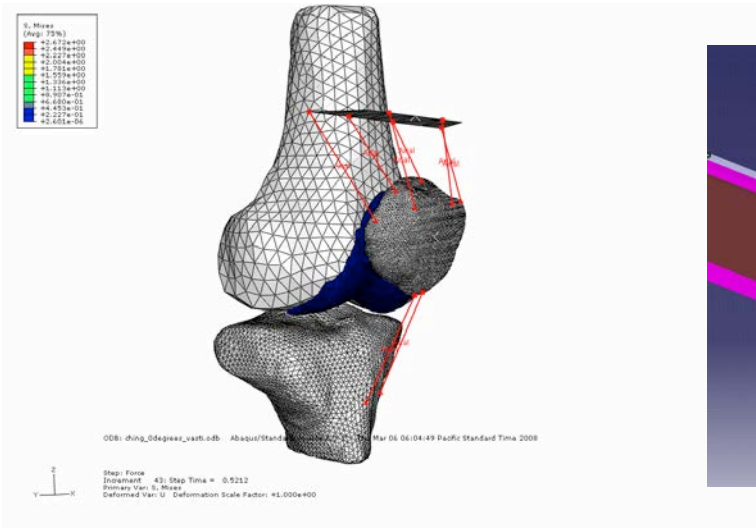
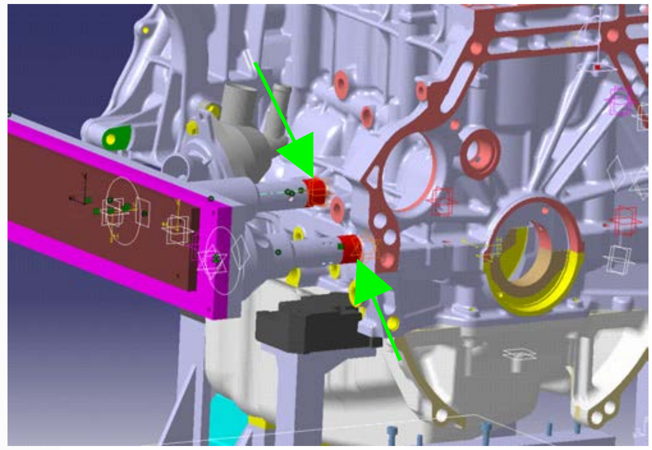
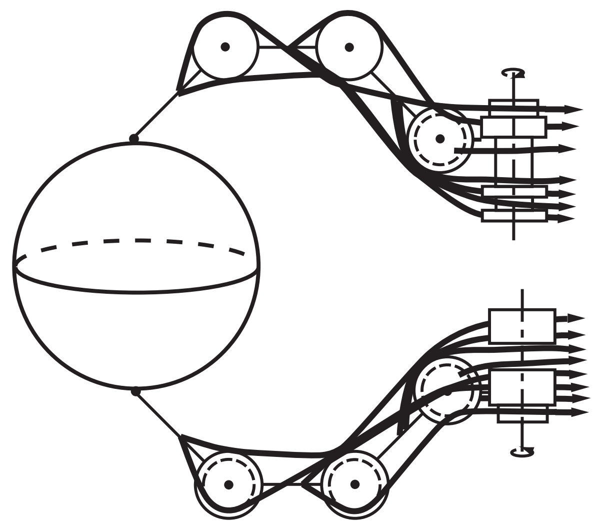
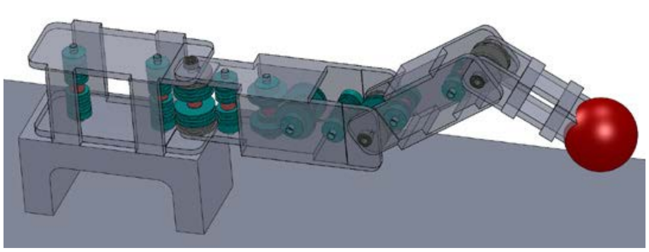
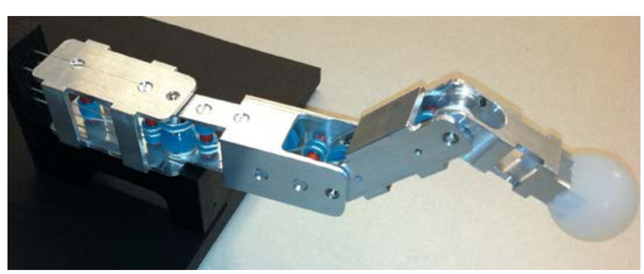



# EXPERIENCE PORTFOLIO

*Josh Inouye*

*Last updated: February 22nd, 2012*

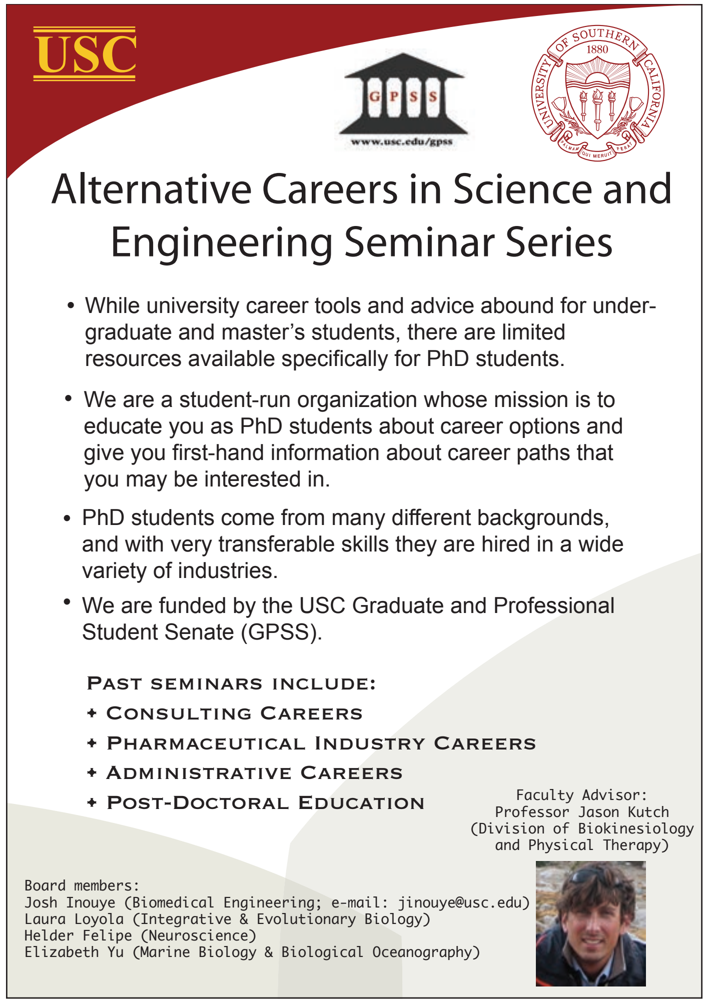
# TABLE OF CONTENTS

# President, USC Alternative Careers in Science and Engineering

*President, 2011-2012 Academic Year*
*Treasurer, 2010-2011 Academic Year*

Responsibilities:

- Recruited academic and industry professionals to be panelists at graduate student seminars on careers with a PhD.
- Recruited other board members.
- Obtained recognition as an official student organization.
- Registered with GPSS (Graduate and Professional Student Senate) to be able to get school funding for events.
- Organized meetings and managed events and correspondence with board members, panelists, student organization office, event caterers, and funding sources.




Past Panelists:

**Consulting Careers:**
- Christine Raasch, Ph.D., Principal at Exponent
- Cyrus Arman, Ph.D., Head of West Coast Operations, Deallus Group

**Administrative Careers:**
- Nelson Bickers, Ph.D., USC Vice Provost for Undergraduate Programs
- Timothy Pinkston, Ph.D., USC Senior Associate Dean of Engineering
- Mark Todd, Ph.D., USC Associate Dean for Graduate Programs

**Post-Doctoral Education**
- Jimmy Bonaiuto, Ph.D., Caltech Biological Sciences post-doc
- Jason Kutch, Ph.D., USC Assistant Professor of Biokinesiology and Physical Therapy
- Malancha Gupta, Ph.D., USC Assistant Professor of Chemical Engineering

# Founder and Head Coach, Greenbrier Middle School MATHCOUNTS Team

*2002-2003 Academic Year*

Here are the kids and I at the regional competition. From L to R: Tiffany Adams, Lindsey Powell, Rachel Ryan, Tabatha Pilgrim, Merry Ellen Dirksen, Michelle Sweic, Hye-Ji Park, Daniel Graybeal, and me.

In 1999, I was the Georgia state champion of the MATHCOUNTS competition (A United States national math competition program for middle school students) while attending a small private school. During my senior year at a large public school (2002), I decided to start the same club at the local public middle school (Greenbrier MS, Evans, GA) for my senior project. It was a very rewarding experience, and the club still exists today. **5 of the middle school students I coached went on to attend Georgia Tech.** A few years ago, Greenbrier Middle School's team won the regional competition and went on to compete at the state level.

Here I give Tiffany and Michelle some practice countdown problems: ones that they try to solve as quickly as possible

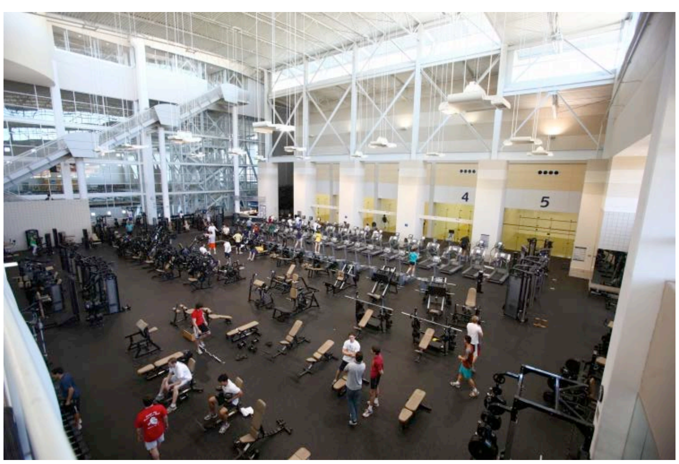
Accomplishments:

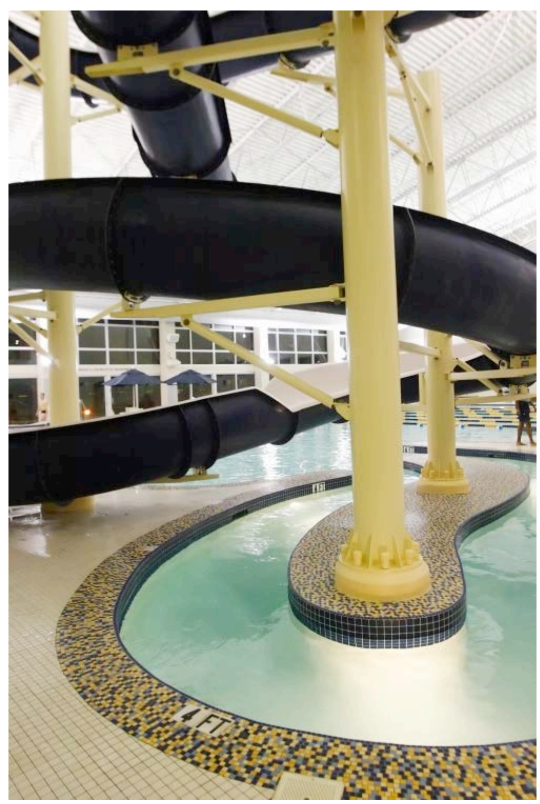
- Obtained official school recognition by finding a teacher to sponsor the club's initiation.
- Led weekly problem set practices.
- Registered and coached team for regional competition.

