

The Art of Robotics: Toward a Holistic Approach

Alexander Volkov Jr.

Master of Science in Robotics
Thesis Defense
July 31, 2018



Talk Agenda

1. Background The BFD; how I ended up here
2. The Big Picture Cover the central themes of this talk.
3. A Unifying Framework An old framework, revived.
4. Touching Robots Tactile sensing, contact modeling, whiskers, robot pain.
5. Conclusions Review key points and propose some future work.
6. Acknowledgments & Questions *“Please clap...”*



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- ✦ **End Game:** Develop a Unified Framework for Understanding Robotics

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 - ▶ **Talk Purpose:** Provide an overview of my thesis dissertation for the committee

Talk Title Etymology I

- ✚ “The Art of Electronics”, by *Horowitz & Hill*



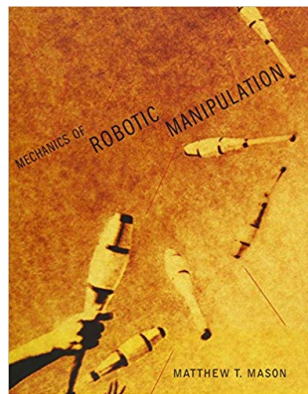
Talk Title Etymology I

- ✚ “The Art of Electronics”, by *Horowitz & Hill*
 - ❖ Literally the electrical engineering bible
 - ❖ Incredibly thorough
 - ❖ Perfect balance of practicality and rigor



Talk Title Etymology II

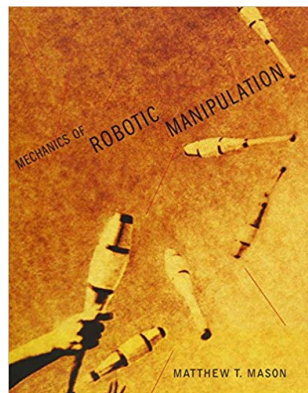
- ✦ “Mechanics of Robotic Manipulation”, by *Mason*¹ [1]



¹Matt, I'll take my referral payments by mail.

Talk Title Etymology II

- ❖ “Mechanics of Robotic Manipulation”, by *Mason*¹ [1]
 - ❖ “Manipulation is an art...” (p.1)



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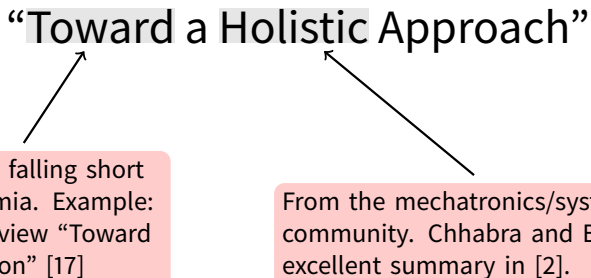
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When you concede falling short of a goal in academia. Example: Mason's Annual Review "Toward Robotic Manipulation" [17]

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From the mechatronics/systems engineering community. Chhabra and Emami provide an excellent summary in [2].

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- ▶ “What’s the system bandwidth?”

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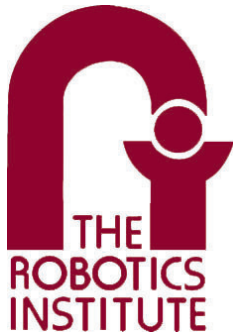
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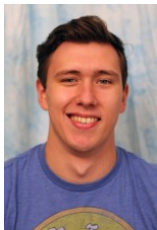
- ▶ “90% of solving a problem is finding the right representation”
- ▶ “Everything breaks at the interfaces”

How I Ended Up Here (Some Context) II



“Time to become a robotics master...”

How I Ended Up Here (Some Context) III

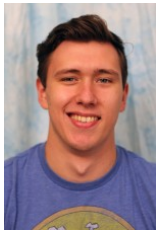


“Legged locomotion is cool...”



