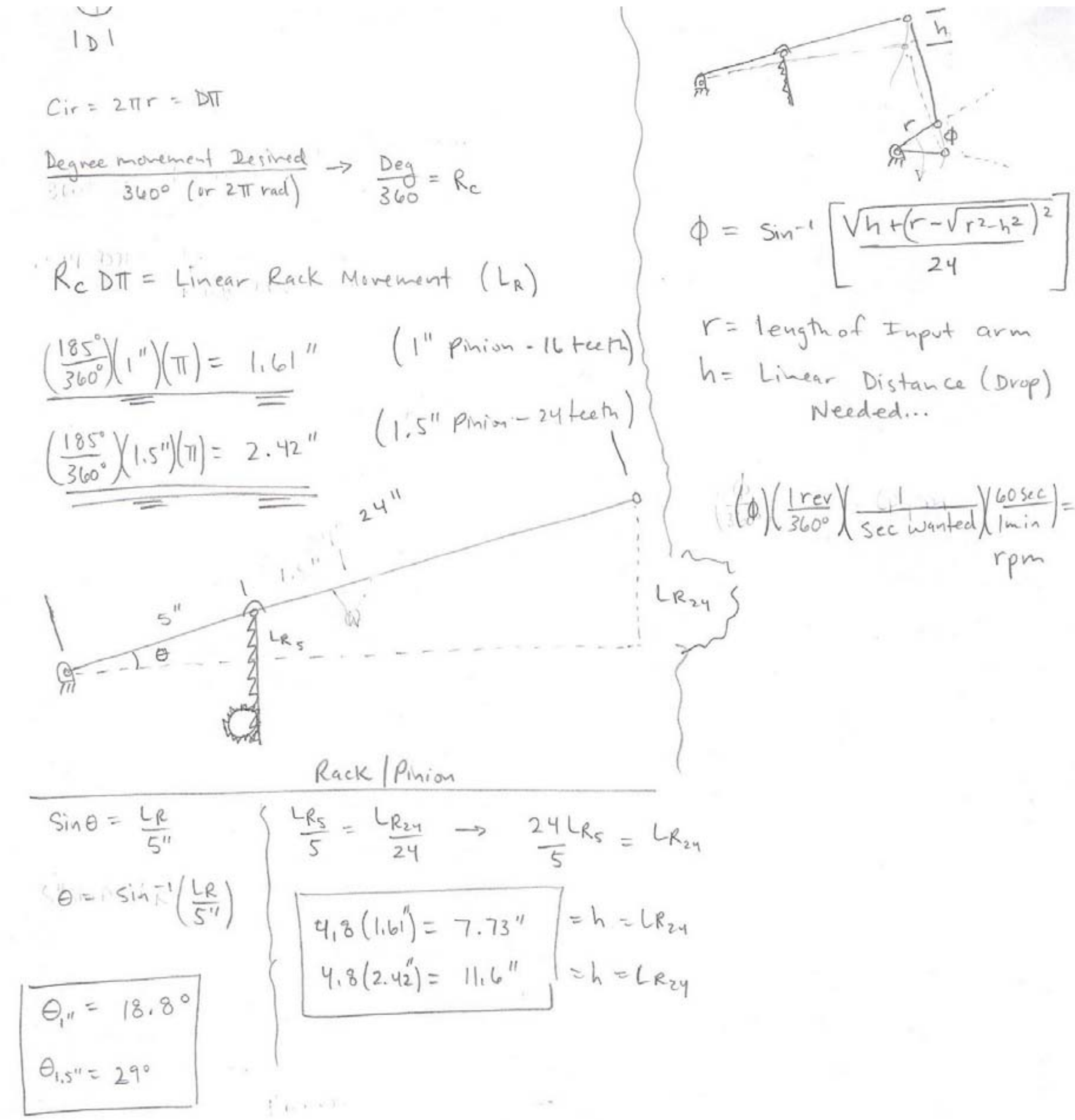
<u>Pacman</u> (Assume $\phi \sim 90°$, $\theta \sim 5°$ @ max input)

$l_1 = 6.5''$

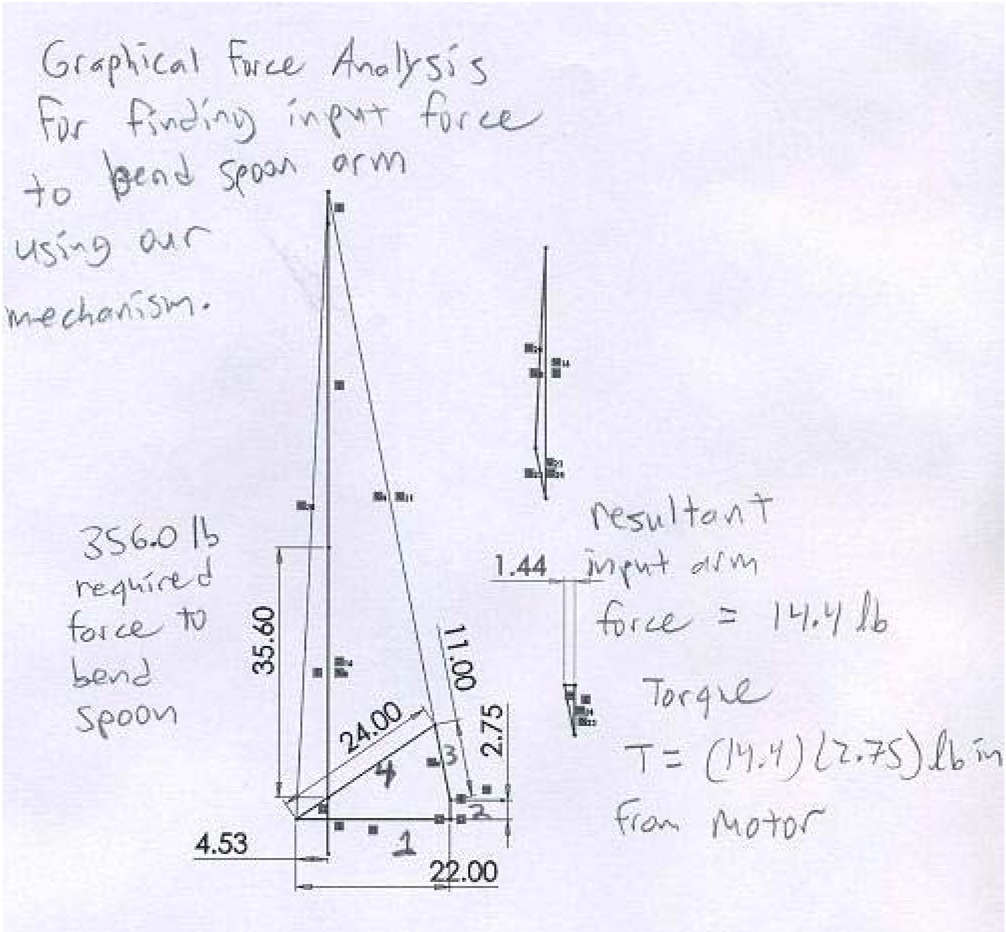
$L_1 = 24''$

$MA = \dfrac{24 \sin(90°)}{6.5 \sin(5°)} = 42:1$

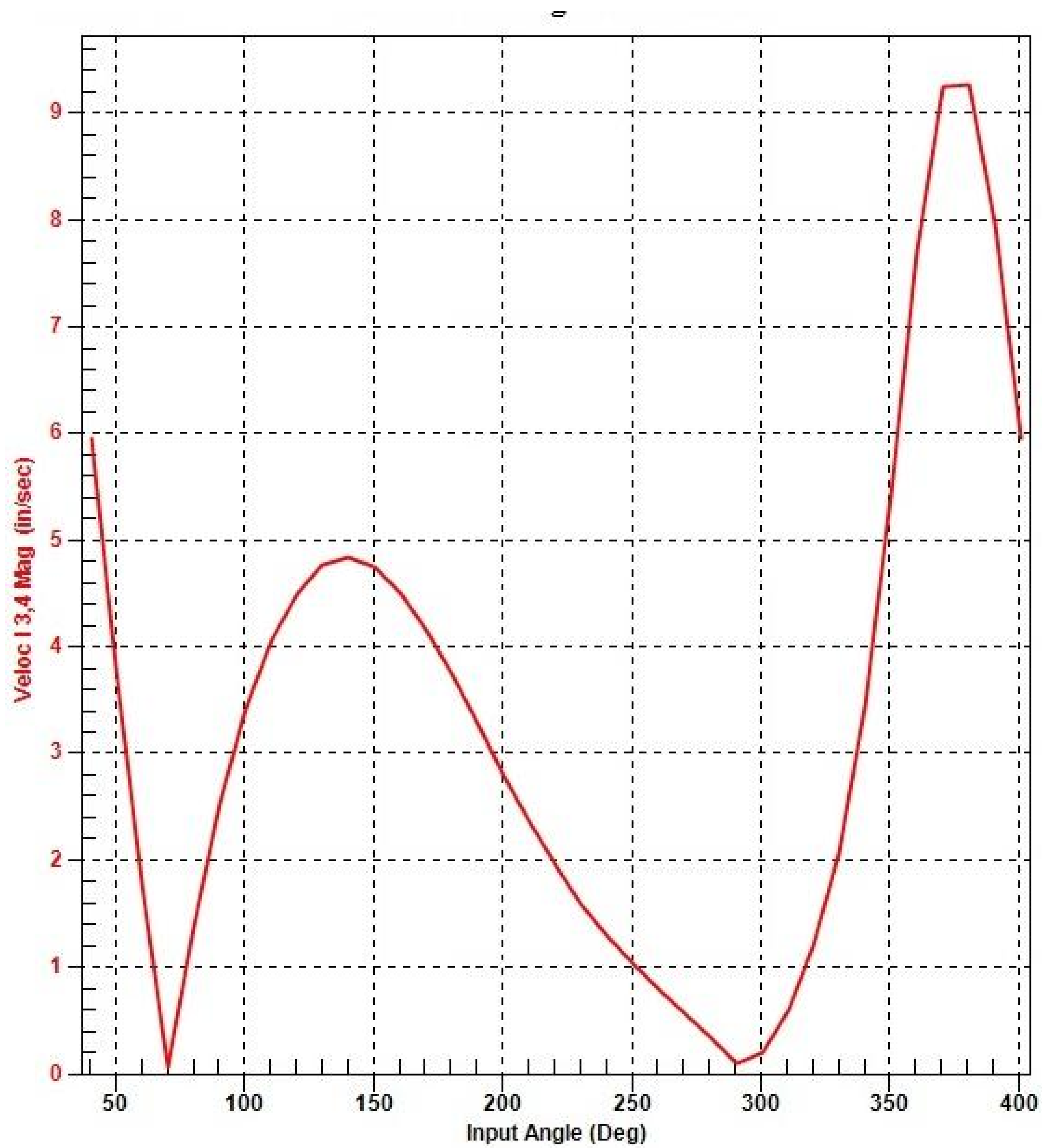
Calculations 4. This figure shows the calculations used to approximate the mechanical advantage for our rack Grashoff mechanism. This same method was used to find the mechanical advantage for our "pacman" Grashoff mechanism. Initially, when the most amount of force was needed to yield the spoon, we found that we would have a mech. adv. of 42:1. For the "pacman" Grashoff, the mech. adv. maxed out at 50:1, near the angle at which the "pacman" would do its job. Given these values, we were able to apply angles and lengths to our mechanisms.