# Facility Supervisor, Georgia Tech Campus Recreation Center

*Facility Assistant, 2004*
*Facility Supervisor, 2005-2007*
*Manager: Jon Hart*

- Oversaw employees and controlled building activities to ensure safety and maintain a high level of customer satisfaction.
- Analyzed and researched customer complaints/ problems to determine effective resolutions.
- Managed equipment and desk service.





## Board Member, Trojan Investing Society

*2008-2009 Academic Year*

- Wrote articles of interest for the club newsletter and the Bulls & Bears Press.
- Attended board meetings.
- Advertised club activities at the student involvement fair.

TROJAN INVESTING SOCIETY

# Trojan Investing Newsletter

April 7, 2008 Issue 2 - Volume 1

## An Introduction to Call Options

By Joshua Inouye

Think Apple is headed up? If for some reason you are extremely confident that Apple's stock will rise, say, $20 by April 18th, buying a call will most effectively leverage your position—maximizing profits. If you bought stock on March

**Table 1. Option Traders**

| | |
|---|---|
| Purchaser of Contract | Right to buy shares at strike price |
| Sell of Contract (Writer) | Obligation to sell shares at strike price |

PDF (360 KB)


HIGH RISK, HIGH RETURN 7

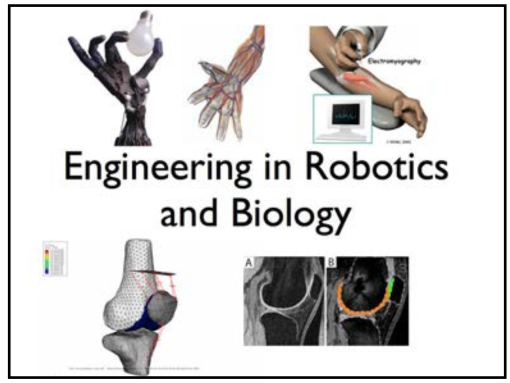
### UNDERSTANDING THE ZERO-SUM GAME *By Joshua Inouye*

The zero-sum game is an extremely important concept that can cause many investors to lose money in the stock market, or at least not produce returns that equal those of the overall market. In stocks, every person that outperforms the market does so because someone else un- lieve that someone else will lose to them in the zero-sum game, the success is probably largely attributable to luck. With enough individuals and fund managers out there, some have to beat the market according to the laws of probability. Consider the classic example of 1,000,000

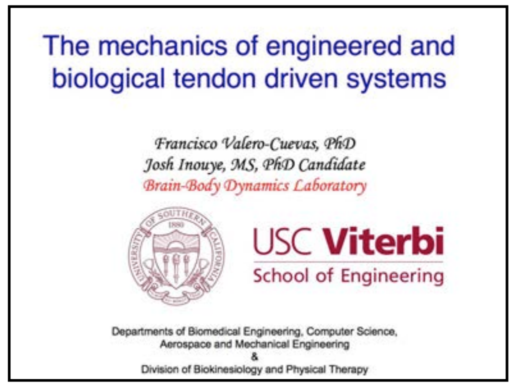
PDF (1.44 MB)

# Invited Presentations

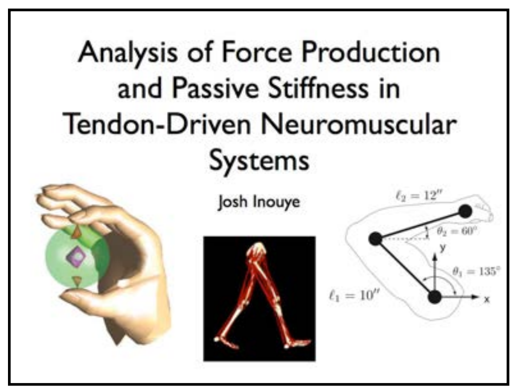
“Engineering in Robotics and Biology”
- USC EE-200 (Foundations of Electrical Engineering Systems)
- Instructor: Professor Keith Chugg
- Los Angeles, CA
- October 5th, 2011



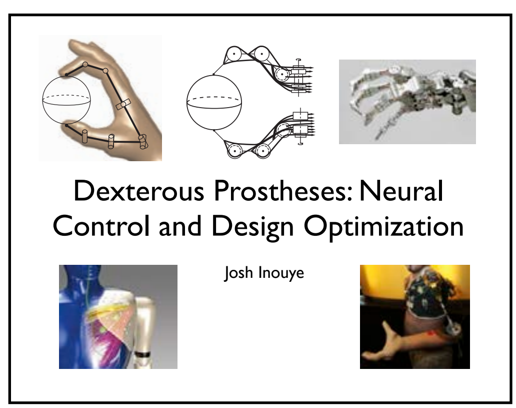

“The Mechanics of Engineered and Biological Tendon-Driven Systems”
- Guest speaker with Francisco Valero-Cuevas
- DLR, German Aerospace Center
- Munich, Germany
- October 20th, 2011




“Analysis of Force Production and Passive Stiffness in Tendon-Driven Neuromuscular Systems”
- USC Division of Biokinesiology and Physical Therapy Seminar Series
- Los Angeles, CA
- October 27th, 2011




“Dexterous Prostheses: Neural Control and Design Optimization”
- USC BME−452 (Introduction to Biomimetic Neural Engineering)
- Instructor: Dr. Tuan Hoang
- Los Angeles, CA
- November 9th, 2011



## Internship: Southern Nuclear Company

*Summer 2004, Plant Votgle, Waynesboro, GA*
*Mechanical Engineering Department*

I completed this internship during the summer after my freshman year in college. A large project that I completed was creating a **network-based search program** for pdf files of past work orders. Before my program was written, the workers had to search through many large notebooks full of hard copies of work orders to obtain information. I scanned all the work orders myself over several days. My search program, which I coded in **HTML, Javascript, and XML,** could be used from any computer in the whole plant to search for and view one or more pdf files remotely.

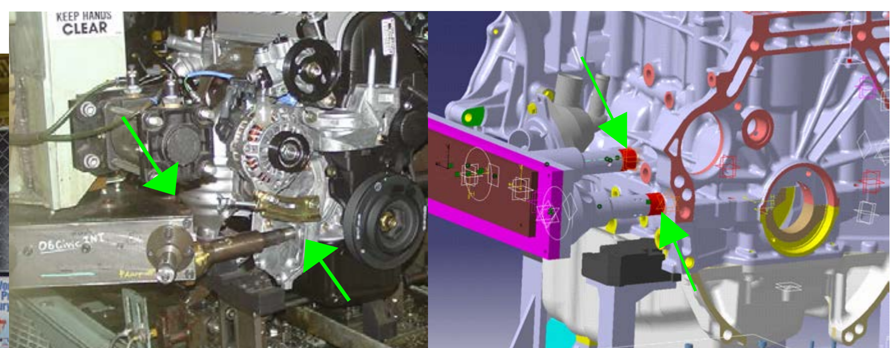
Another small project that I worked on was documenting power line locations in hundreds of images to allow for safe and secure security design change plans.

I also learned the **basics of welding** for a few days at the plant.

## Internship: Honda of America Manufacturing

*Summer 2005, Anna Engine Plant, Marysville, OH*
*Materials Service Department*

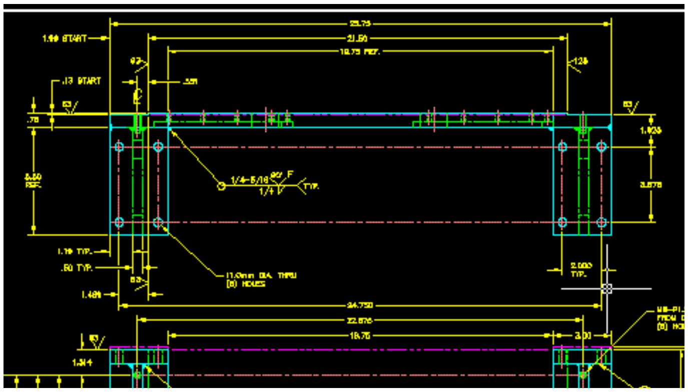
This internship occurred after my sophomore year in college. I learned many **fabrication skills** in the shop and gained a large amount of real-world experience with the **CAD programs** CATIA and AutoCAD.


Engine transfer system

One large project I had was to create CATIA models of the engine transfer system seen above. I made lots of measurements of the real system and then created the models so that new parts could be appropriately designed.

Another large project I had was the fabrication of a large end-stopper for a conveyor belt shown below along with the AutoCAD drawing I created. It involved lots of welding, cutting, and drilling to create this, and it ended up saving lots of space since a large former table could be removed.



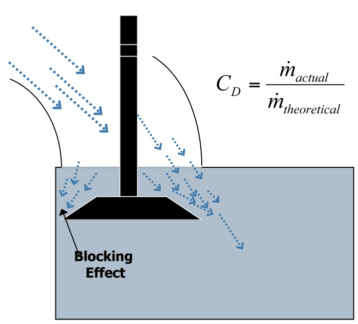
Conveyor belt end-stopper

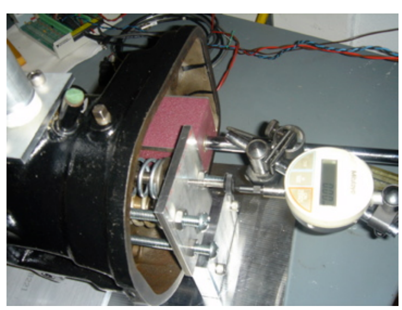
## Internship: Automotive Research

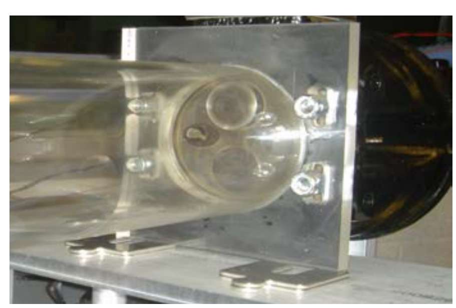
*Summer 2006, Oakland University*
*National Science Foundation Research Experience for Undergraduates*
*Mechanical Engineering Department. Advisors: Profs. Brian Sangeorzan and Laila Guessous*

This research experience first exposed me to the world of **academic research**. I had two group projects over the summer, and I was put in charge of both teams.

