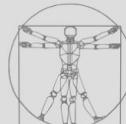


Minimality + Design Automation

Simpler robots are better,
but it gets complicated.

How can computers help us?

Organizers: Andrea Censi, Jason O'Kane, and Dylan Shell



**ROBOTICS
SCIENCE AND SYSTEMS**

June 18-22, 2016

University of Michigan

What are the fewest resources necessary to perform a task?

a natural theoretical question

practically useful

intellectually deep

remains fundamentally open



The Graeae

Deino, Enyo, and Pemphredo

necessary to graduate past one-offs
software and hardware aspects
difficult to decide what to focus on

How to automate the process of designing robots?

Long history of thinking about minimality/minimalism in robotics...



From left: Shankar Sastry, Vince Hayward, Jean-Paul Laumond, Lydia Kavraki, Yoshi Nokamura (occluded!), Swee Mok, Shigeo Hirose, Matt Mason, Karl Bohringer, Bruce Donald, Antonio Bicchi, Ken Goldberg, Mike Erdmann, Greg Chirikjian, Richard Wallace, John Canny, and Greg Walsh.

See <http://www.ier.berkeley.edu/~goldberg/minimalism/> for more details.

Long history of thinking about minimality/minimalism in robotics...

First the ICRA 1996 workshop organized by K. Goldberg and A. Bicchi.

Then the RSS'08 workshop organized by R. Ghrist, S. LaValle, and G. Pappas.

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The 1996 workshop gave this definition:

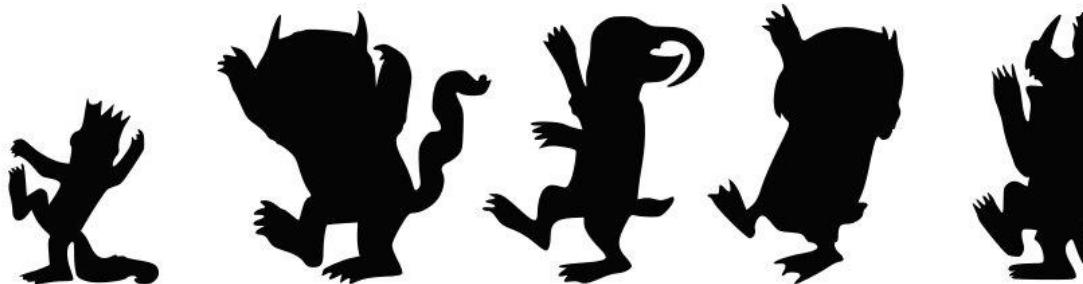
By “minimalism” it is meant the pursuit of the least complex solution to a given class of tasks, by, e.g., using the minimal number of actuators or control variables (dof), or the simplest set of sensors.

But simpler robots seldom result in a cake walk

P. Cheeseman et al. (1991)

“Where the Really Hard Problems Are”

IJCAI, pp. 331–337.

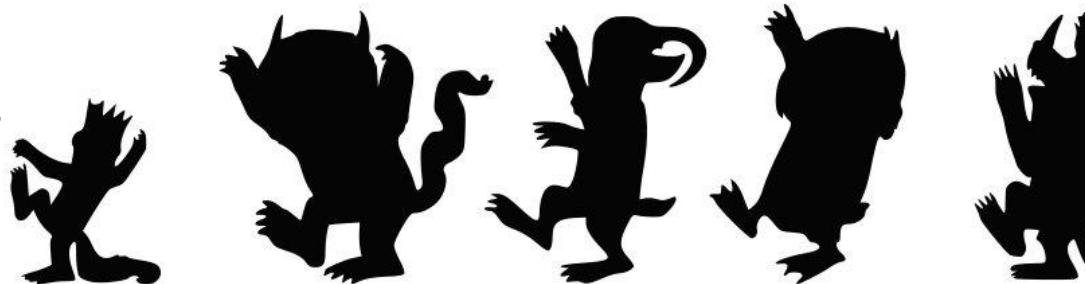


More capable robots don't always make life easier

T. Smithers (1994) "On why better robots make it harder", From Animals to Animats, Simulation of Adaptive Behavior, pp. 64—72.

But simpler robots seldom result in a cake walk

P. Cheeseman et al. (1991)
"Where the Really Hard Problems Are"
IJCAI, pp. 331—337.



Minimality in all forms:

sensing — use the simplest sensor possible

actuation — use the simplest actuators

computation — use the least computation power, the smallest representations, ...

communication — use the least bandwidth, energy, connectivity, ...

All of these could be defined as “*resource constraints*”

“Creativity arises
from constraints”

Igor Stravinsky



Robot design automation

Growing body of work in automated synthesis of robot controllers for tasks

- Leverages extensive advances in program synthesis and verification of software

Automating design

To make progress with design decisions we need computers to help.

But...

What tools would make for a starting point for broader questions about design?

What is their likely performance when several resource constraints become active?