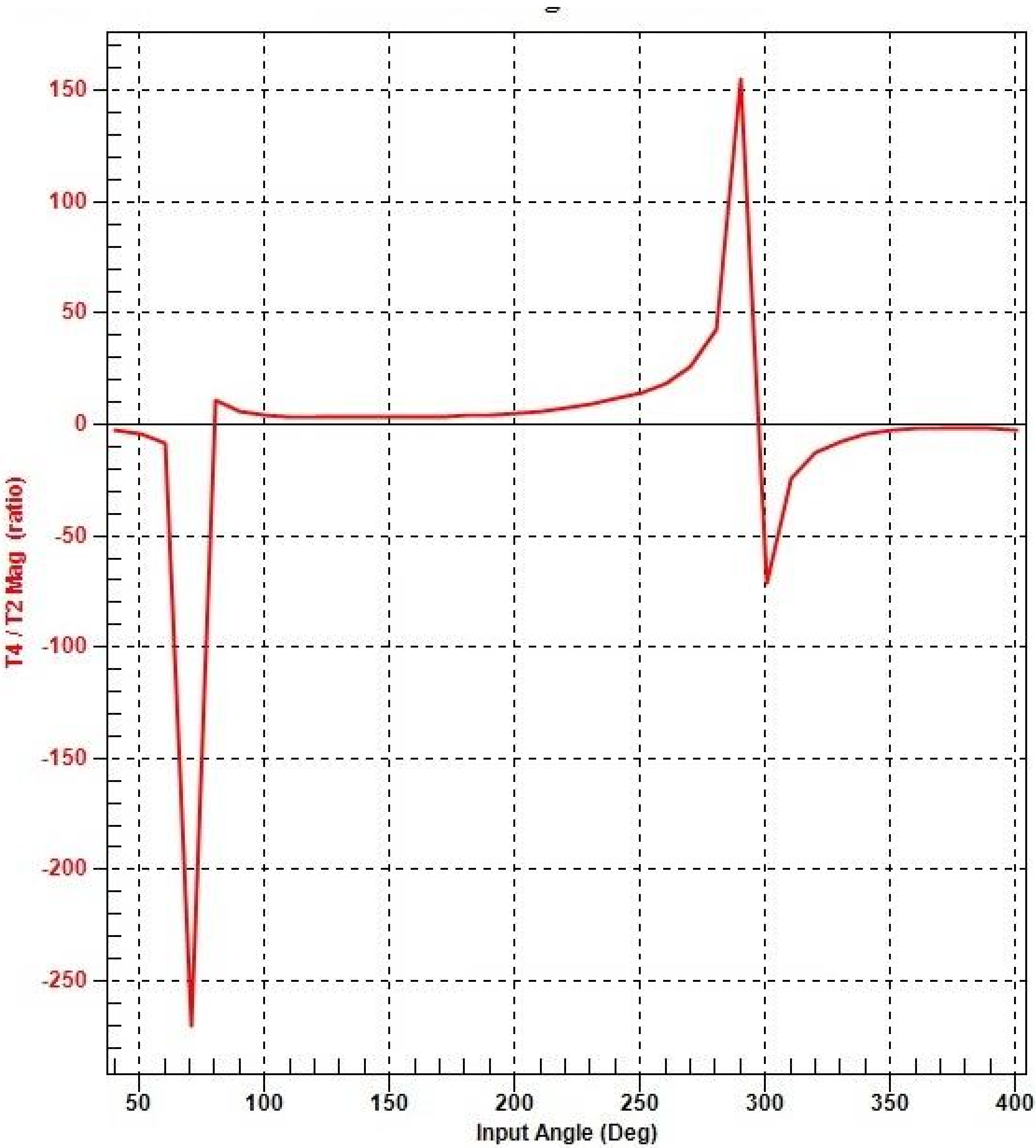
Calculations 5. This figure shows how our pinion rotation, which affects the rate at which the spoon is bent, depended on the dimensions of the rack and arms. These figure were therefore used to dimension our design.



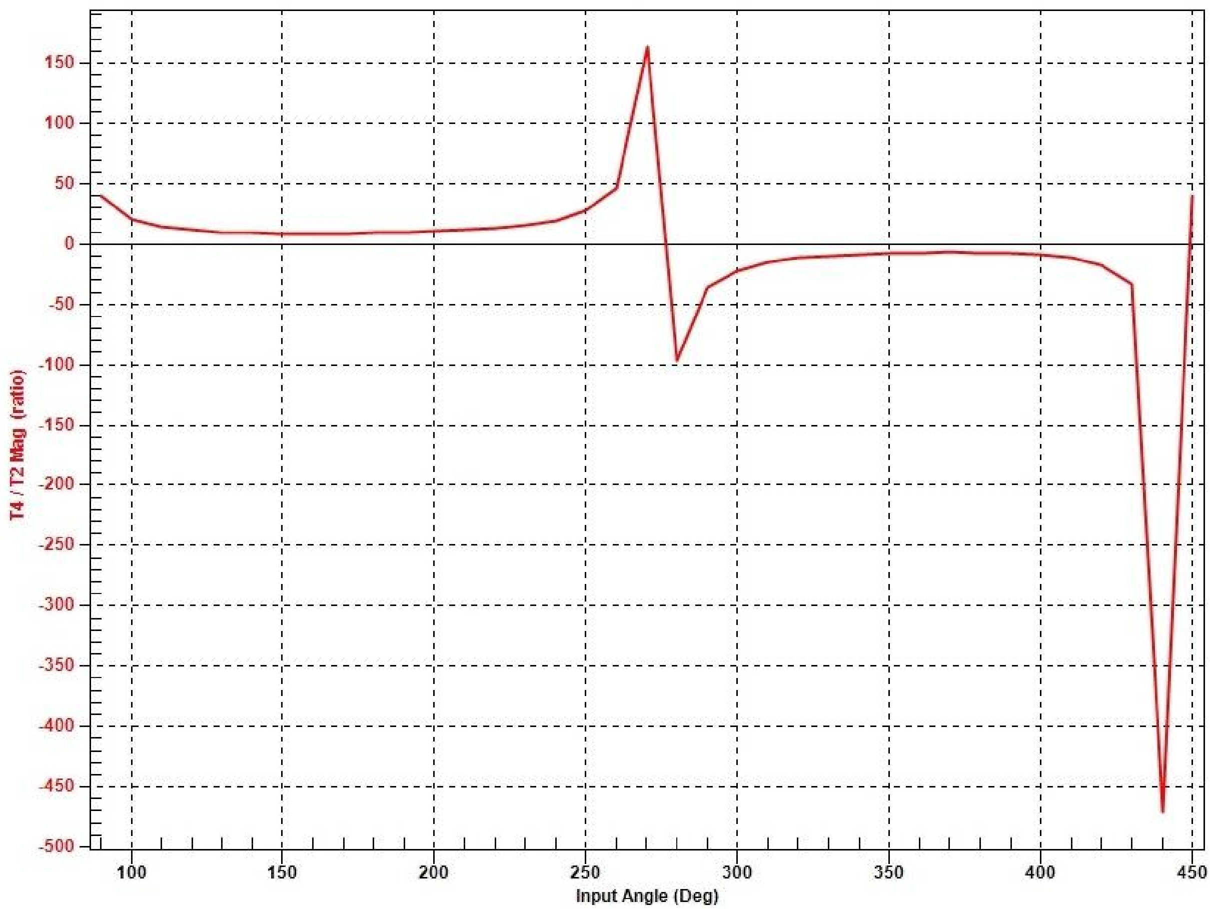
Calculations 6. This figure depicts the use of graphical force analysis using CAD software to determine the minimum input force required to bend the spoon, however, still assuming a yielding neutral axis at the center.



Plot 1. This graph shows the velocity of pin 3-4 vs. link 2 angle for the “pacman” Grashoff mechanism. Note that our mechanism has a quick-return attribute.



Plot 2. This graph shows the output torque/input torques vs. link 2 angle for the “pacman” Grashoff mechanism. Note that the output torque is greatest when it is actually doing its bending.