The first project involved investigation of the blocking effect observed in intake valve airflow experimentally and theoretically. We estimated the effect theoretically and then designed an experimental setup to measure airflow versus distance from cylinder wall to valve edge.





Project 1: Intake valve air flow experiment.

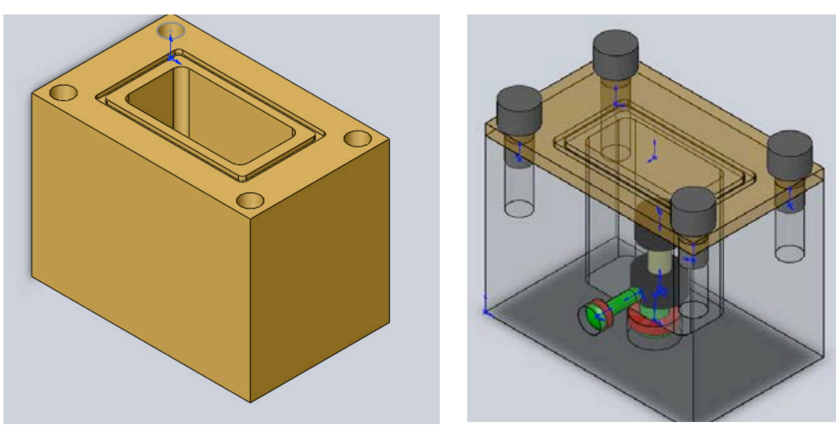
The second project was the design and fabrication of a experimental setup for a high-temperature, pulsating air flow. The goal of this project was to experimentally verify the accuracy of a **computer model** which characterizes the response of a thermocouple to a high temperature, pulsating gas flow, such as that found in an engine exhaust manifold. Knowledge of engine exhaust gas temperatures is important in the design of exhaust manifolds, the prediction of catalytic converter performance, as well as the prediction of under-hood thermal loading.

Project 2: High-temperature, pulsating airflow experiment.

## Internship: Bone Mechanics Research

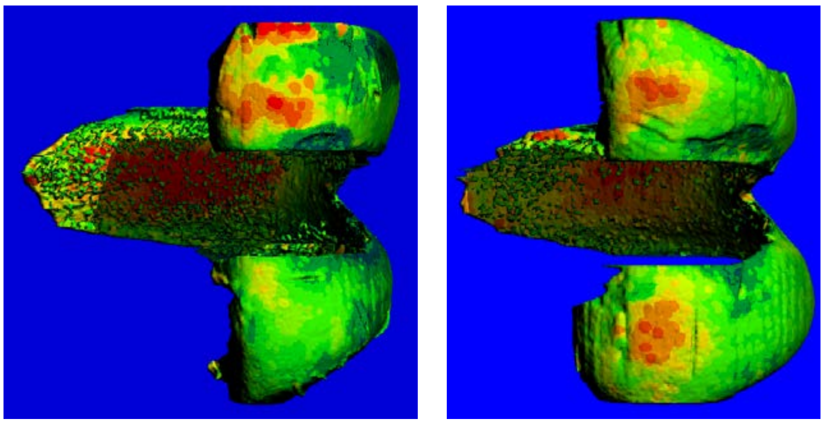
*Summer 2007, Georgia Institute of Technology*
*Musculoskeletal Research Laboratory*
*Mechanical Engineering Department*
*Advisor: Prof. Robert Guldberg and Angela Lin*

Following graduation in May of 2007, I conducted this internship before beginning graduate school. One of my main projects was designing parts (shown below) for mechanical testing of trabecular bone samples in **SolidWorks**.



Project 1: Parts design for mechanical testing of trabecular bone samples.

In my second project, I was first exposed to **imaging and segmentation techniques** while working on micro-CT images rat knee cartilage. These images were to be turned into thickness maps, shown below, for subsequent analysis.

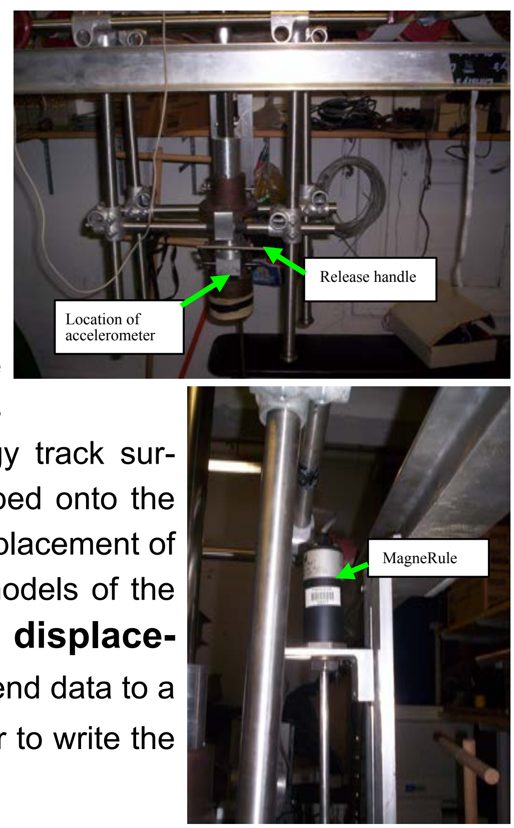


Thickness maps of rat knee cartilage from micro-CT images.

## Impact Tester Project

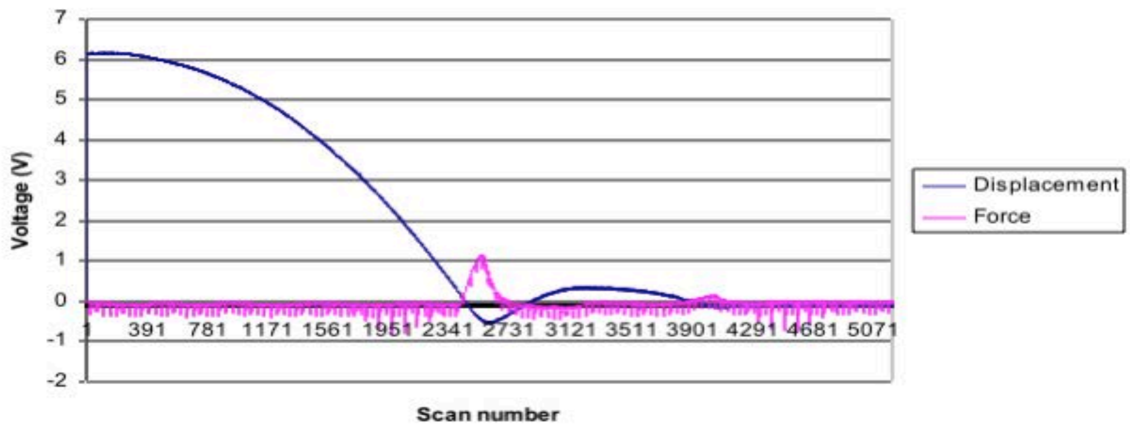
*Fall 2007, University of Southern California*
*Sports Biomechanics Research Laboratory*
*Biomedical Engineering Department*
*PhD Laboratory Rotations*
*Advisor: Professor Jill McNitt-Gray*

For 6 weeks, I worked on instrumenting and preparing an old impact tester for use in studies that looked at the effects of various surfaces on sports-related impacts and movements (i.e., gymnastics landing mats, spongy track surfaces, etc.). It had a heavy weight that would be dropped onto the surface from a height of 3 feet. The acceleration and displacement of the weight was used to create and validate dynamic models of the surface. I had to set up an **accelerometer and a displacement sensor** with a data acquisition box that would send data to a computer via **LabView**. I had to learn LabView in order to write the code to acquire the data from the test impacts.




Impact Tester

The figure below shows the displacement and acceleration data from a test drop of the weight onto a gymnastics mat.

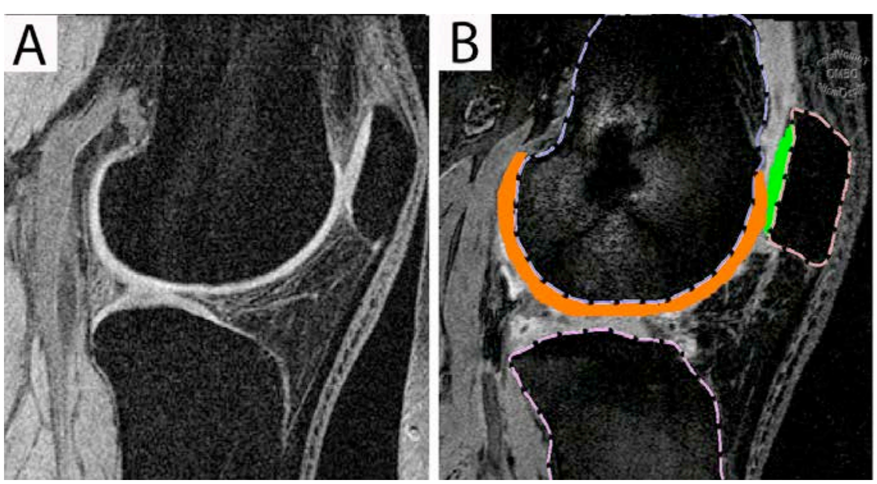



Raw data from impact tester.

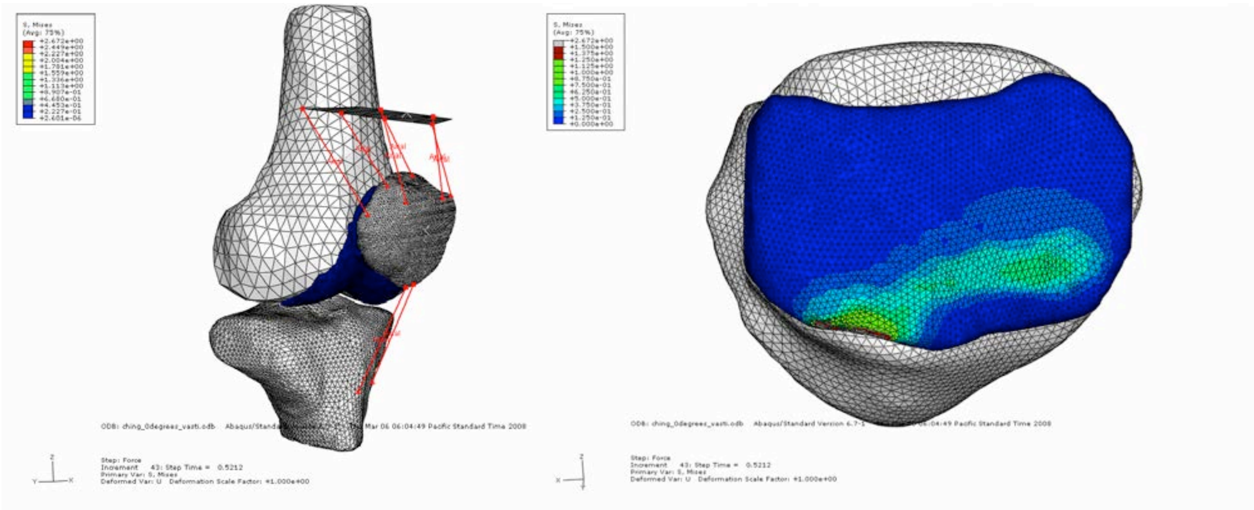
## Finite Element Modeling of the Knee (Symposium Paper)

*Spring 2008, University of Southern California*
*Musculoskeletal Biomechanics Research Laboratory*
*Division of Biokinesiology and Physical Therapy*
*PhD Laboratory Rotations*
*Advisor: Professor Christopher Powers*
*Presented at the 12th Annual Fred S. Grodins Graduate Research Symposium.*

My second lab rotation was 6 weeks creating **finite-element meshes from MRI scan slices**. The meshes were then imported into Abaqus and the stress distributions were analyzed. Development of new treatments for patellofemoral pain was the main purpose of this study.