How I Ended Up Here (Some Context) IV

“Great! Here’s absolutely no funding.”

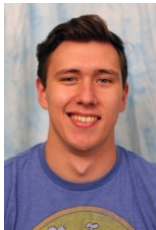


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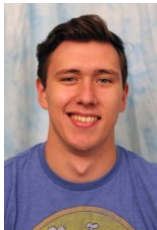


“Umm...”



How I Ended Up Here (Some Context) VI

“Wait! Go talk to Matt Mason!”

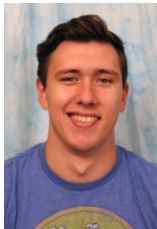


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How I Ended Up Here (Some Context) VII

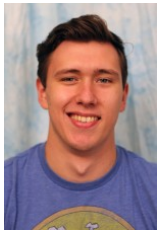
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How I Ended Up Here (Some Context) VIII



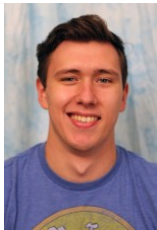
“(skeptical) Okay...”

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And I have money!
And I don’t micromanage!”



How I Ended Up Here (Some Context) IX

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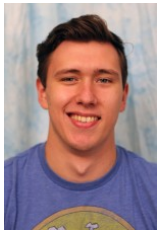


“(excited) Works for me!”



How I Ended Up Here (Some Context) X

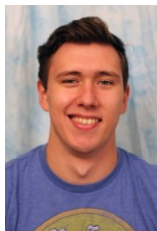
“Fantastic, go forth and prosper!”



“(excited) Works for me!”



How I Ended Up Here (Some Context) XI



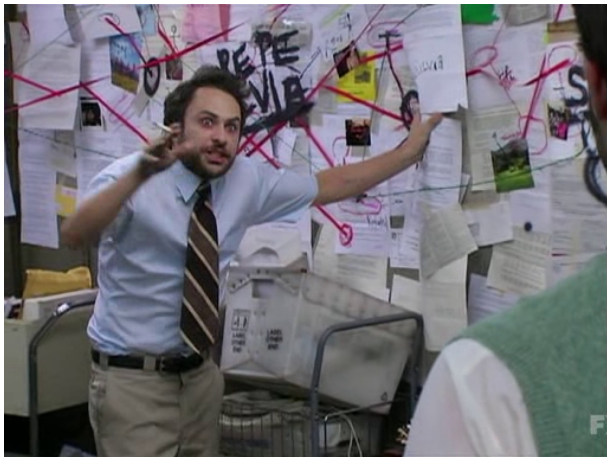
“I’ve been meaning to read Hogan’s famous *Impedance Control* [3] paper, I guess I’ll start there...”



How I Ended Up Here (Some Context) XII

... Two Years Later ...

Me, circa July 2018



“So it’s all about causality... and feedback!”



The Big Picture

Back to Basics

✚ Want a concise *theory of robotics*...

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- ❖ Inherently a *breadth-first* approach, since we're looking for a unifying framework

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- ✚ I know it's a cliché to bring this up...but I must!
 - ✚ Does the ambiguity really matter?
 - ✚ Maybe not, but some unifying *theme* would be useful!

Problem 2: What is Manipulation?

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- ✚ To be honest, I had a very shallow understanding of manipulation until I met Matt
 - ✚ I imagined it was just factory robot stuff
 - ✚ It took some reflection to appreciate the depth of “manipulation”

Problem 2: What is Manipulation?

“Manipulation refers to an agent’s control of its environment through selective contact.”