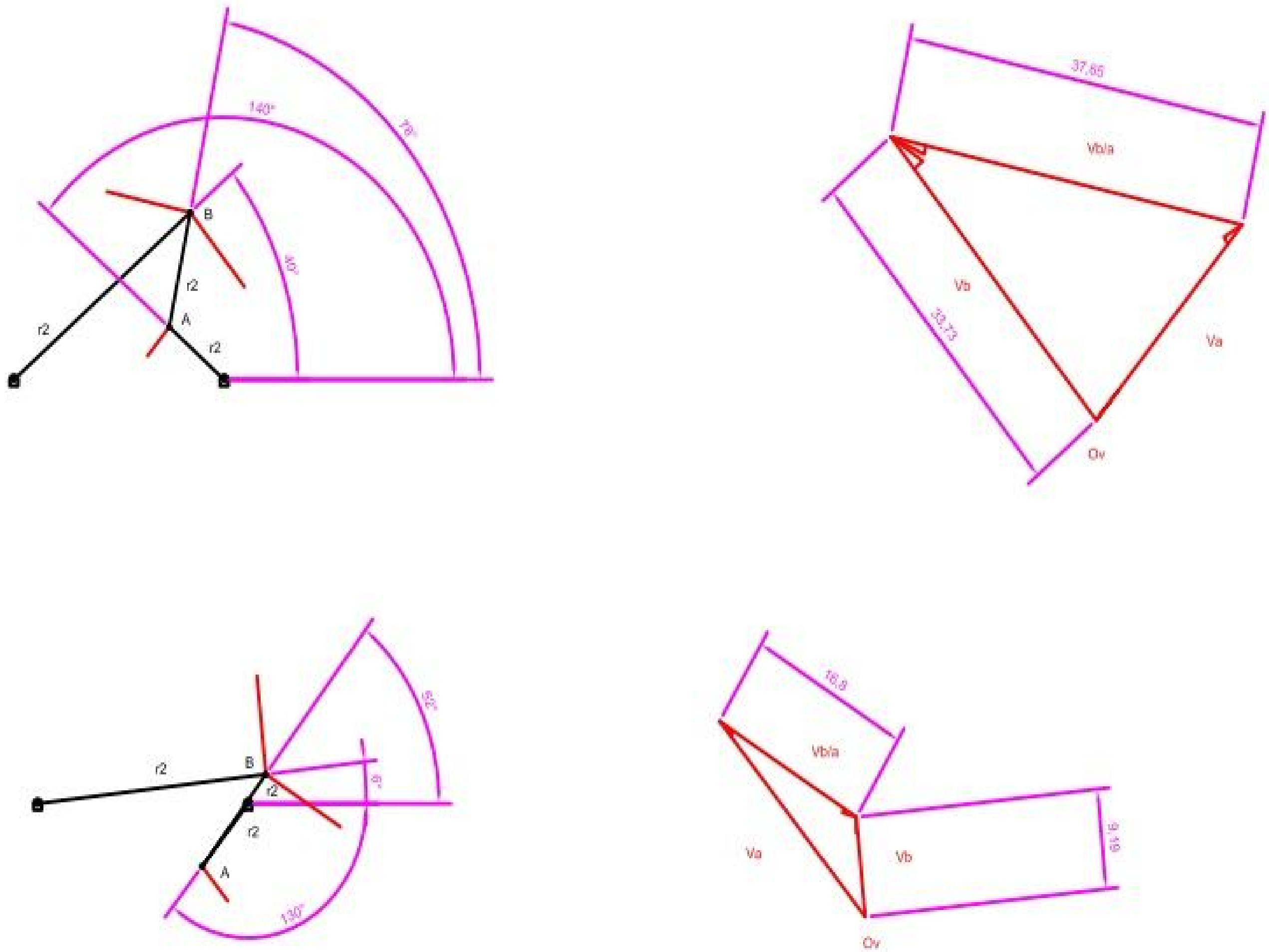


Plot 3. This graph shows the output torque/input torques vs. link 2 angle for the rack Grashoff mechanism. Note that the ratio never falls below 8 until after the spoon handle has been bent .

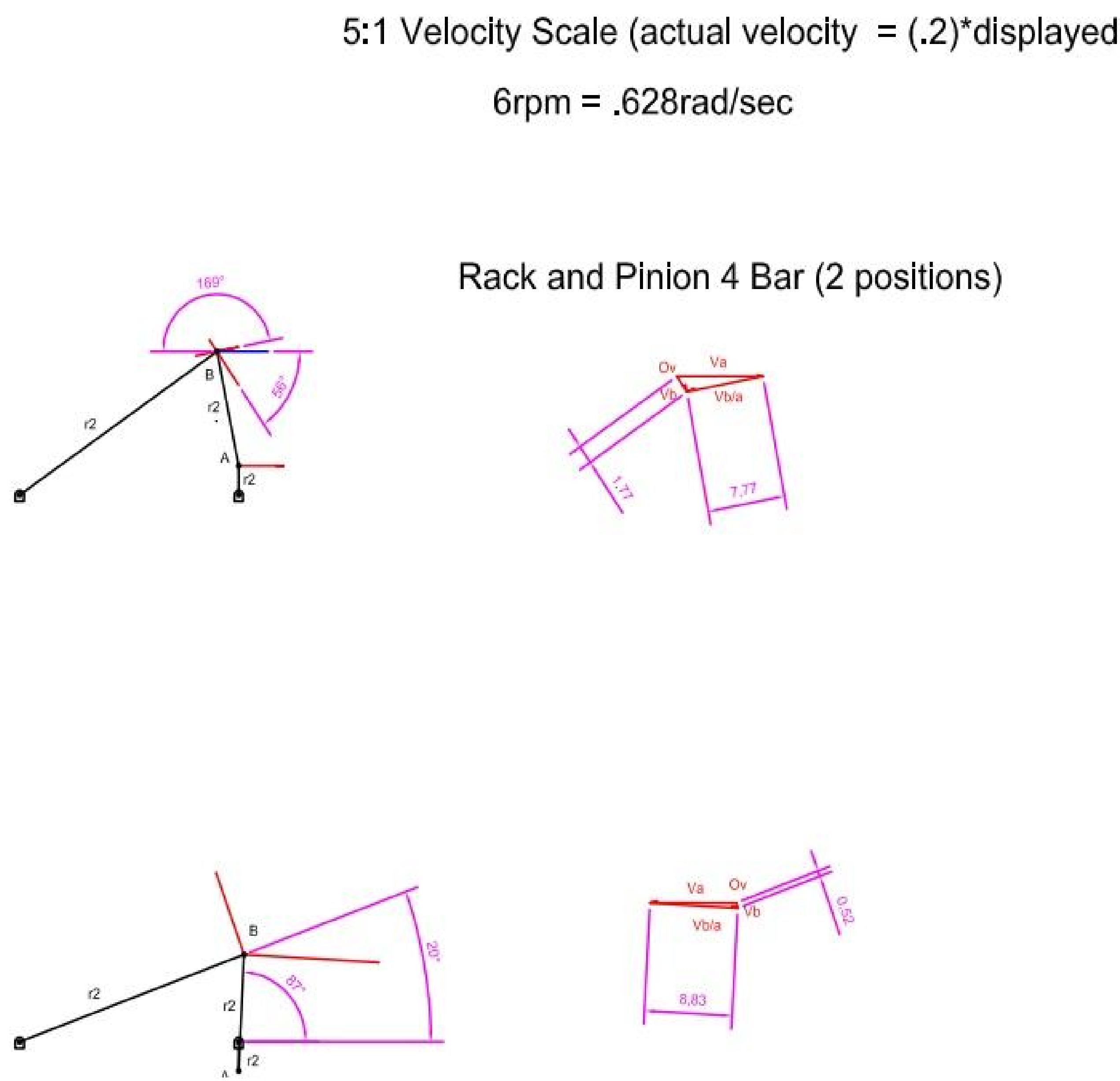
5:1 Velocity Scale (actual velocity = (.2)*displayed

6rpm = .628rad/sec

Pacman 4 Bar (2 positions)



Calculations 7. This figure shows the velocity polygon method used to find the velocity of link 4 in the “pacman” Grashoff mechanism, using our motor input rotational velocity of 0.628 rad/sec.



Calculations 8. This figure shows the velocity polygon method used to find the velocity of link 4 in the rack Grashoff mechanism, using our motor input rotational velocity of 0.628 rad/sec.

Discussion

Our initial concept for bending a spoon in the manner that we had intended turned out to be very difficult and time consuming to actually manufacture. Due to the large input forces and the strength and small lever arm of the spoon, our mechanism turned out to have some disadvantages. These problems included:

- Heavy mechanism
- High amounts of friction
- Miss alignments
- Spoon arm Pre-bend
- Large required input force
- Motor mounting issues

The most significant problem was the fact that the majority of our mechanism was made of steel. This not only added extra weight to our mechanism, but increased manufacturing time, since steel is very difficult to cut. Also, because we used scrap steel for our project, instead of purchasing expensive unused steel, any imperfections within the material, like rust and curvature, had to be adjusted for in our overall design. Another main problem which arose during manufacturing was dealing with friction and deflection. Again, because of the large size of our mechanism, our tolerances had to be very tight. This led to high amounts of friction in some areas, especially at the input force side, where all the "link 2" members were joined to the motor. This led to constant tweaking of mounting alignments, which sometimes led to misalignment, which in turn led to deflection of some members during mechanism operation. Another problem, which was addressed with an external mechanism, was the difficulty of bending in the final "tooth" of the spoon bottle opener. To simplify our design we decided to have an external press to enact a "pre-bend" in the spoon's arm. Later, the "pacman" would come in and finish the tooth formation. Finally, because of our small lever arm and two separate processes, our project required a larger, bulky, low rpm and high torque motor. The mere size and weight issues of the motor stalled the progress of our project. The difficulty came in developing a mounting device and a way to mate the motor to our gear mechanism without creating instability and/or requiring us to change our core design. These problems were all dealt with however, even if we could do things differently for the future.