(A) MRI scan slice. (B) Cartilage and bone segmentation.



Finite element model of knee with stress distribution.

**In-vivo assessment of patellofemoral joint stress using a finite-element analysis approach.**

**Authors:** Josh Inouye, Shawn Farrokhi, Christopher Powers

**Abstract:** Subject-specific finite-element models of the patellofemoral joint are used to quantitatively evaluate the maximal stress and the stress distribution over the surfaces of the patellar and femoral cartilage. High-resolution MRI images with 1.0 mm slice thickness taken with a 3.0-T General Electric (GE Healthcare, Milwaukee, WI) MR scanner were segmented using Sliceomatic software (Tomovision, Montreal, Quebec) to create a 3-D model of the patellofemoral joint. Loaded MRI scans were taken with the subject in a static squat position with the knee joint at angles of 0, 30, and 60 degrees. These scans were also segmented in order to determine the appropriate positions of the knee components for each knee joint angle. The segmented components were the femur, the tibia, the patella, the patellar cartilage, and the femoral cartilage. The bones were modeled as rigid bodies, and the cartilage as linearly elastic material, which has been determined to be appropriate for the loading situation being simulated (a static squat).1 A finite-element mesh was created for each of the components using Hypermesh software (Altair Engineering Inc., Troy, MI) for subsequent use in Abaqus software (SIMULIA, Providence, RI) to determine subject-specific cartilage stresses.

PDF (657 KB)

Poster PDF (460 KB)

## Statistical Consulting

*July 2008*

*Universal Surveillance Systems-USS Corp, Rancho Cucamonga, CA*

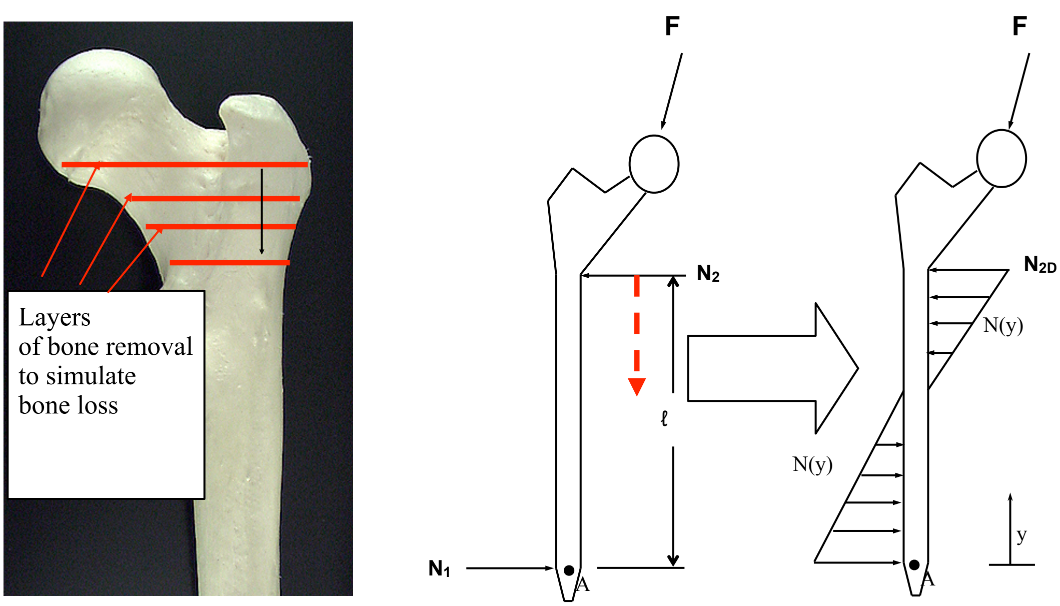
I independently consulted with this company in a tag time and motion study. I collected experimental data from timed trials of security tag use and wrote a **technical white paper** on the **statistical differences** among the various tags. Some of the tags tested are shown below.

Security tags tested in statistical study.

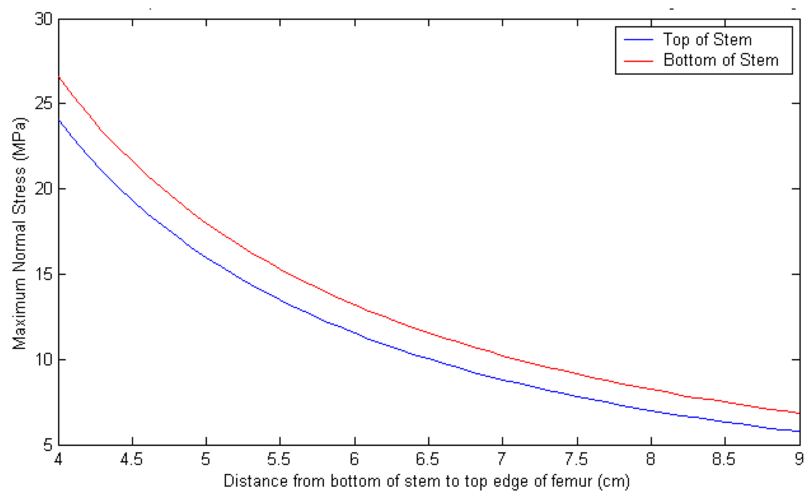
## Hip Implant Analysis (Symposium Paper)

*Spring 2009, University of Southern California*
*Implant Performance Laboratory*
*Orthopaedic Hospital, Los Angeles, CA*
*PhD Laboratory Rotations*
*Advisor: Professor Edward Ebramzadeh*
*Presented at the 13th Annual Fred S. Grodins Graduate Research Symposium.*

My third lab rotation was involved many small projects but the main one was analyzing the amount of bone an osteoporotic patient could lose before a hip implant would fail on them.




Analysis of hip implants subjected to surrounding bone loss.



Maximum stress decreases with increasing amounts of bone present.

**In Vitro Assessment of Allowable Bone Loss for Implantation of a Zweymuller Stem for Total Hip Arthroplasty Revision Surgery**

**Authors:** Josh Inouye, Edward Ebramzadeh, Sophia Sangiorgio

**Abstract:** Total hip arthroplasty patients typically experience some degree of stress shielding and subsequent bone remodeling during the life of the primary femoral stem. If a patient experiences pain, subsidence of the stem, or stem loosening, a revision surgery is necessary. The purpose of this experiment is to determine, by finite-element modeling and in-vitro testing, what amount of bone loss in the proximal femur is permissible for a Zweymuller stem to be achieve stability.

PDF (622 KB)

Poster PDF (291 KB)

## Internship: Rehabilitation Engineering

*Summer 2010*

*Pathokinesiology Laboratory*

*Rancho Los Amigos National Rehabilitation Center, Downey, CA*

*Supervisor: Philip Requejo*

This internship gave me experience at the **interface of engineering and clinical issues**. One of my main projects was to design and fabricate a **load cell array** for instrumenting a car seat. This is part of a setup that is used for determining forces on individuals with spinal cord injuries as they enter and exit the car.


Instrumented car seat.

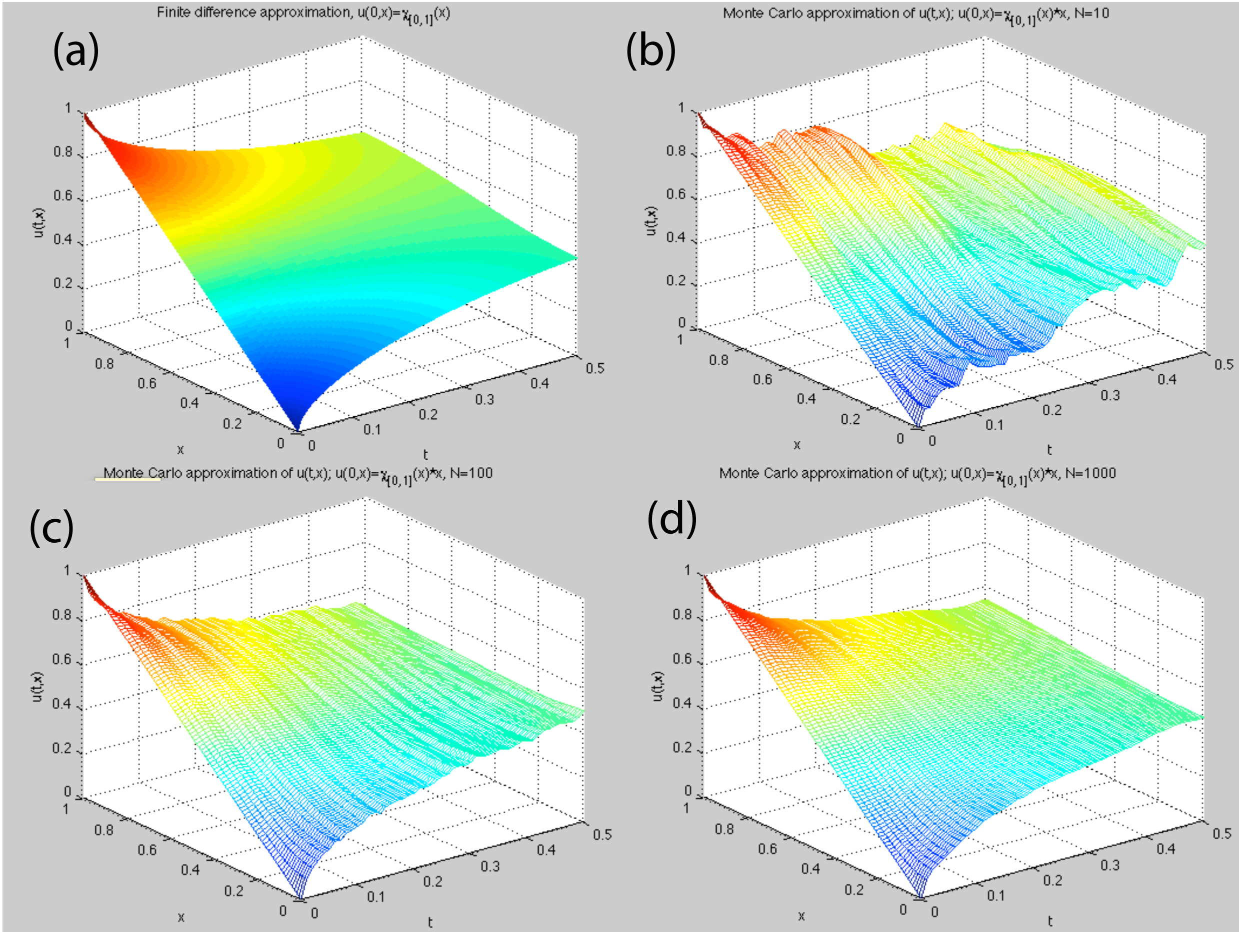
Car seat installed in car for testing.

