USC Viterbi
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Proposed Directed Research
BME 790, Spring 2017

Dear Dr. Newton and Dr. Valero-Cuevas,

Below is a proposed week-to-week agenda for this semester's directed research. As previously discussed, I will complete weekly reviews in the form of **2-3 PowerPoint slides** that aim to summarize the important and **relevant topics** covered that week **as they pertain to biomechanics/neuromechanics**. After 8 weeks, I will then consolidate the accumulated slides into a **10-15 PowerPoint presentation** that I will present with aims to not only summarize the topic but also **discuss its application towards our research**.

My overall goal with this collaborative research will be to gain a better understanding of the mathematical operations that can be done on high dimensional manifolds so that I might find a better way to address the constraints the nervous system faces when controlling limb movements.

Primary Resource

An Introduction to Geometric Mechanics and Differential Geometry by Ross L Hatton and Howie Choset

Secondary Resources

Calculus On Manifolds: A Modern Approach To Classical Theorems Of Advanced Calculus by Michael Spivak

Dr. Mohammad Ghomi's lecture notes on differential geometry
(http://people.math.gatech.edu/~ghomi/LectureNotes/index.html)

Dr. Wulf Rossman's *Lectures on Differential Geometry*
(http://mysite.science.uottawa.ca/rossmann/Differential%20Geometry%20book_files/Diffgeo.pdf)

A. Farshchiansadegh, A. Melendez-Calderon, R. Ranganathan, T. D. Murphey, and F. Mussa-Ivaldi, 2016. *Sensory agreement guides energy optimization in human movements*. PLOS Computational Biology 12, p. e1004861.

Schultz, J. A., E. Johnson, and T. D. Murphey. *Trajectory Optimization in Discrete Mechanics*. Differential-Geometric Methods in Computational Multibody System Dynamics: Springer International Publishing, In Press

E. Johnson, J. Schultz, and T.D. Murphey. *The trep environment is a computation package for simulation and control of constrained mechanical systems*. (https://github.com/MurpheyLab/trep).

R. Murray and S. Sastry, 1993. *Nonholonomic Motion Planning: Steering Using Sinusoids*. IEEE Transactions on Automatic Control 38, pp. 700-716

G. Walsh and S. Sastry, 1995. *On Reorienting Linked Rigid Bodies Using Internal Motions*. IEEE Transactions on Robotics and Automation 11, pp. 139-146

S. Kelly and R. M. Murray, 1995. *Geometric Phases and Robotic Locomotion*. J. Robotic Systems 12, pp. 417-431

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J. B. Melli, C. W. Rowley, and D. S. Rufat, 2006. *Motion Planning for an Articulated Body in a Perfect Planar Fluid,* SIAM Journal of Applied Dynamical Systems 5, pp. 650-669

R. L. Hatton and H. Choset, 2010. *Connection Vector Fields and Optimized Coordinates for Swimming Systems at Low and High Reynolds Numbers.* Proceedings of the ASME Dynamic Systems and Controls Conference (DSCC)

R. L. Hatton and H. Choset, 2011. *Geometric Motion Planning: The Local Connection, Stokes's Theorem, and the Importance of Coordinate Choice.* International Journal of Robotics Research 30, pp. 988-1014

Weekly Agenda

Week of:	Topic	Book Section(s):	Slides due on:
1/16-1/22	Direct product, isomorphism (homeomorphisms), diffeomorphism, manifolds, groups, Lie group, tangent spaces, vector fields, Semi-direct products, linear algebra (vector algebra, matrix anxiety, null spaces, index notation?)	*Choset* Ch 1.1-1.4	**(Due 1/20/17)**
1/23-1/29	Special Euclidean Group velocities, spatial and body velocities in two dimensions, lifted actions, lifted action examples, geodesics, adjoint and exponential map	*Choset* Ch 1.5-1.6	**(Due 1/27/17)**
1/30-2/5	Articulated sytems, fixed base systems (new ross notation), proximal vs. medial vs. distal, start mobile articulated systems, holonomic constraints	*Choset* Ch 2.1-2.2	**(Due 2/3/17)**
2/6-2/12	mobile articulated systems, generalized body frames, Jacobians	*Choset* Ch 2.3-2.5	**(Due 2/10/17)**
2/13-2/19	Kinematic Locomotion up to differential car - Pfaffian constraints and Connection, connection vector fields, directional linearity, linearity, nonholonomic constraints	*Choset* Ch 3.1-3.3	**(Due 2/17/17)**
2/20-2/26	Connection vectorfields, no-slide and inertial constraints locomotion, one-forms, co-vectors, Noether's Theorem, Noether's Theorem revisited, locomotion in fluids	*Choset* Ch 3.4	**(Due 2/24/17)**
2/27-3/5	Gaits, Basic definition of non-communitive and non conservative effects, Lie bracket, curl and Stokes Theorem, review one-forms, two forms, re-explain curl, Lie brackets, and Stokes theorem again	*Choset* Ch 4	**(Due 3/3/17)**
3/6-3/12	Coordinate optimization, Hodge-Helmoltz Decomposition, Gait efficiency, Distance metrics, geodesics, curvature	*Choset* Ch 5	**(Due 3/10/17)**

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Final Presentation

The 10-15 PowerPoint slide presentation at the culmination of the 8 weeks of study will be presented during the week of March 20, 2017 (date, time, and location to be determined based on scheduling availability).

Please look over the proposed schedule and the relevant topics covered each week. I have taken these weekly benchmarks from Dr. Choset's course syllabus and have allocated them to the 8-week schedule. If you feel that either some of these topics are out of the scope of this rotation or that perhaps the schedule could be condensed to allow a few weeks of applied (or extended) research, then please let me know what alterations I can make to finalize this schedule.

I am looking forward to collaborating this semester and I am especially excited about returning to my mathematical roots! Please feel free to contact me with any questions, comments, or suggestions.

Sincerely,

Daniel Hagen