There is room for improvement and additions for future designs. As stated before the use of steel caused many problems that needed to be fixed. Therefore, reducing the overall size would not only reduce the amount of steel used, but would cut back on manufacturing time and perhaps decrease spoon-bend time or increase output forces in some areas. Also to help in decreasing manufacturing time, the entire base, pivot base, and gear housing could all be one piece, made of cast iron. Therefore, the only parts needing to be manufactured would be the arms, the clamp, and the rack and pinion. To reduce friction, the addition of ball bearings to pivots, and higher quality bushings, would be very beneficial. To deal with the tooth formation, an additional process could be added to the mechanism to do away with the external pre-bender. Considering the transportability of our mechanism, it would be beneficial to change where our motor was mounted. If allowed access to more material, we would attache the motor to our base below our mechanism, as to lower the overall center of mass, and also to keep it out of the way. Also, because the main market for this mechanism would be tourism/entertainment and novelty items, adding such things as an embosser and keyring attachment would add value to our mechanism. Imagine a prospective UC Berkeley student visiting the campus. He could visit our Cal Student Store, insert his money into our mechanism, and watch as a spoon transforms into a bottle opener with the words "UC BERKELEY" embossed on the spoon's arm, complete with a keyring. This could easily be sold for $5. And with a production cost of around $500, profit could be amassed quickly.

In conclusion our concept completed its task of bending a simple teaspoon into a bottle opener with robustness. It performed its task quickly and precisely. Therefore, our mechanism was a success. This accomplishment can be attributed to the overcompensation for input forces, the use of high strength material, and the timing of both processes using two Grashoff mechanisms. Our design allowed for our mechanism to have 1 degree of freedom, simplifying our design by removing synchronization issues and allowing our mechanism to be more compact with the addition of only one motor.

References

Accubend
http://www.mandellinormalizzati.it/root_prodotti//PROGRAMMA%20STAMPI%20TRANCIA/Sistema%20piegatura%20rotativa%20ACCUBEND/DanlyIEM-Accu-Bend.pdf

Ready Bender

http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCAQFjAA&url=http%3A%2F%2Fwww.readytechnology.com%2Fcatalogs%2FREADYBenderCatalog.pdf&ei=QInhTs_rEI_MiQKYpYj_CQ&usg=AFQjCNFc8DU-Tm14ezZXRI0K-cxlKnGXeg&sig2=axUdqHdPfutALTzmw0gq8w

Linkages Student Edition Ver. 10.0 Rev. 1.6.0 2/13/11 by Robert L. Norton
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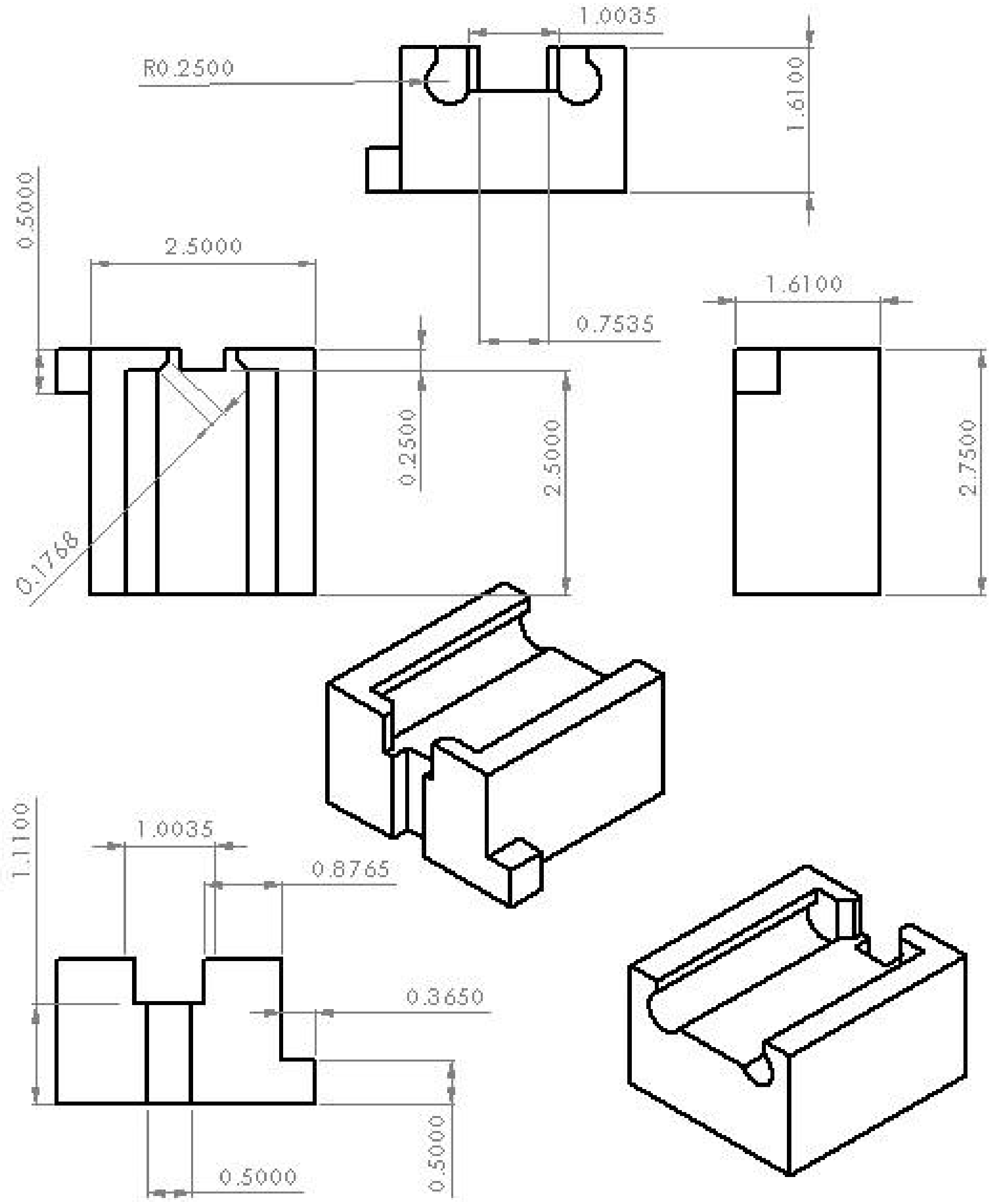
www.designofmachinery.com