In addition, I provided assistance in obtaining and analysis of **motion capture data** for wheelchair users. I learned about and used Visual 3D for the analysis.

## Project on Stochastic Differential Equations

*Fall 2010, University of Southern California*
*Independent project, MATH 509 (Stochastic Differential Equations)*
*Instructor: Professor Remigijus Mikulevicius*

As I was taking this course (as an elective), I realized that the concepts that I learned about heat transfer in my mechanical engineering courses at Georgia tech were extremely similar to some that we were learning in this class. A basic **second-order partial differential equation** (PDE) looked almost identical to the heat diffusion equation used in heat transfer by conduction. Furthermore, we learned that we could approximate second-order PDEs by averaging **Monte Carlo realizations of Brownian motion** in a simple stochastic differential equation (SDE). With the guidance of Professor Mikulevicius, I made the connection between the two and verified that my heat transfer principles would correlate exactly with what was learned in this class. The finite difference approximation to the heat diffusion equation and the increasing accuracy of the Monte Carlo approximations with more realizations is evident from the figure below.




(a) Finite difference approximation to heat diffusion equation. (b) Monte Carlo approximation of heat diffusion equation with SDEs. N=10. (c) Monte Carlo, N=100. (d) Monte Carlo, N=1000.

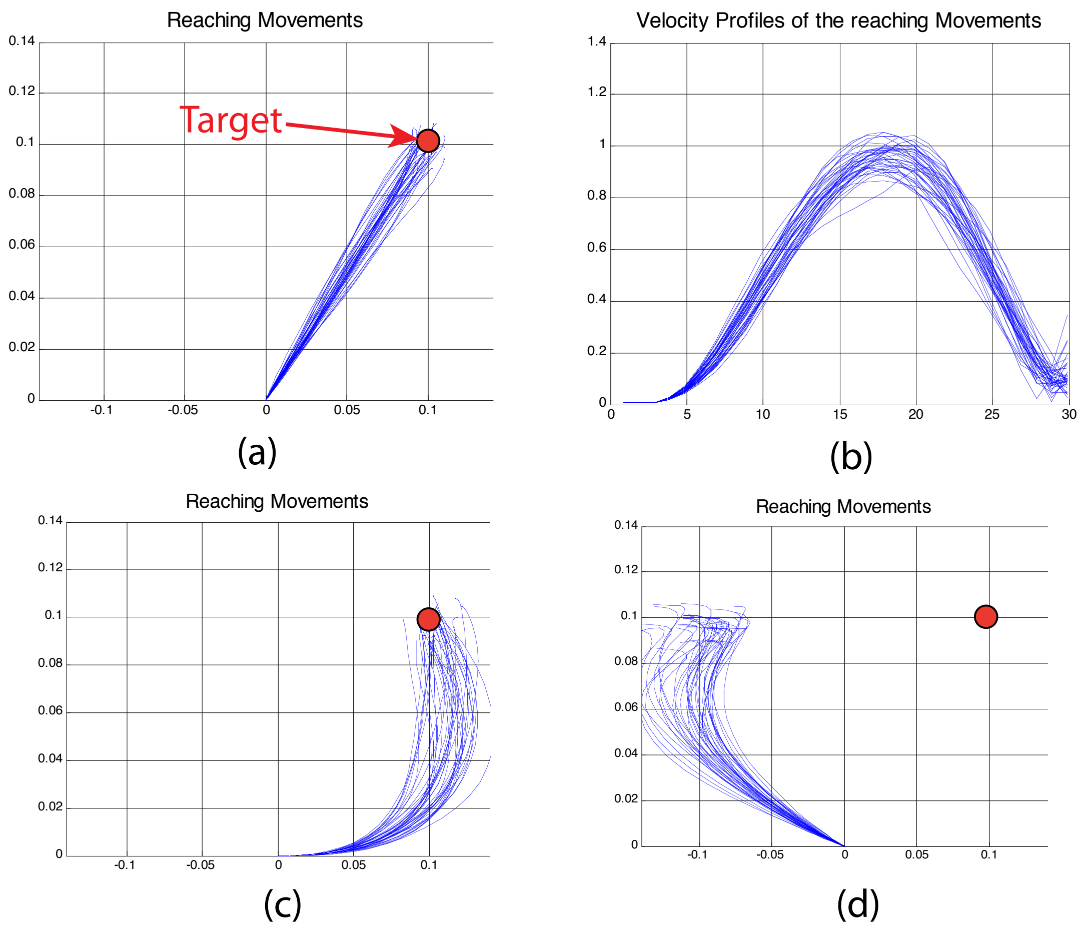
## Project on Stochastic Optimal Control

*Fall 2010, University of Southern California*

*Class project, BME 599 (Neuromuscular Systems)*

*Instructor: Professor Francisco Valero-Cuevas*

This project involved modeling humans' arms as they reached out for an object in front of them. The problem was to formulate a linear quadratic regulator (LQR) and also a **linear quadratic gaussian regulator** (LQG) for different conditions of reaching movements such as force-fields and velocity-fields under a finite time horizon. Different controllers were shown to be optimal for different conditions, and the optimality disappeared when conditions changed. Examples are shown in the figure below.

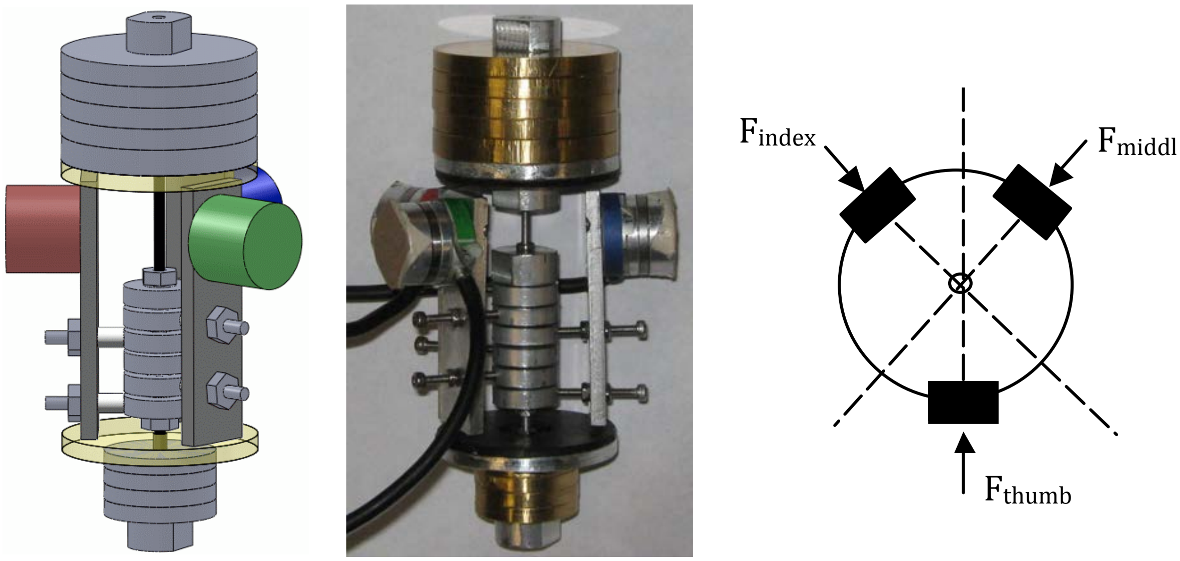



(a) Optimal reaching paths under normal conditions. (b) Velocity profiles of optimal reaching paths. (c) Optimal reaching paths under a force field. (d) Non-optimal reaching paths under normal conditions.

# Unstable Grasp Mechanics Device (Symposium and Conference Papers)

*Spring 2010, University of Southern California*
*Brain-Body Dynamics Laboratory*
*Advisor: Professor Francisco Valero-Cuevas*
*Presented at the 14th Annual Fred S. Grodins Graduate Research Symposium (Best poster award) and ASME 2010 Summer Bioengineering Conference*

This is a device that I **designed and fabricated** for studying unstable grasp mechanics and the neural control of fingers during grasp.




SolidWorks model, actual device, and schematic
diagram of required finger actions for grasp.

### Design and Fabrication of a Device for Studying Unstable Grasp Mechanics

**Symposium:** Proceedings of the 14th Annual Fred S. Grodins Graduate Research Symposium. Los Angeles, CA, 2010.

**Authors:** Josh Inouye, Cornelius Raths, Francisco Valero-Cuevas

**Abstract:** Fingertip forces during static grasp exhibit rich stochastic dynamics. Here we present a device that was designed and fabricated in order to extend dynamical studies of grasp and uncover underlying neuromuscular mechanisms. Previous experiments have used a device that locks three force sensors (one each for the thumb, index, and middle fingers) into a fixed position and a weight is attached to the bottom of the device. The new device can also be locked, but can additionally be released so that the sensors are free to pivot about the center. This device enables studies that involve perturbation of an inherently unstable static grasp.