— *Matt Mason*, “Toward Robotic Manipulation” [17]

Problem 3: Locomotion and Manipulation, Segregated

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Problem 3: Locomotion and Manipulation, Segregated

- ❖ Locomotion and manipulation are studied separately in robotics
 - ❖ ... and biomechanics, for that matter
 - ❖ Seems quite natural at first, we all talk about the two as separate specializations in robotics
- ❖ Eventually, the notion of “*duality*” comes up...
 - ❖ Locomotion and manipulation sometimes overlap
 - ▶ Pai et al.’s *Platonic Beasts* [5]
 - ▶ Mason et al.’s *Mobipulator* [6] [7]
 - ▶ Also, literally everywhere in biology
 - ❖ Perhaps it just comes down to a change of reference?
 - ▶ Just a matter of “what pushes off of what?”
 - ▶ Locomotion is “self-manipulation”, e.g. Aaron Johnson’s PhD thesis [8] and related works [9][20]

Problem 3: Locomotion and Manipulation, United

- ✚ The “self-manipulation” view of locomotion is consistent with our definition of “manipulation”:
 - ✚ An agent may control its environment through selective contact (i.e. “manipulation”) by moving about in it (i.e. “locomotion”).²

²It helps to take on an egocentric point of view to visualize this.

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So locomotion is just a subset of manipulation!

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Problem 3: Locomotion and Manipulation, United

✚ Not a terribly practical insight...

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- ✚ Not a terribly practical insight... but thinking back to *Problem 1*...

So locomotion is just a subset of manipulation!

Embodiment & Hogan's Physical-Equivalence Principle

✦ Embodiment

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- ❖ Presently resides in the cognitive science community (as in “embodied *cognition*”)

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A Unifying Framework

The Port-Hamiltonian Framework

- Port-based Analysis
- Hamiltonian Dynamics
 -
-

Bond Graphs

Hamiltonian Dynamics

Dissipative Elements

Putting it All Together

Touching Robots

A Note on Stiffness and Collisions

✚ **STOP COLLIDING STIFF OBJECTS AND EXPECTING RELIABLE RESULTS**

The Most Important Sensory Modality

Contact Models

Terminator 2 Got It Right

Closing Thoughts

Closing Thoughts

✚ Woo, Beamer!



Acknowledgments

Cheers

Committee

Lab

The other profs

Jean

Cameron

Cats

Parents for debt free education



Questions?



Bibliography

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Other Things

Teaching with CMU's Gelfand Outreach Center

- Introduction to Robotics with the Finch Platform
 - ❖ Each session is 5 days, 3 hrs/day
 - ❖ 4th and 5th graders
 - ❖ 1 session Summer 2017 + 2 sessions Summer 2018

Carnegie Mellon University



Teaching with CMU's Gelfand Outreach Center

- ❖ Saturday Series LEGO WeDo Robotics
 - ❖ 3 hour course
 - ❖ 2nd and 3rd graders
 - ❖ 1 session Spring 2018

Carnegie Mellon University



Robotics Institute Meme Facebook Page

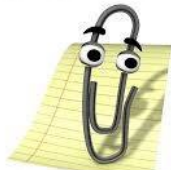


Robotics Institute Meme Facebook Page



- Some statistics:
- ❖ The RI's first and only meme page
 - ❖ Formed in March 2018
 - ❖ 170 members
 - ❖ 30 memes, 23 original contributions!

IT LOOKS LIKE YOU'RE TRYING
TO WRITE YOUR THESIS



WOULD YOU LIKE TO BE
STRICKEN WITH CRIPPLING SELF
DOUBT AND WRITERS BLOCK?

How to optimize on Lie manifolds

~~How to draw an owl~~

1.



2.



1. Some basics

A 3D rigid body transform, $G \in SE(3)$:

$$G = \begin{bmatrix} \mathbf{R} & \mathbf{t} \\ 0 & 1 \end{bmatrix}$$

where $\mathbf{R} \in SO(3)$. During optimization,
a minimal representation is given by
 $\xi \in se(3)$ of the associated lie algebra.
oh btw, log map is bla.
exp map is blabla.

~~1. Draw some circles~~

~~2. Draw the rest of the fucking owl~~

2. Optimize on the fucking manifold!