Appendices

Clamp Base 2D: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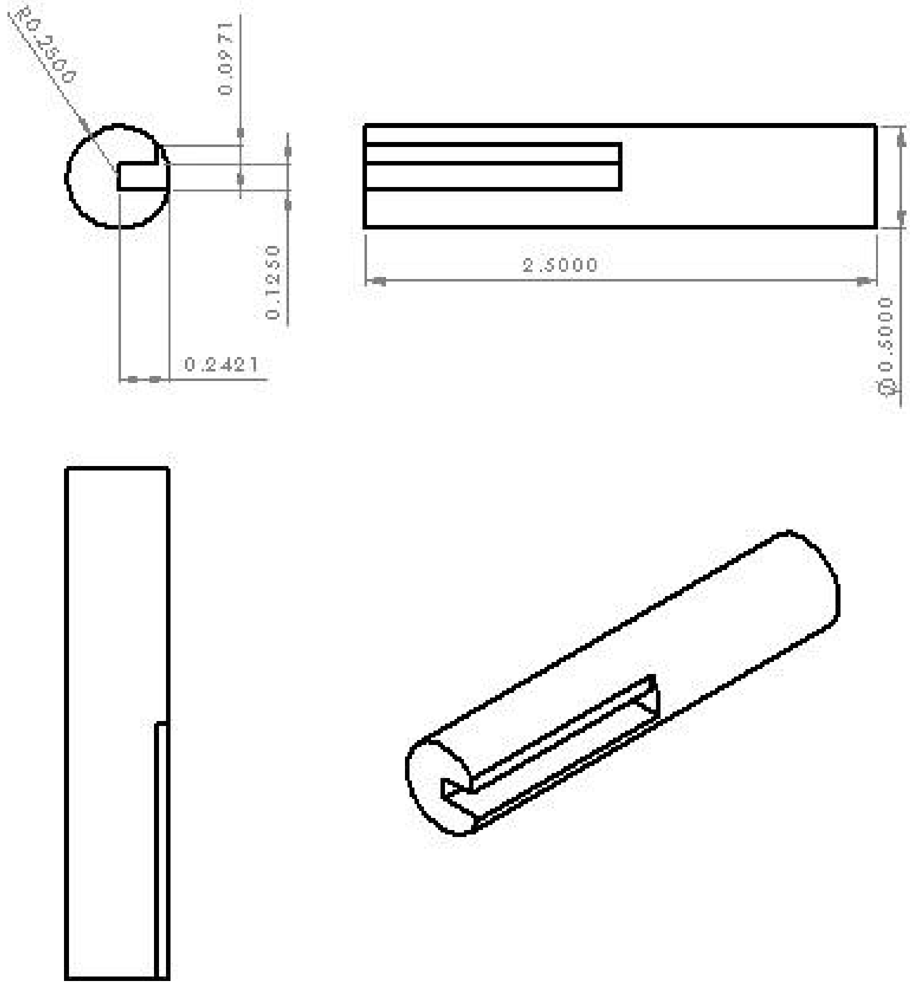
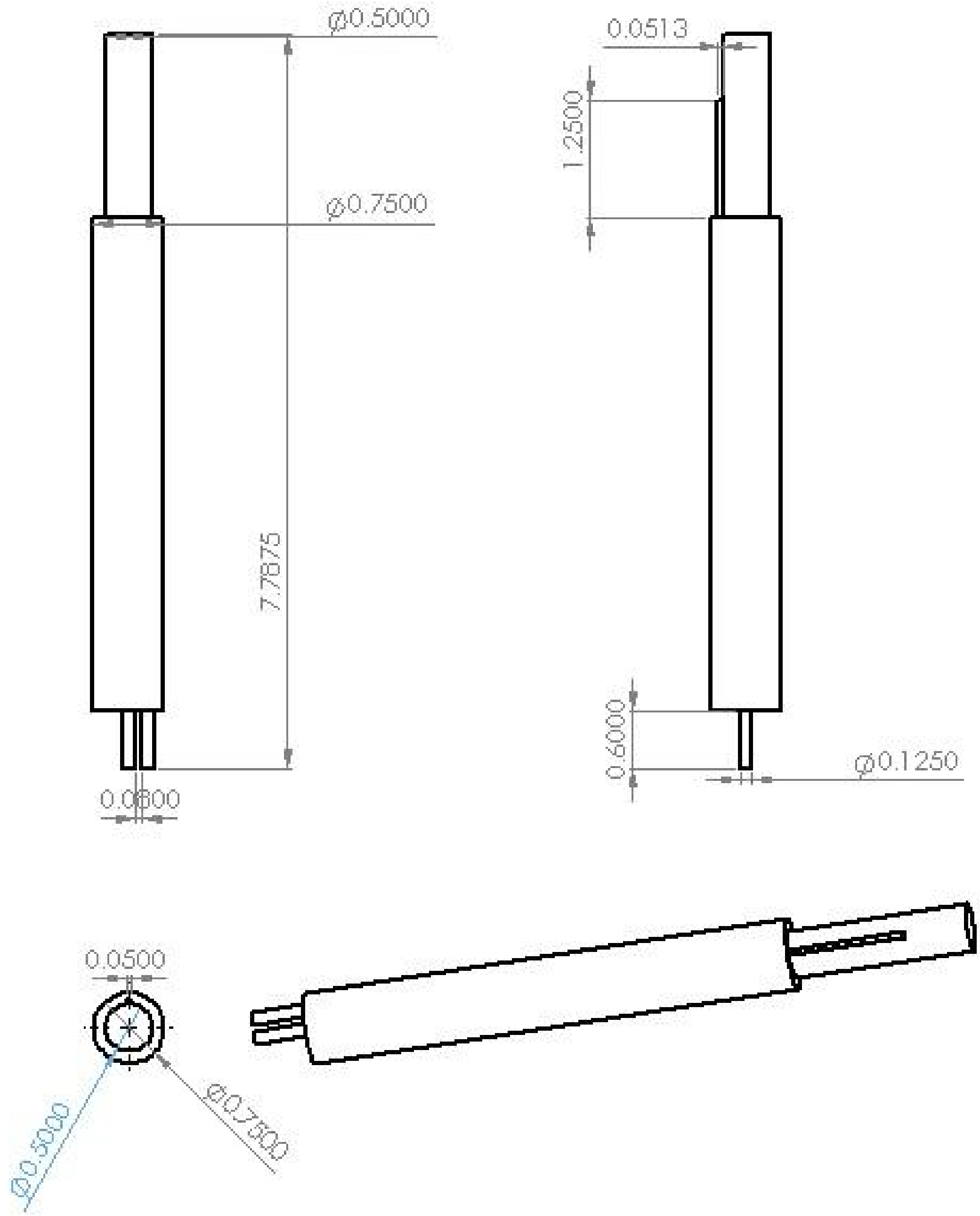
0.8765
0.3650
0.5000
0.5000

Clam Pins 2D:



Axel with Key 2D:


Ø0.5000
Ø0.7500
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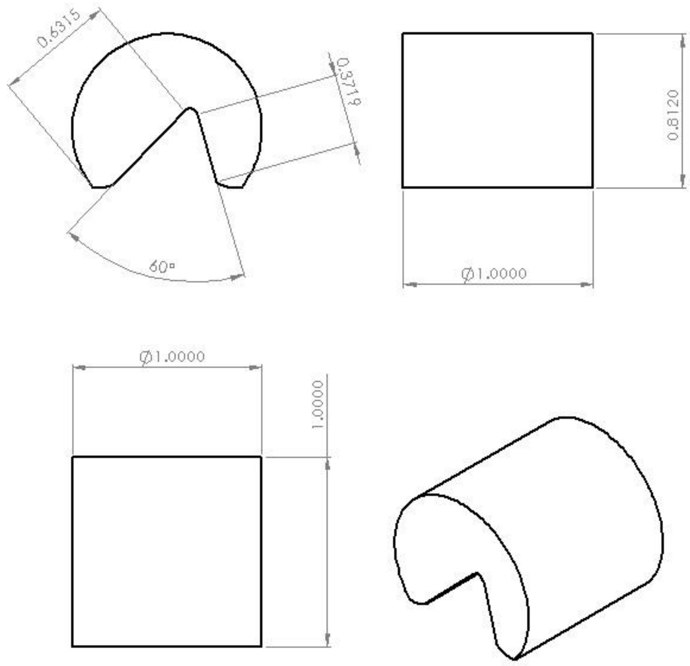
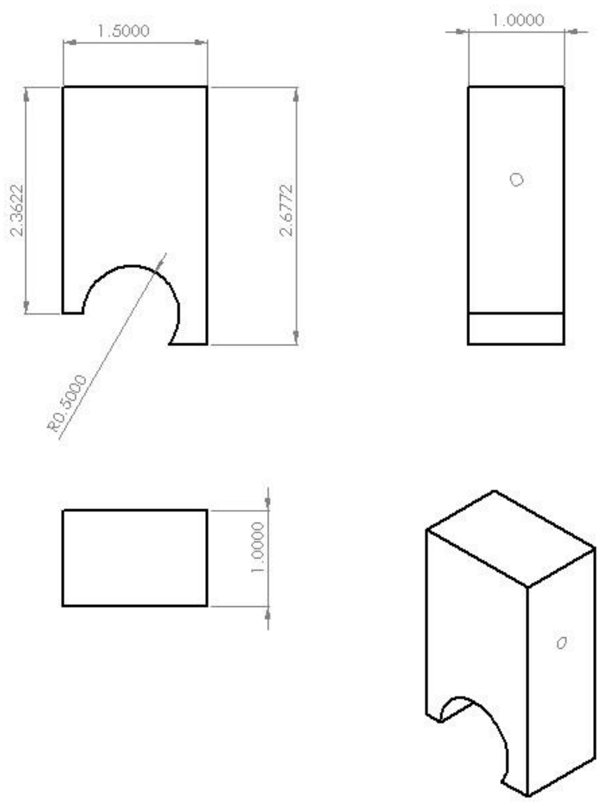
Ø0.7500

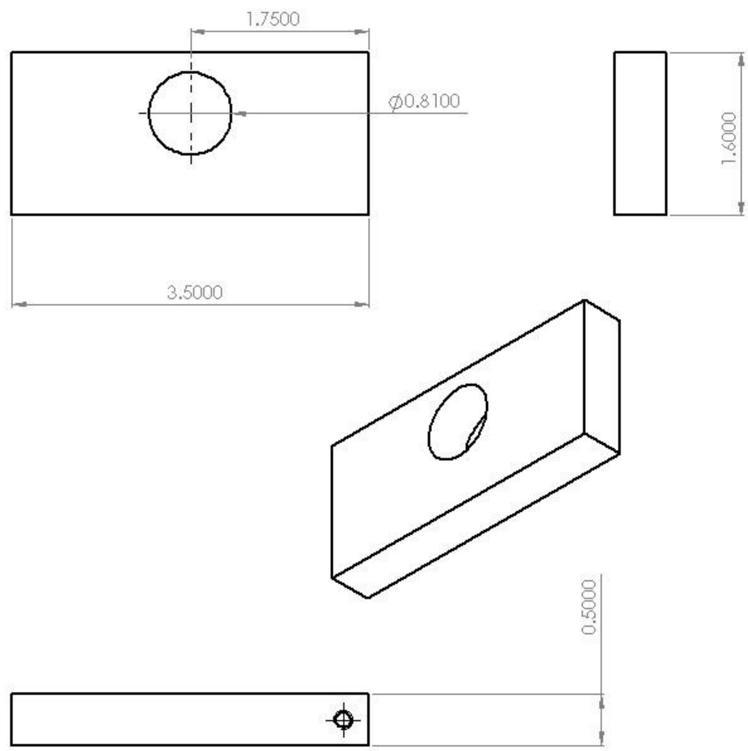
"Pacman" 2D:



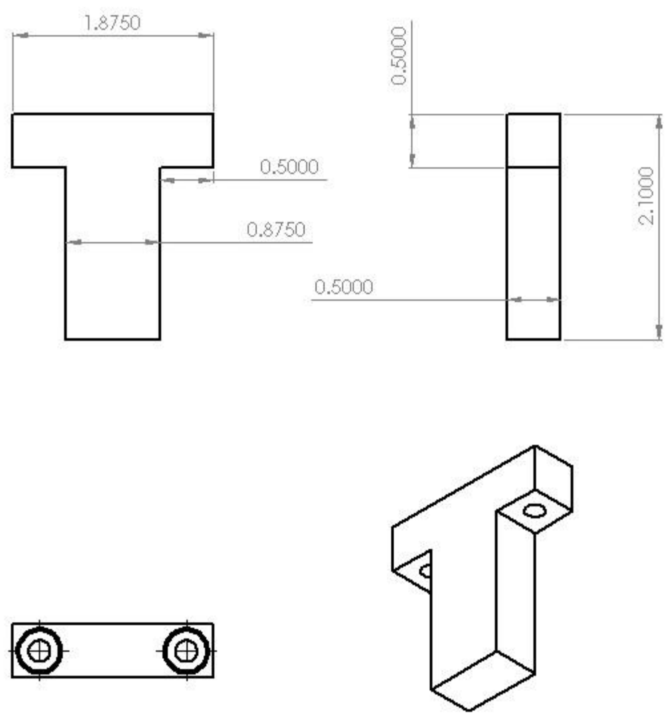
"Pacman" Holder 2D:



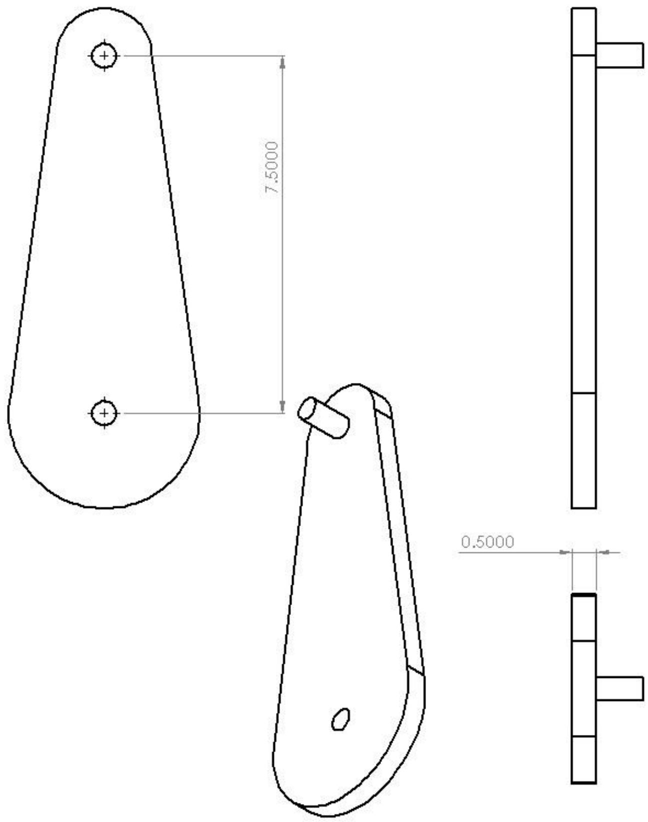
Pinion Holder 2D:



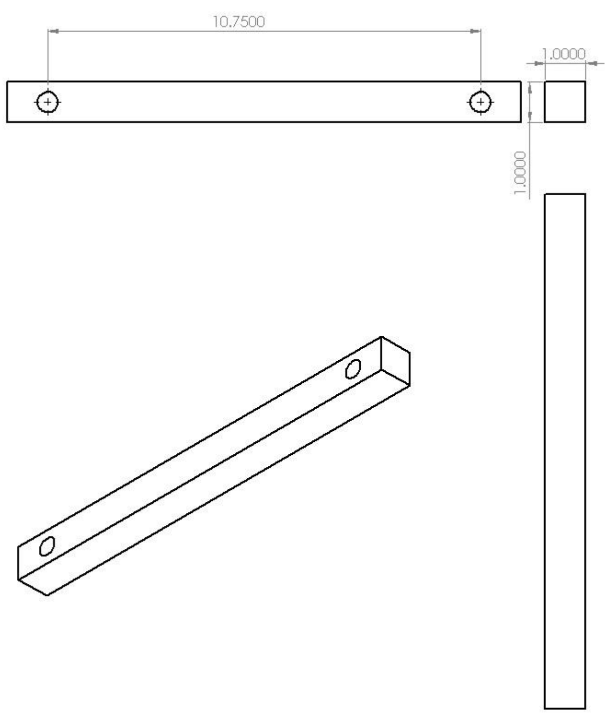
Rack Guide 2D:



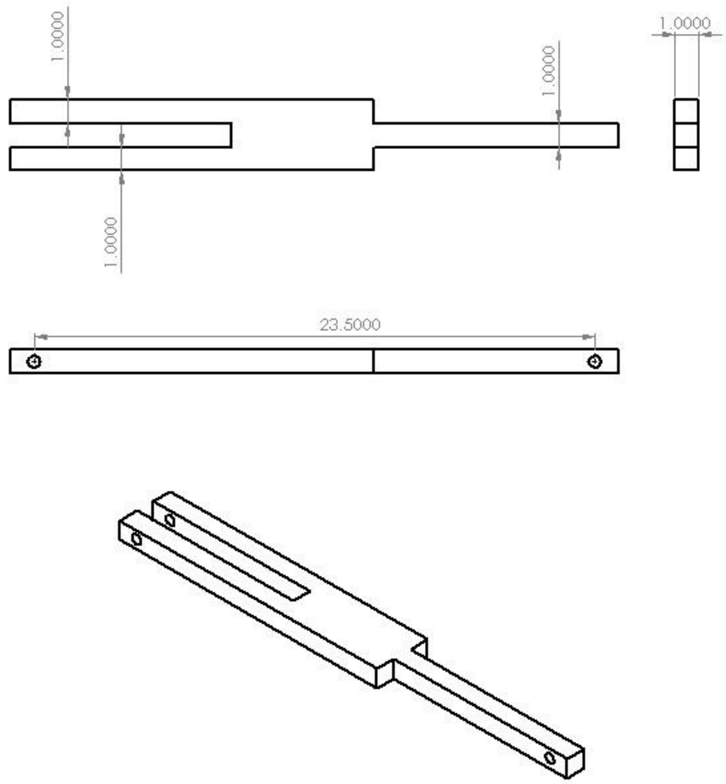
Link 2 for “Pacman” Grashoff 2D:



Link 3 for “Pacman” Grashoff 2D:



Link 4 for “Pacman” Grashoff 2D:



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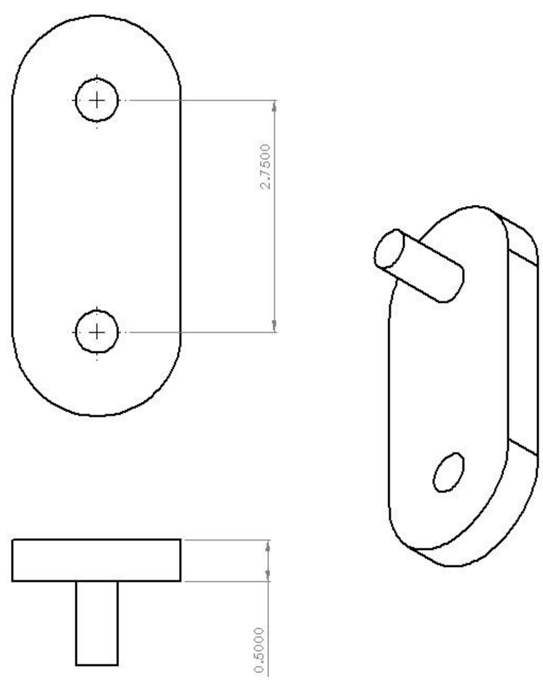
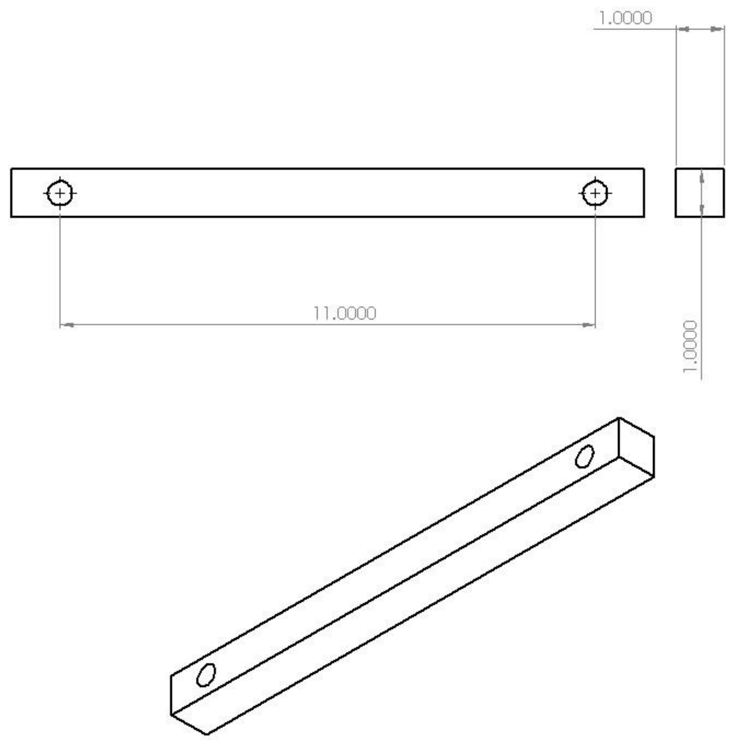
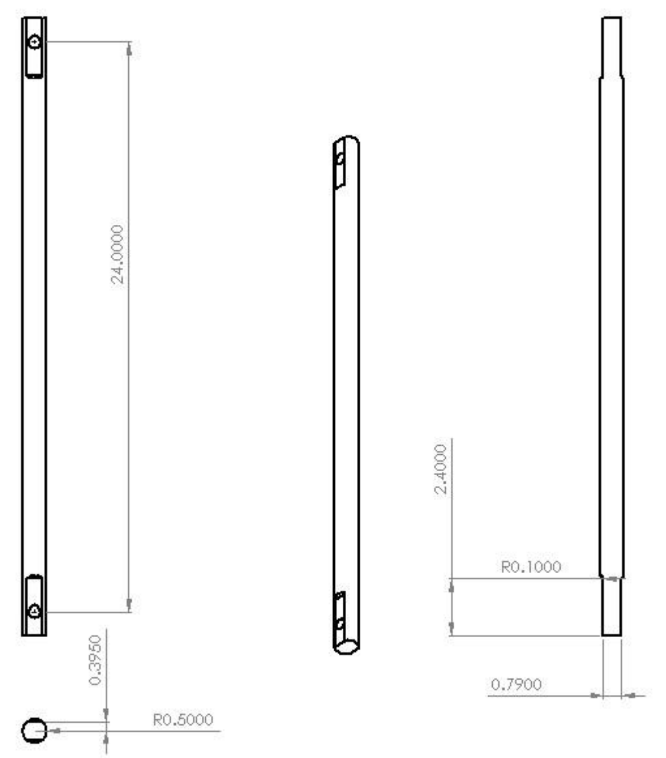


Link 3 for Rack Grashoff 2D:



Link 4 for Rack Grashoff 2D:



Human Power Generation

Pedal Power Team Spring 2012 Semester Report
Vinh Hoang, Darshan Kasar, Shail Shah, Chathu Abeyrathna, Matt Roeschke, Kyle Zampaglione
May 13, 2012

1. Introduction

The primary goal of the pedal power team is to retrofit a stationary exercise bike with an energy conversion system that transforms mechanical work into electrical work. Our team wants to use the stationary bike as an education tool at the Recreational Sports Facility (RSF) in order to ultimately power an iPad that would promote the benefits and potential of human power generation. In regards to this semester, the team has completely overhauled the designed developed during the fall 2011 semester. In order to power the shaft-driven electric generator, the bike has been transitioned from a gear/chain system to an intermediate gear system driven by timing belts. In addition, we have ordered and machined all the necessary parts in order to fully assemble our design and completed over half of the total assembly.