PDF (202 KB)

Poster PDF (317 KB)

### The Spatio-Temporal Structure of Force Variability in Static Grasp Suggests a Continually Active Neural Controller

**Conference:** Proceedings of the ASME 2010 Summer Bioengineering Conference. Naples, FL.

**Authors:** Kornelius Racz, Josh Inouye, Francisco Valero-Cuevas

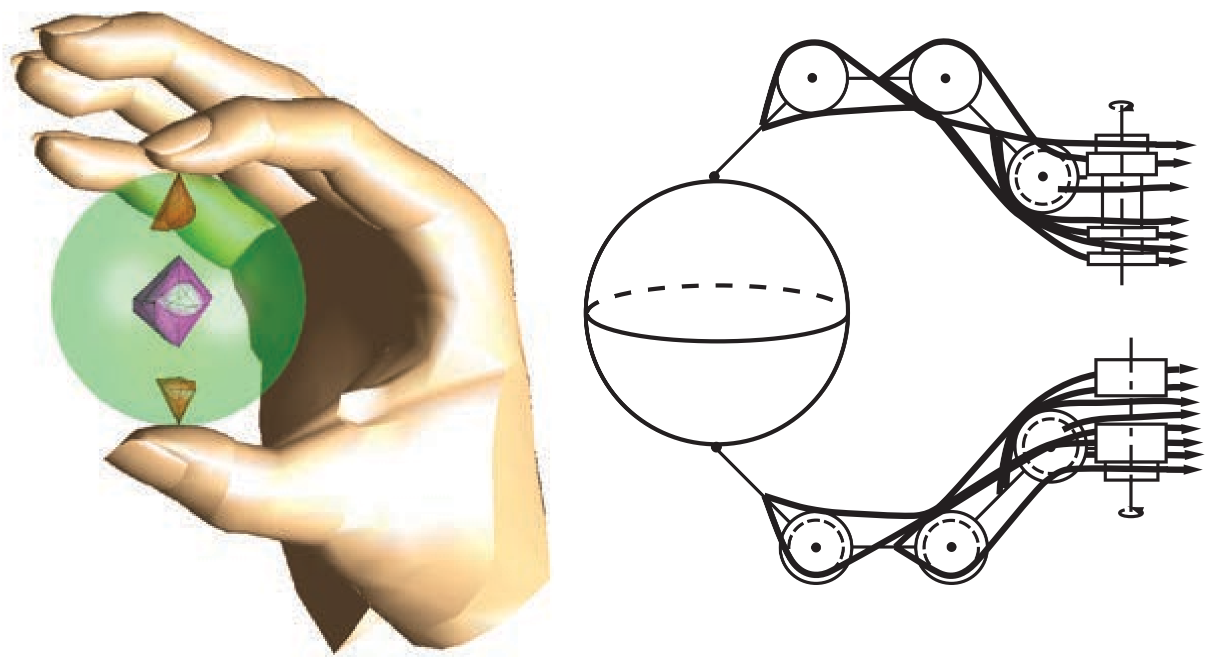
**Abstract:** Fingertip forces during static grasp exhibit rich stochastic dynamics. Here we present a device that was designed and fabricated in order to extend dynamical studies of grasp and uncover underlying neuromuscular mechanisms. Previous experiments have used a device that locks three force sensors (one each for the thumb, index, and middle fingers) into a fixed position and a weight is attached to the bottom of the device. The new device can also be locked, but can additionally be released so that the

sensors are free to pivot about the center. This device enables studies that involve perturbation of an inherently unstable static grasp.

PDF (196 KB)

## Computational Grasp Analysis (Journal, Conference, and Symposium Papers)

*2010-2011, University of Southern California*
*Brain-Body Dynamics Laboratory*
*Advisor: Professor Francisco Valero-Cuevas*
*Various publication venues*



Human and robotic grasp.

A large part of my dissertation research is concerned with computational modeling of human and robotic grasping abilities.

### A Comprehensive Computational Framework to Evaluate Grasp Quality of Tendon-Driven Hands with Arbitrary Topology

**Conference:** Proceedings of the 21st Annual Meeting of the Society for the Neural Control of Movement, San Juan, Puerto Rico, 2011.
**Authors:** Josh Inouye, Cornelius Raths, Francisco Valero-Cuevas
**Abstract:** Fingertip forces during static grasp exhibit rich stochastic dynamics. Here we present a device that was designed and fabricated in order to extend dynamical studies of grasp and uncover underlying neuromuscular mechanisms. Previous experiments have used a device that locks three force sensors (one each for the thumb, index, and middle fingers) into a fixed position and a weight is attached to the bottom of the device. The new device can also be locked, but can additionally be released so that the

sensors are free to pivot about the center. This device enables studies that involve perturbation of an inherently unstable static grasp.

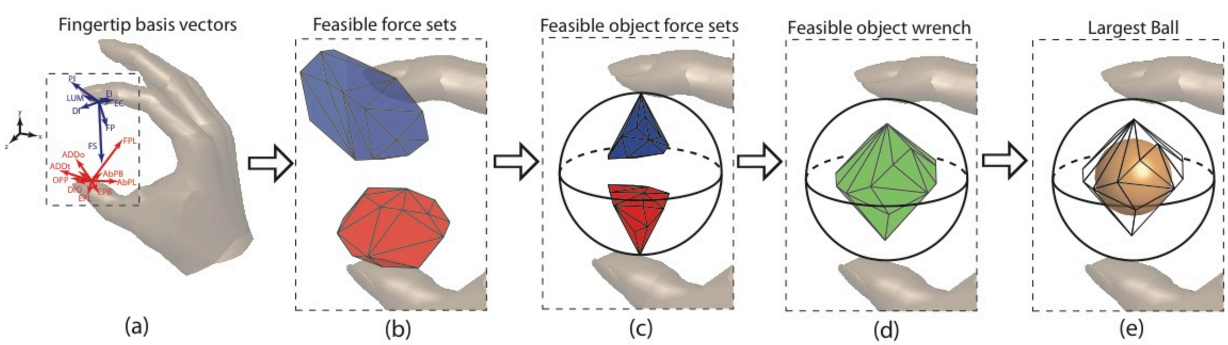
Poster PDF (922 KB)

## A novel methodology to compare grasp quality: application to two dominant tendon−driven designs

**Conference:** Proceedings of the 35th Annual Meeting of the American Society of Biomechanics, Long Beach, CA. August 13th, 2011.
**Authors:** Josh Inouye, Jason Kutch, Francisco Valero-Cuevas
**Abstract:** The design of biologically-inspired tendon-driven systems for grasping and manipulation is a longstanding problem. Some advantages of tendon-driven over torque-driven systems include light weight, small size, high speed, remote actuation, and significant design flexibility in setting moment arms and maximal tendon tensions. This allows optimization of system output capabilities for a particular task. Previous research on grasp quality for tendon- driven hands has computed a grasp quality metric based on a very specific, pre-defined task wrench space. However, they note that their methodology, which utilizes a linear programming approach, does not generalize to the full set of feasible grasp wrenches. Here we demonstrate a comprehensive technique for computing the full set of feasible grasp wrenches for any arbitrary tendon-driven finger topology and grasp configuration, allowing the calculation of global grasp quality metrics. To the best of our knowledge, this is the first time that the complete exploration of grasp capabilities is possible for arbitrary tendon-driven hand designs. We present this complete analysis for two- and three-finger grasps performed by 3D fingers, each with four kinematic degrees of freedom (DOFs, one ad-abduction and three flexion-extension joints), with two different tendon routing.

PDF (397 KB)

Poster PDF (585 KB)




Procedure for calculating human grasp quality following onset of peripheral neuropathies.

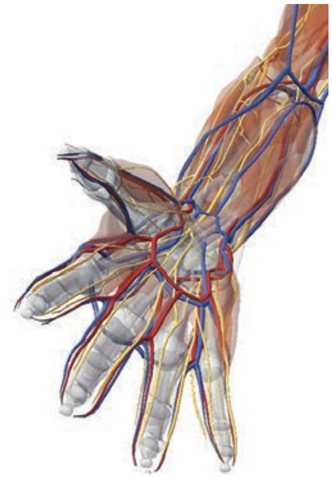
## Quantitative prediction of grasp impairment following peripheral neuropathies of the hand.

**Conference:** Proceedings of the 35th Annual Meeting of the American Society of Biomechanics, Long Beach, CA. August 13th, 2011.
**Authors:** Josh Inouye, Jason Kutch, Francisco Valero-Cuevas
**Abstract:** Grasping is a fundamental hand function that is impaired or eliminated following peripheral neuropathies of the hand. Using a novel computational framework for calculating grasp quality of tendon-driven hands, we predicted grasp quality for various degrees of simulated peripheral neuropathies: (i)

carpal tunnel syndrome, (ii) low median nerve palsy, (iii) low ulnar nerve palsy, and (iv) low radial nerve palsy.

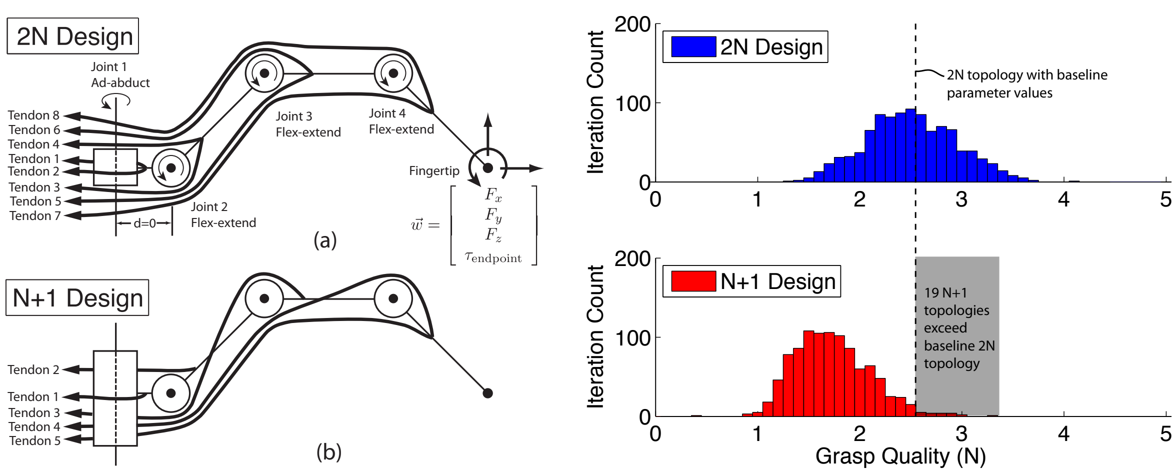
PDF (343 KB)

Poster PDF (652 KB)



## A Novel Synthesis of Computational Approaches Enables Task-Independent Optimization of Grasp Quality of Tendon-Driven Hands

**Journal:** IEEE Transactions on Robotics. Accepted February 2012.
**Authors:** Josh Inouye, Jason Kutch, and Francisco Valero-Cuevas
**Abstract:** We propose a complete methodology to find the full set of feasible grasp wrenches and the corresponding wrench-direction-independent grasp quality for a tendon-driven hand with arbitrary design parameters. Monte Carlo simulations on two representative designs combined with multiple linear regression identified the parameters with the greatest potential to increase this grasp metric. This synthesis of computational approaches now enables the systematic design, evaluation and optimization of tendon-driven hands.




Grasp quality for two tendon routings.