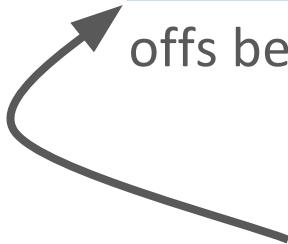
Today

Minimality + Design Automation

- Spur on discussion of these topics individually but wish to emphasize their interplay
- Desire to invigorate discussion among the various researchers

We need to understand the interplay between problem requirements, task constraints, relationships and trade-offs between resources and capabilities.

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Past research on minimality thinks hard about **these things**

We need to understand the interplay between problem requirements, task constraints, relationships and trade-offs between resources and capabilities.

Past research on minimality thinks hard about **these things** and also **these too**

We need to understand the interplay between problem requirements, task constraints, relationships and trade-offs between resources and capabilities.

“It has often been said that a person does not really understand something until he teaches it to someone else.



Donald Knuth

We need to understand the interplay between problem requirements, task constraints, relationships and trade-offs between resources and capabilities.

“It has often been said that a person does not really understand something until he teaches it to someone else. Actually a person does not *really* understand something until he can teach it to a *computer*.”



Donald Knuth

We need to **understand** the interplay between problem requirements, task constraints, relationships and trade-offs between resources and capabilities.

4 Questions

The intended outcome of this workshop is to reach a clearer understanding of four questions

1. Which parts of the design process are ready to be, or have already been, distilled into crisp formalisms? Which parts of the process are not quite there yet, but are within striking distance?

1. Which parts of the design process are ready to be, or have already been, distilled into crisp formalisms? Which parts of the process are not quite there yet, but are within striking distance?
2. Which parts are amenable to automated reasoning?

3. What algorithmic tools and representations are most suitable?

- 3.** What algorithmic tools and representations are most suitable?

- 4.** What will future “VLSI” tools for robotics look like, and how will they interact?

4 Questions

The intended outcome of this workshop is to reach a clearer understanding of four questions

Including:

list of instances (and references)
“folklore” results

How we'll run this workshop

Dissatisfaction about workshops increasingly becoming mini-conferences (now that conferences have become mini-journals)...

Not this one!

Dissatisfaction about workshops increasingly becoming mini-conferences (now that conferences have become mini-journals)...

Not this one!

Short talks, in which every participant has 5+5+5 minutes:

- 5 minutes to introduce themselves and to show an “incendiary idea”
 - an idea unlikely to elicit universal agreement in the community, but likely to generate discussion
- 5 minutes to talk about their work
- 5 minutes for post-talk discussion and hand-over.

Dissatisfaction about workshops increasingly becoming mini-conferences (now that conferences have become mini-journals)...

Not this one!

A breakout group activity called [The Robot Design Game](#), which seeks to explore the tradeoffs in resource constraints inherent in robot design problems.

Schedule

<http://minimality.mit.edu>



9:00-9:30 Dylan Shell **YOU are here!**

9:30-9:45 Andrea Censi **“Co-Design Problems in Robotics”**

9:45-10:00 Jason O'Kane **“Design Automation is Hard. Deal with It.”**

10:00-10:30 Break

10:30-10:45 Sawyer Fuller **“Don't Model Things. Just Build Robots.”**

10:45-11:00 Matteo Bianchi **“Minimality and Under-Sensing: A Human-Inspired Approach.”**

11:00-11:15 Ron Fearing **“Minimal Actuation in Legged Locomotion”**

11:15-11:30 Alberto Rodriguez **<<sssh, it's a secret>>**

11:30-11:45 Dan Aukes **“Automating the Design Process for Folding Laminate Devices”**

Schedule (cont.)

11:45-1:45 Lunch

1:45-2:00 Greg Chirikjian “From Binary-Actuated Manipulators to Lie Groups”

2:00-2:15 Aaron Becker “Minimality in Control: Sometimes Less is All You've Got”

2:15-2:30 Yu Zhang “Minimality in Multi-Robot Systems”

2:30-2:45 Hadas Kress-Gazit “Synthesizing Robots from Specifications”

3:00-3:30 Introduction to The Robot Design Game

3:30-4:00 Break

4:00-5:15 The Robot Design Game

5:15-5:30 Discussion

Image Credits

Picture of the Graeae

<http://greekmythologicalcreatures.blogspot.com/2014/02/sphinx.html>

ICRA'96 Workshop Attendees

<http://www.ior.berkeley.edu/~goldberg/minimalism/>

Clinton Election Sticker

<http://www.zazzle.co.uk>

Igor Stravinsky (edited, but based on)

<http://jazzdagama.com/wp-content/uploads/2016/03/Igor-Stravinsky.jpg>

Where the wild things are clipart

<http://www.clipartkid.com/>

Donald Knuth

<http://data.businessworld.cz/>

You are here dot

<http://thelandofcolor.com/wp-content/uploads/2012/03/You-are-here.png>