2. Method

At the beginning of the semester, our team analyzed the mock-up of the gear-chain system that was on the recumbent bike. This system used to two bike gears in order to ramp-up the user's input rpm to a faster rate. The output gear was connected directly to the shaft of the electric generator. When testing this design, our team realized that the electric generator was not receiving the necessary rpm to maintain a constant, steady charge. Another problem that was discovered was that this current system did not produce any resistance to the user. Therefore, when the user pedaled faster and faster, the pedals would start to slip and the user's legs would spin out. Thus, our team set out to create new system that would generate the required rpm for the electric generator and offer an adjustable resistance feedback to the user.

In order to produce a constant voltage for powering the iPad, the electric generator required an input rpm of at least 2000 rpm to generate 12 volts. The user inputs about 60-65 rpm. To achieve the 2000 rpm, we needed a larger gear-up ratio. The input gear (large gear) of the current system had 53-teeth and to amplify the user input's rpm of 65 rpm to 2000 rpm, the newly designed system would need an amplification ratio of input to output of 1 to 31. With the current input gear, this amplification ratio would be difficult to attain since small gears of 8 teeth or smaller are hard to find and not as robust for a recumbent bike. Hence, our team decided to use a intermediate pulley-belt system because the parts that were available would allow the system to produce the necessary 2000 rpm and were much more robust.

2.1 The intermediate Gear system

The intermediate pulley-belt system utilized two stages. At each stage, the rpm of the user would be multiplied by 6 and the rpm at the generator shaft would be, in theory, 2340 rpm which is more than enough to produce a constant voltage. The pulleys that could be purchased (from McMaster Carr) allowed us to achieve this gear ratio and were robust parts that would be able to handle the high speeds and torque. Our implementation of this design will be discussed in more detail later in this report. Furthermore, the pulley-belt system provided additional benefits. Since we were using toothed-belts, the risk of the belts slipping off the pulleys was greatly reduced. Furthermore, the belts increased the safety of system since there are no moving sharp edges like those in a chain-gear system. The parts that were purchased for this design are shown in table 1.

Line	Part Number	Description	Quantity	Unit Price ($)	Purchased from:
1	6495K23	L and H Series Timing Belt Pulley, L-Series, Fit 1/2" Belt Width, 1.438" OD, 10 Teeth	2	16.65	McMaster Carr
2	6484K159	Trapezoidal Tooth Neoprene Timing Belt, 3/8" Pitch, Trade Size 450L, 45" Outer Circle, 1/2" W	2	16.27	McMaster Carr
3	6495K222	L and H Series Timing Belt Pulley, L-Series, Fit 1/2" Belt, 7.13" OD, SD Bushing	2	87.62	McMaster Carr
4	7208K51	Steel Flange-Mounted Ball Bearing, for Shaft Diameter 3/8", Overall Length 2-1/2"	2	22.23	McMaster Carr

Table1: Purchased parts for the intermediate gear system

Our team retained the original shaft-driven electric motor used during the Fall 2011 semester. Conventionally, we decided that the electric generator must sustain ~12 volts in order to effectively charge the battery of an iPad. In order to safely produce 12 volts from our electric motor, we experimentally determined that the shaft must rotate at ~2300 rpm. (See Appendix A.)

Implementation

Main observation
[Challenges Faced]
[What we have currently assembled]

Conclusion

Our immediate next step is to finish the assembly of the bike. Our team projects to have the electric generator fully mounted to the bike and connected with the intermediate gear system by the end of Summer 2012. In order to accomplish this task, we will first need to place an idler in the primary gear system to reduce the slack that is in the current belt. This entails purchasing and installing a bearing that is designed to accommodate our idler pulley. This part will be found on McMaster. Another major task is to mount the motor to the bicycle. For this, we will need to have our design for the primary system set in stone so that we can position the motor accordingly. The mechanism for mounting the motor can be carried over from the Fall 2011 bike design.

Once these two tasks have been accomplished we should have the physical components of the bike finished. What will be left to accomplish is the electronics system and perhaps additional features like adjustable resistance. For the electronics, most of the components which are currently used on the “Pedal A Watt” bicycle found in the lab will be brought over. This means that we will be wiring the motor to a powerpack, which can then be rerouted to the iPad charger. This task should be trivial, with the biggest concern being only that the system is contained and aesthetically pleasing. In terms of user resistance, this is a feature we would like to incorporate but have not yet designed. One idea for implementation is to use mechanical arm to increase the tension in the belts. A more sophisticated design suggestion would be to use a microcontroller with a variable resistor that can create a back EMF to slow the system. Our team hopes to showcase the pedal-powered iPad in late 2012 or early 2013.

Acknowledgements:

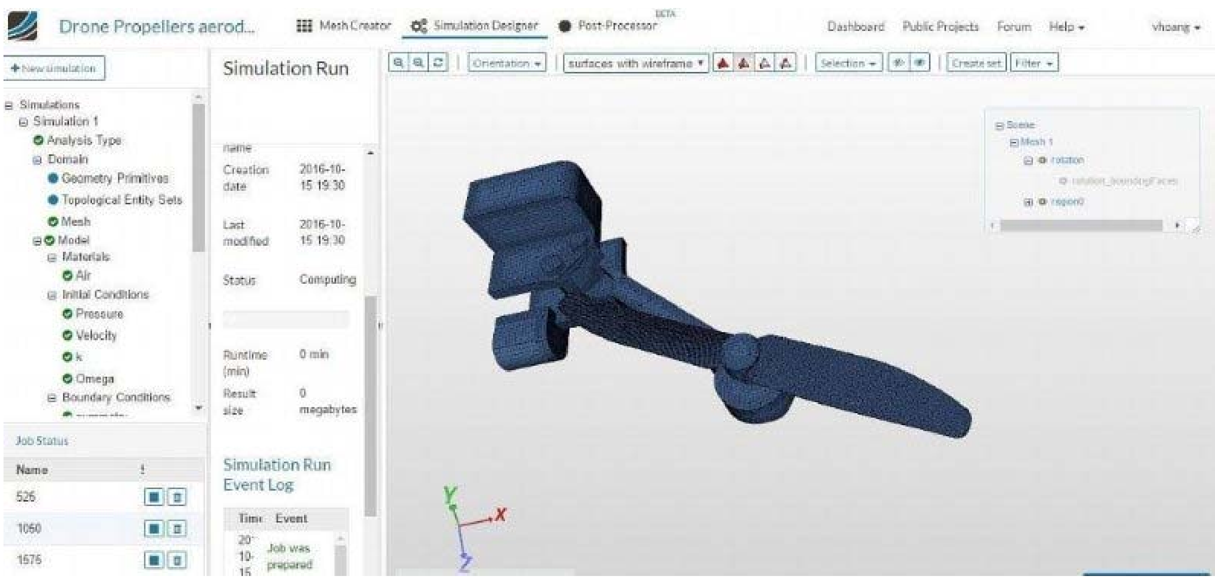
Dr. Agogino

Mick & Gordon (Etcheverry Machine shop)

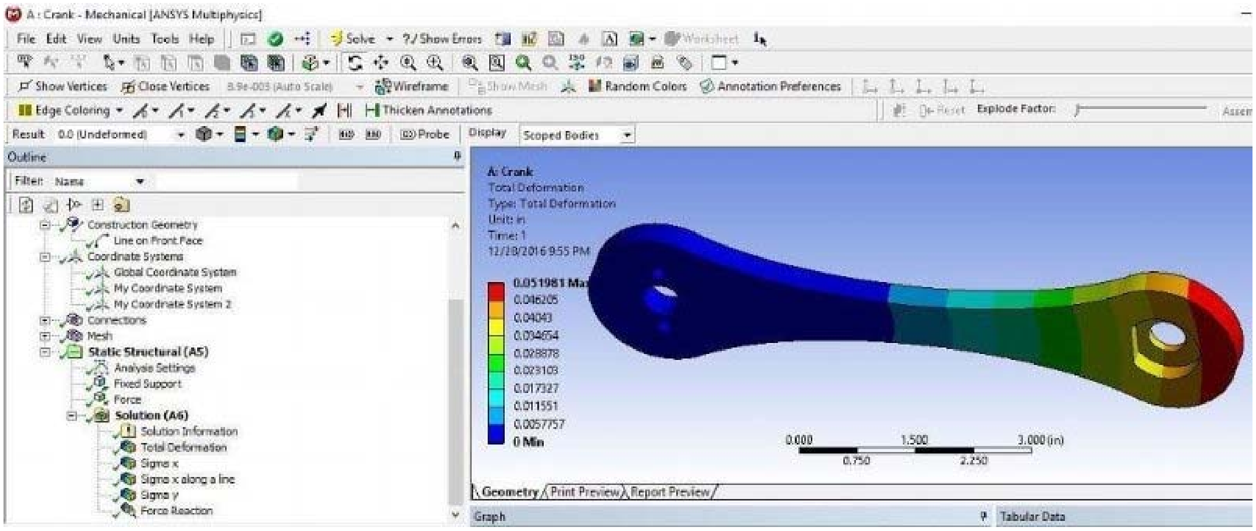
Maja Haji (research lead)