# Mechanics of Tendon-Driven Systems (Book Chapter)

*Spring 2011, University of Southern California*

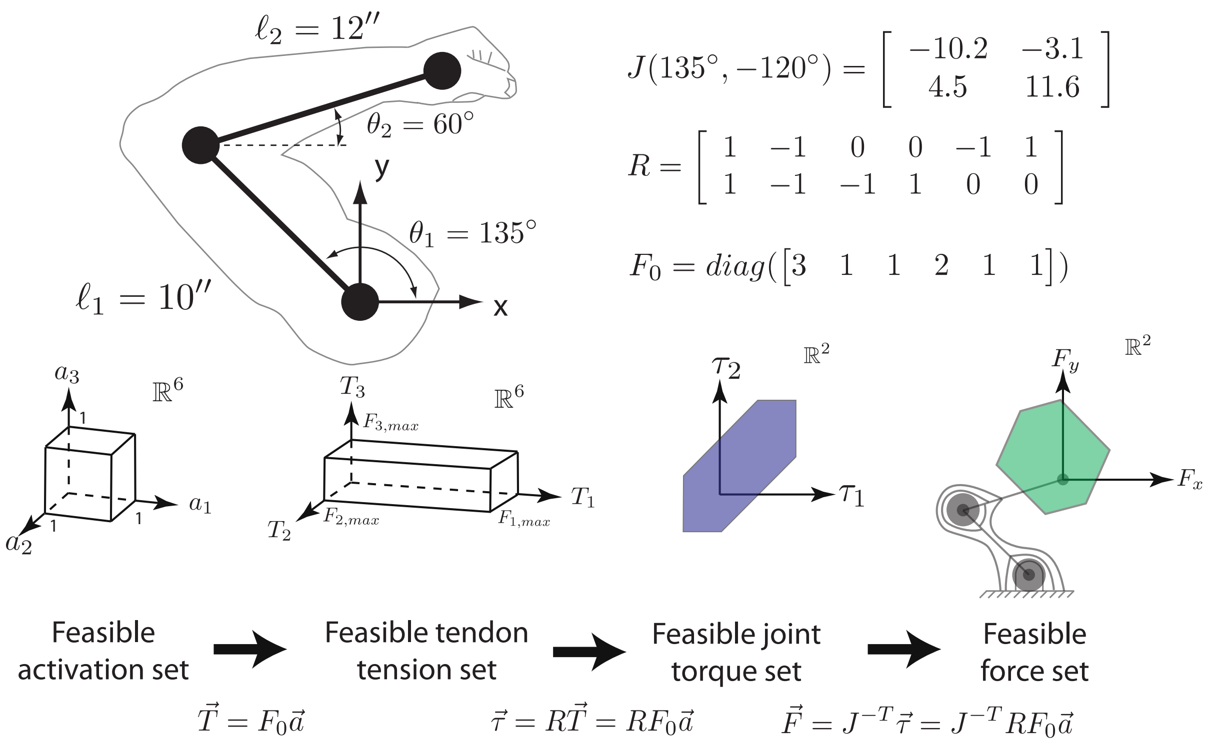
*Brain-Body Dynamics Laboratory*

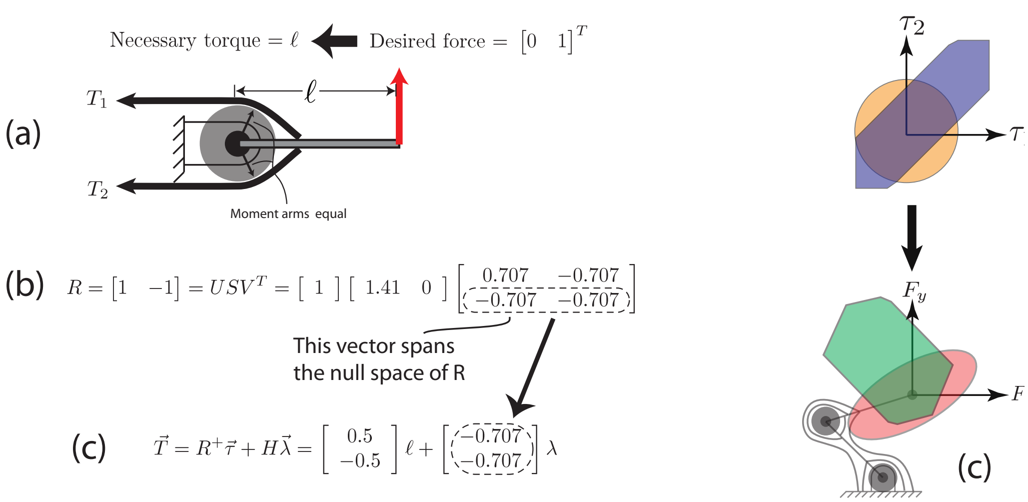
*Advisor: Professor Francisco Valero-Cuevas*

**Citation:**

Valero−Cuevas FJ, Inouye JM, Kutch JJ, Theodorou EA**. "Mechanics of Tendon−Driven Systems: Consequences to the neuromuscular control of limbs and the design of robotic systems." In *The Human Hand: A Source of Inspiration for Robotic Hands*. Springer Tracts in Advanced Robotics. In Review.

**All authors contributed equally to this work.



# Cartesian Stiffness Control (Conference Paper)

*Fall 2011, University of Southern California*

*Brain-Body Dynamics Laboratory*

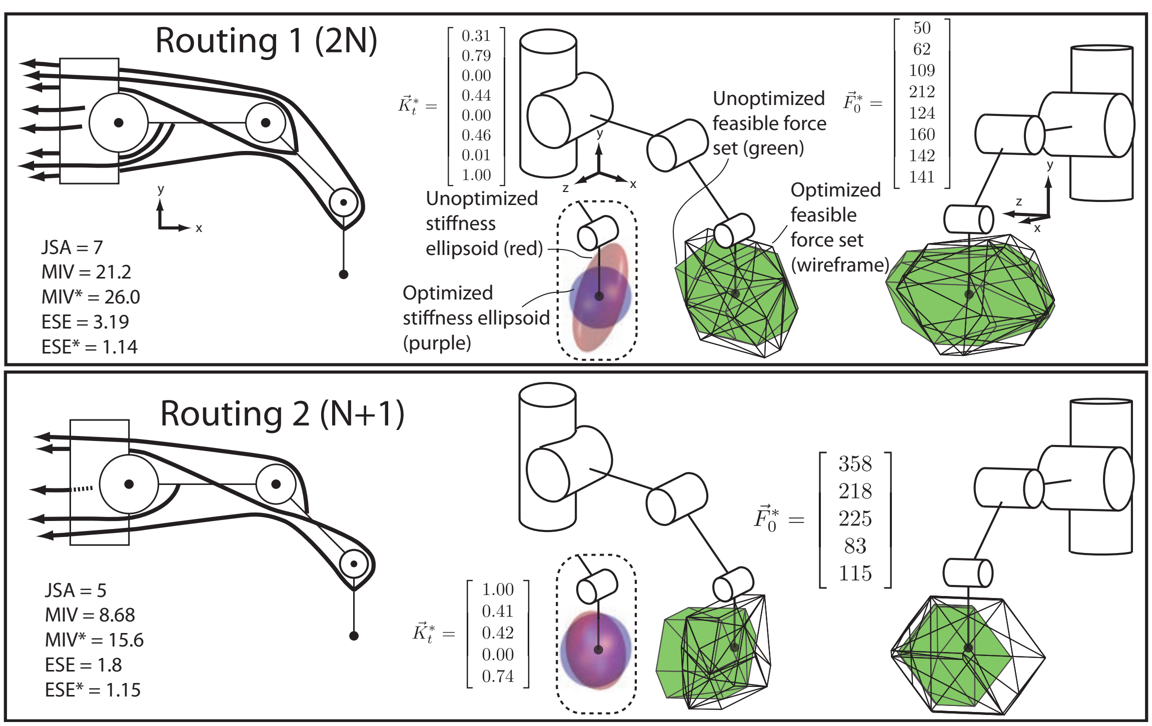
*Advisor: Professor Francisco Valero-Cuevas*

### Asymmetric Routings With Fewer Tendons Can Offer Both Flexible Endpoint Stiffness Control and High Force−Production Capabilities in Robotic Fingers

**Conference:** 2012 IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics. Special section on bio-inspired design and control of robot hands. Submitted January 2012.

**Authors:** Josh Inouye and Francisco Valero-Cuevas

**Abstract:** The force-production and passive stiffness capabilities of fingers are two critical design specifications for dexterous robotic hands. We used the link and joint kinematic parameters of the 4-DOF DLR index finger to explore the tradeoff between these two design specifications as a function of the number, routing, stiffness, and strength of each tendon. Our innovative computational approach allowed building the Pareto front of optimized passive endpoint stiffness (measured by the eccentricity of the endpoint stiffness ellipsoids) vs. maximal force-production capabilities (measured by the size and shape of the force polytope) for 1,200 randomly generated valid designs with 5, 6, 7, or 8 tendons. Our results show that this parametric optimization can increase realizable isotropic forces by up to 80% compared to the default tendon tension distribution. In addition, designs with 5 or 6 tendons can have endpoint stiffness ellipsoids with optimized low eccentricities and with force production capabilities comparable to designs with 7 or 8 tendons. Interestingly, we did not find a systematic tradeoff between force-production and passive stiffness capabilities. However, the choice of number, routing and strength of each tendon greatly affects force and passive stiffness capabilities of robotic finger, which opens up many design opportunities.



# Robotic Finger Construction and Experimentation (Journal Paper)

*Fall 2011, University of Southern California*

*Brain-Body Dynamics Laboratory*

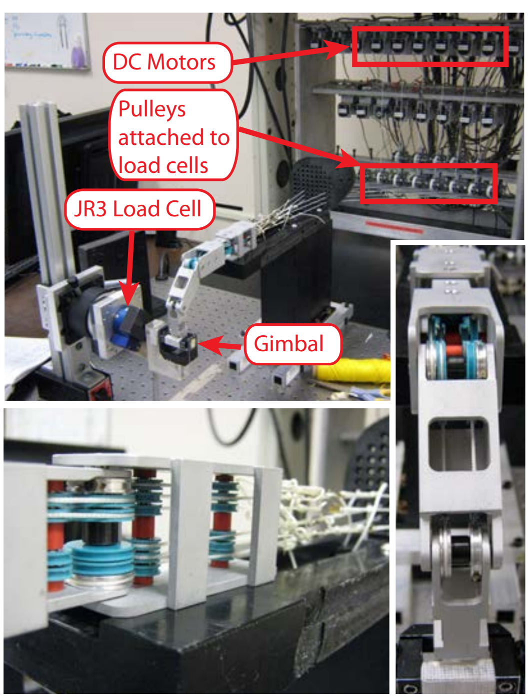
*Advisor: Professor Francisco Valero-Cuevas*

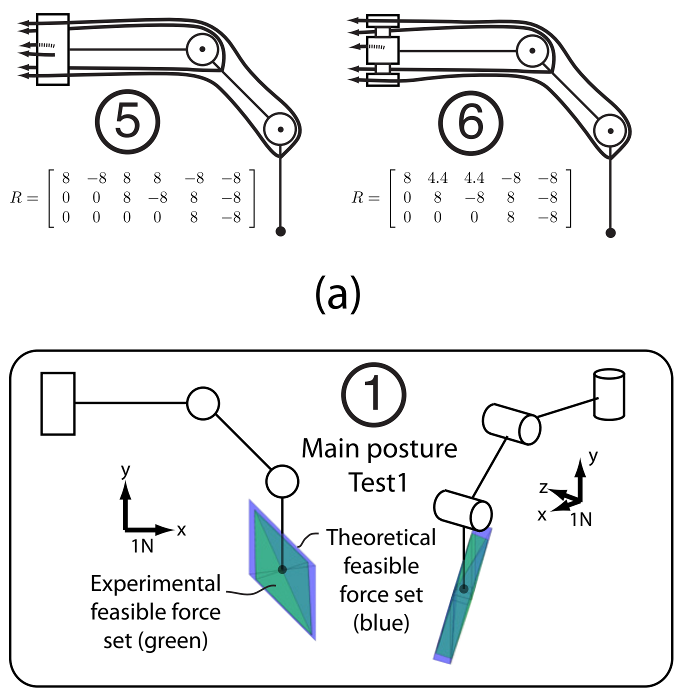
### Optimization of Tendon Topology for Robotic Fingers: Prediction and Implementation

**Journal:** IEEE/ASME Transactions on Mechatronics. Focused section on bio-inspired mechatronics. In revision. Submitted October 2011.

**Authors:** Josh Inouye, Jason Kutch, Francisco Valero-Cuevas

**Abstract:** Force-production capabilities are a very important aspect in the design of robotic fingers, and in this study we systematically analyze and optimize the tendon routing of a robotic finger for this purpose. We constructed a reconfigurable tendon-driven finger that provided a testbed to see whether theoretical and computational predictions would serve as an effective design tool. This fusion of computational optimization and experimental validation has not been done before, to the best of our knowledge. Our experimental results from 6 implemented tendon routings show that theoretical calculations are effective in predicting the size and shape of the feasible force set of physically-constructed fingers, and that small changes in tendon routing can have large effects on performance. Furthermore, we show that routings with fewer tendons can exceed the performance of some routings with more tendons, which can enable simplification of an actuation system and of finger construction.



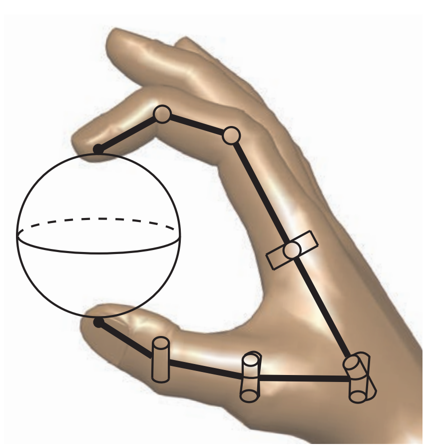



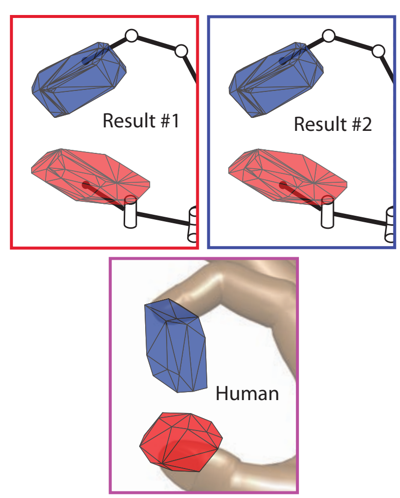
# Comparison of Human and Robotic Hands (Journal and Conference Papers)

*Fall 2011, University of Southern California*
*Brain-Body Dynamics Laboratory*
*Advisor: Professor Francisco Valero-Cuevas*

### Bettering the Human Hand: Anthropomorphic Tendon-Driven Robotic Hands can Exceed Human Grasping Capabilities

**Target Journal:** Proceedings of the National Academy of Sciences (PNAS). Full initial draft completed.
**Conference:** Submitted to the 17th Biannual Meeting of the Canadian Society of Biomechanics. Vancouver, BC, 2012.
**Authors:** Josh Inouye and Francisco Valero-Cuevas
**Abstract:** There is great debate about how effectively the human hand is able to grasp and manipulate objects and whether it is optimized in any sense. Here we compare the grasping capabilities of the physiological human hand and thousands of tendon-driven anthropomorphic hand designs. The anthropomorphic hands are given constraints that allow for fair comparisons to the human hand (friction coefficients, maximal moment arms, and maximal tendon tensions). The layout of the anthropomorphic hand and the D-H parameters of each finger (a 4-DOF index finger and a 5-DOF thumb) are set to those of the commercially available Shadow Hand. We use a previously-developed computational technique to assess the grasp quality of each anthropomorphic hand design. We initially tested designs that had randomly-generated, admissible structure matrices along with equal moment arms and maximal tendon tensions. Next, we used an optimization scheme that employed crossover operations (similar to those used in genetic algorithms) and greedy Markov-Chain Monte Carlo optimization. We find that none of the randomly-generated designs are able to exceed the grasp quality of a human hand and the best one has a grasp quality 45% below that of the human hand, with a mean grasp quality 78% below the human hand. However, optimization of the joint centers of rotation and the distribution of maximal tendon tensions produces hands with grasp qualities that exceed the human hand by 13-45%. In addition, one optimized design was able to outperform a naive 2N design by 501%. This huge difference implies that grasping performance of dexterous prosthetic or anthropomorphic hands can be vastly improved by altering some of the numerous parameters. In addition, we conclude that the human hand is optimized for grasping, at least to an extent, when considering that it vastly outperforms randomly-generated designs.



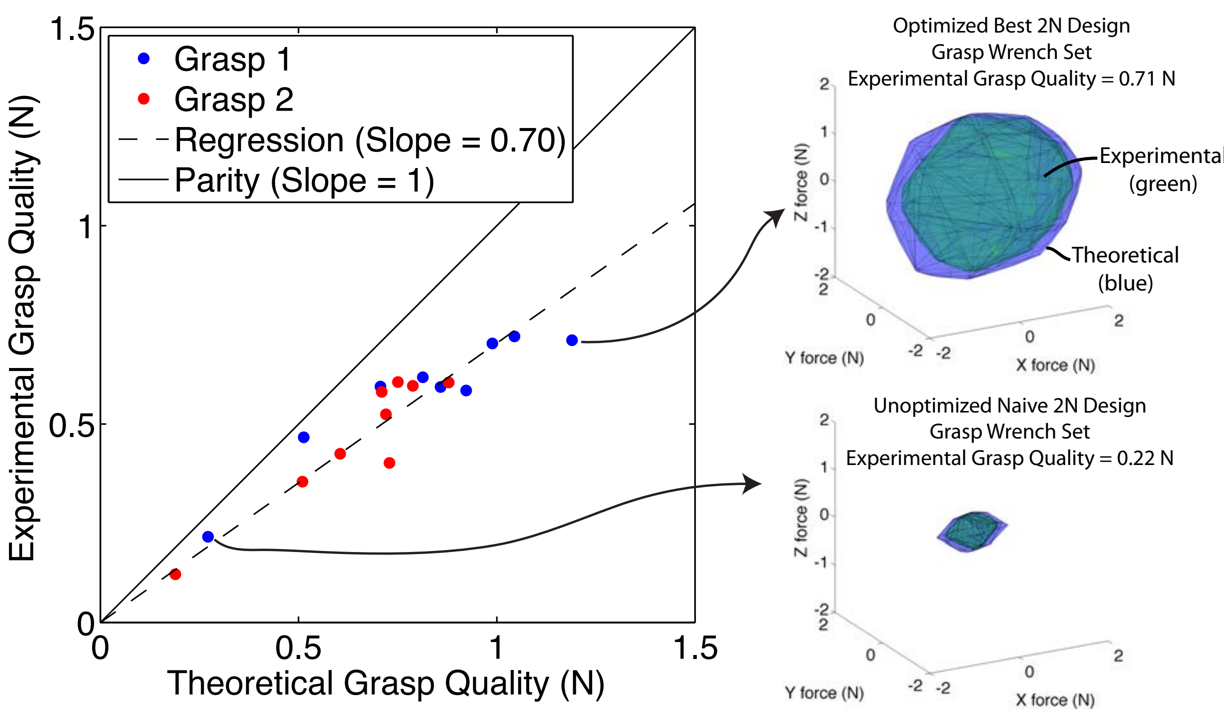


# Robotic Hand Construction and Experimentation (Journal Paper)

*Fall 2011, University of Southern California*
*Brain-Body Dynamics Laboratory*
*Advisor: Professor Francisco Valero-Cuevas*

### Computational Optimization and Experimental Evaluation of Grasp Quality for Tendon-Driven Hands Under Constraints

**Target Journal:** ASME Journal of Mechanical Design. Full initial draft completed.
**Authors:** Josh Inouye and Francisco Valero-Cuevas
**Abstract:** The chief tasks of robotic and prosthetic hands are grasping and manipulating objects, and size and weight constraints are very influential in their design. In this study we use computational modeling to both predict and optimize the grasp quality of a reconfigurable, tendon-driven hand. Our computational results show that grasp quality, measured by the radius of the largest ball in wrench space, could be improved up to 259% by simply making some pulleys smaller and re- distributing the maximal tensions of the tendons. We experimentally evaluated several optimized and unoptimized de- signs, which had either 4, 5, or 6 tendons, and found that the theoretical calculations are effective at predicting grasp quality, with an average friction loss in this system of around 30%. We conclude that this optimization can be a very useful design tool, and that using biologically-inspired asymmetry and parameter variability can be used to maximize performance.



# Computational Modeling of Biomechanical Stiffness Production in the Human Arm (Conference and Journal Papers)

*Spring 2012, University of Southern California*

*Brain-Body Dynamics Laboratory*

*Advisor: Professor Francisco Valero-Cuevas*

### A Novel Computational Approach Helps Explain and Reconcile Conflicting Experimental Findings on the Neural Control of Arm Endpoint Stiffness

**Conference:** Accepted for oral presentation February 2012 to the 22nd Annual Meeting of the Society for the Neural Control of Movement, Venice, Italy, 2012.
**Target Journal:** Journal of Biomechanics. Full initial draft completed.
**Authors:** Josh Inouye and Francisco Valero-Cuevas
**Abstract:** Much debate has arisen from the experimental findings of limb impedance control during reaching movements, and particularly around the regulation of stiffness characteristics, and its relation to minimization of energy expenditure for a particular task. The two chief divergent experimental findings are i) that the CNS has very limited control over endpoint stiffness orientation and ii) that the CNS has almost complete control over endpoint stiffness ellipsoid orientation and eccentricity. In this study, we provide the results from novel theoretical analyses and computational experiments that offer explanations for both of these divergent findings, using only the passive stiffness characteristics of muscles, the arm posture, and a standard 6-muscle planar arm model. There are three chief conclusions from this study. The first is that the mechanical ability to orient stiffness ellipsoids is heavily dependent on even small changes in posture, as well as moment arm ratios of the bi-articular muscles. The second is that neuromuscular synergies drastically reduce endpoint stiffness flexibility. The third is that in the complete absence of synergies, for any desired and realizable endpoint stiffness matrix, there exists a one-dimensional manifold in muscle activation space that can produce that stiffness (i.e., there exists stiffness redundancy). This provides a solution space which the CNS can then search to minimize energy consumption. In summary, this computational study helps to shed light on the differing conclusions of limb stiffness experiments, and its insights also can be used to design new experiments that can further elucidate the mechanisms of learning and plasticity present in the human motor system.