CAD, FAE models

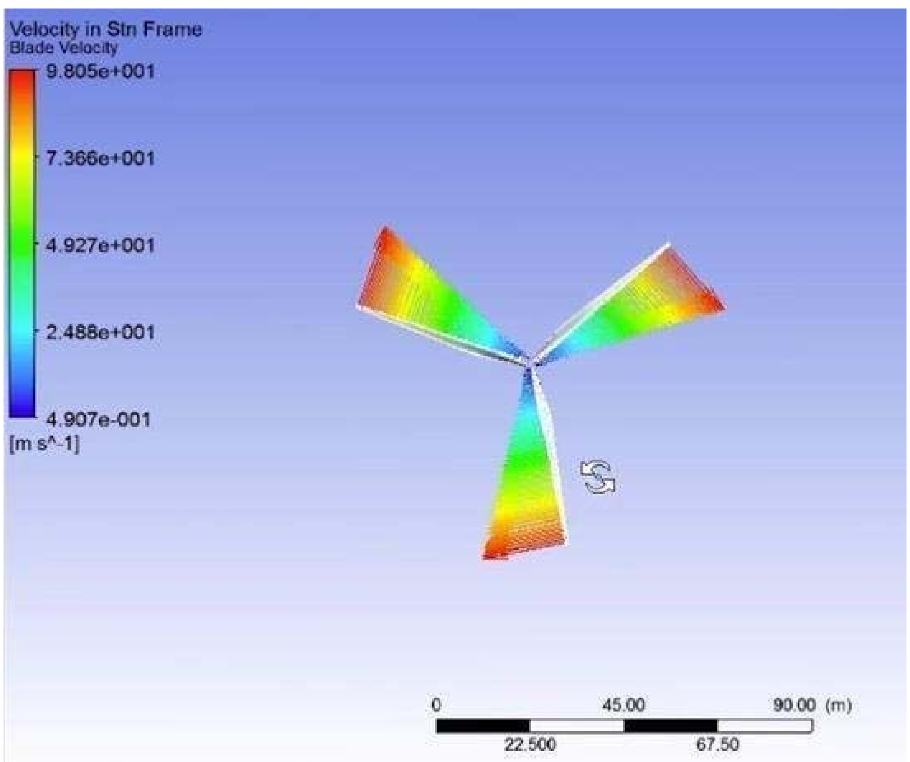
Q train (MTA-NYC) - to scale - SW model



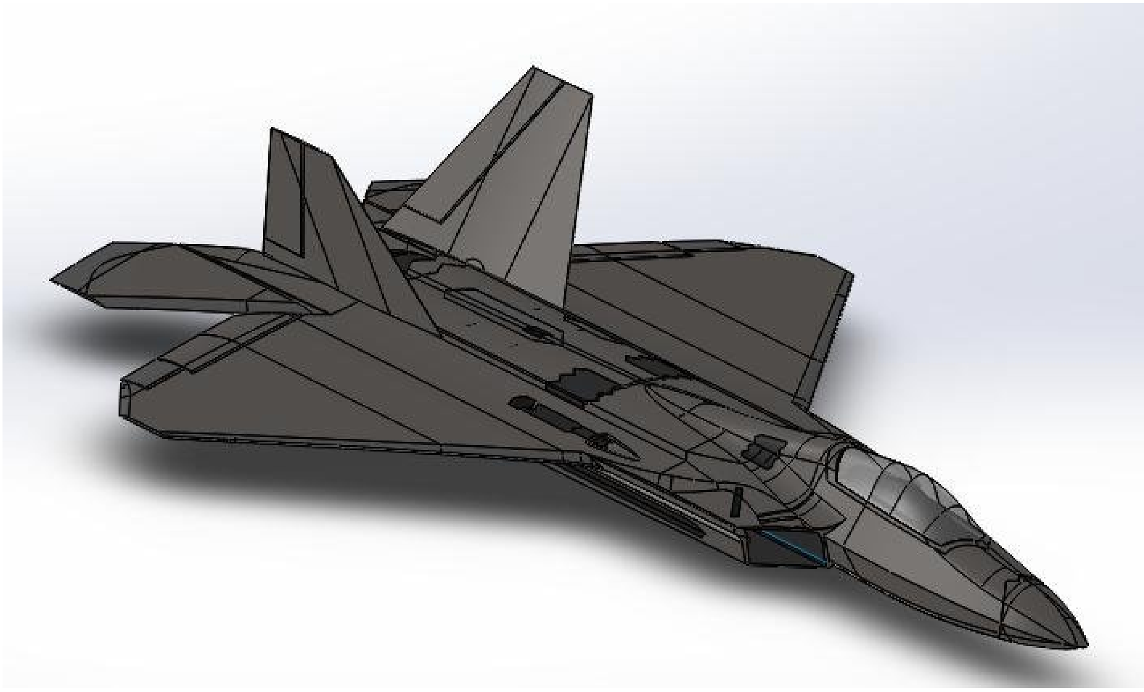
Aerodynamics testing of a quadcopter propeller using SimScale



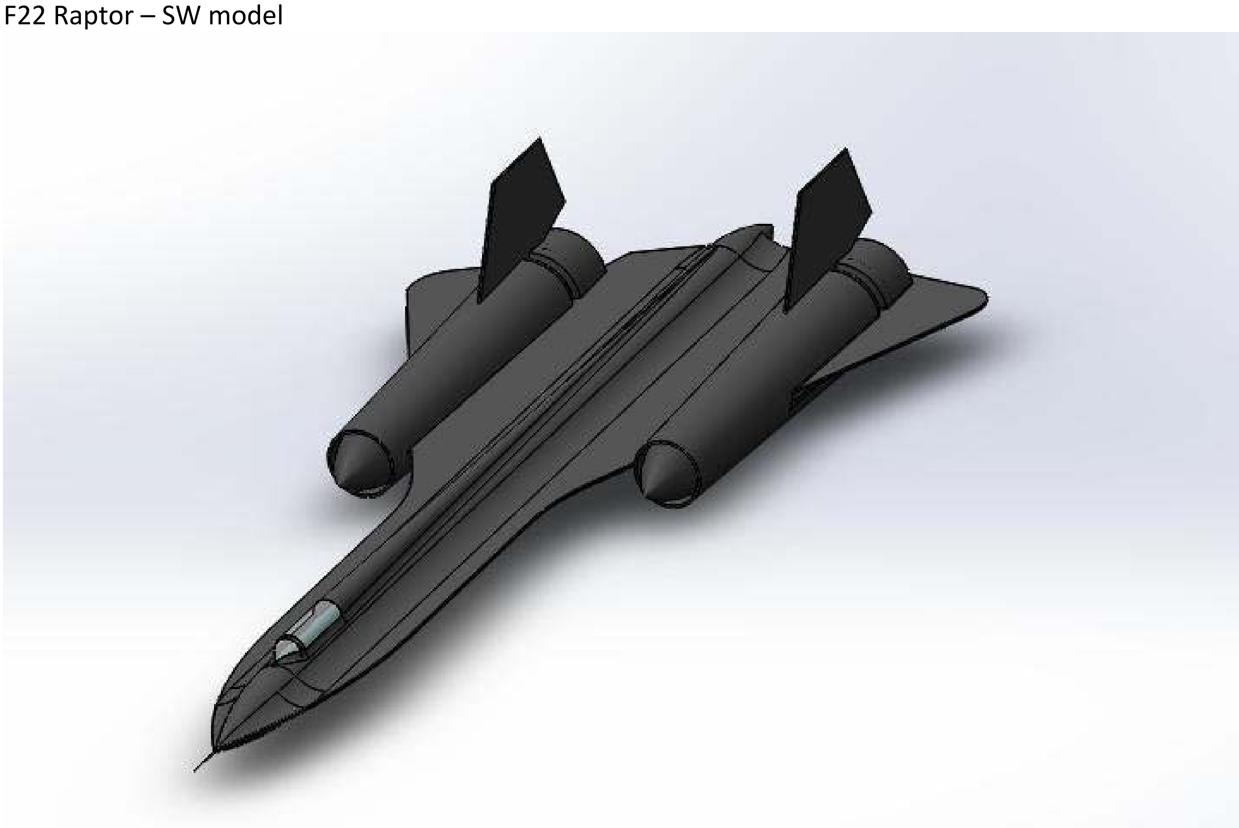
Bike_crank
Consider a crank mounted on a bicycle. When a rider is pedaling the bicycle, she or he is applying a variable force to thisbike crank. To simplify the analysis, we'll neglect the variation of the force with time and focus on the response of thecrank to a static force. This is analogous to taking a video of the bike crank and analyzing a single frame by itself.



turbine_blade
Deformation due to aerodynamic loading of a wind turbine blade by performing a steady-state 1-way FSI (Fluid-Structure Interaction) analysis. Part 1 of the tutorial uses ANSYS Fluent to develop the aerodynamics loading on the blade. In part 2, the pressures on the wetted areas of the blade are passed as pressure loads to ANSYS Mechanical to determine stresses and deformations on the blade



F22 Raptor – SW model



SR71 – SW model

Hobby projects