Low Dimensional Control of High Dimensional Systems

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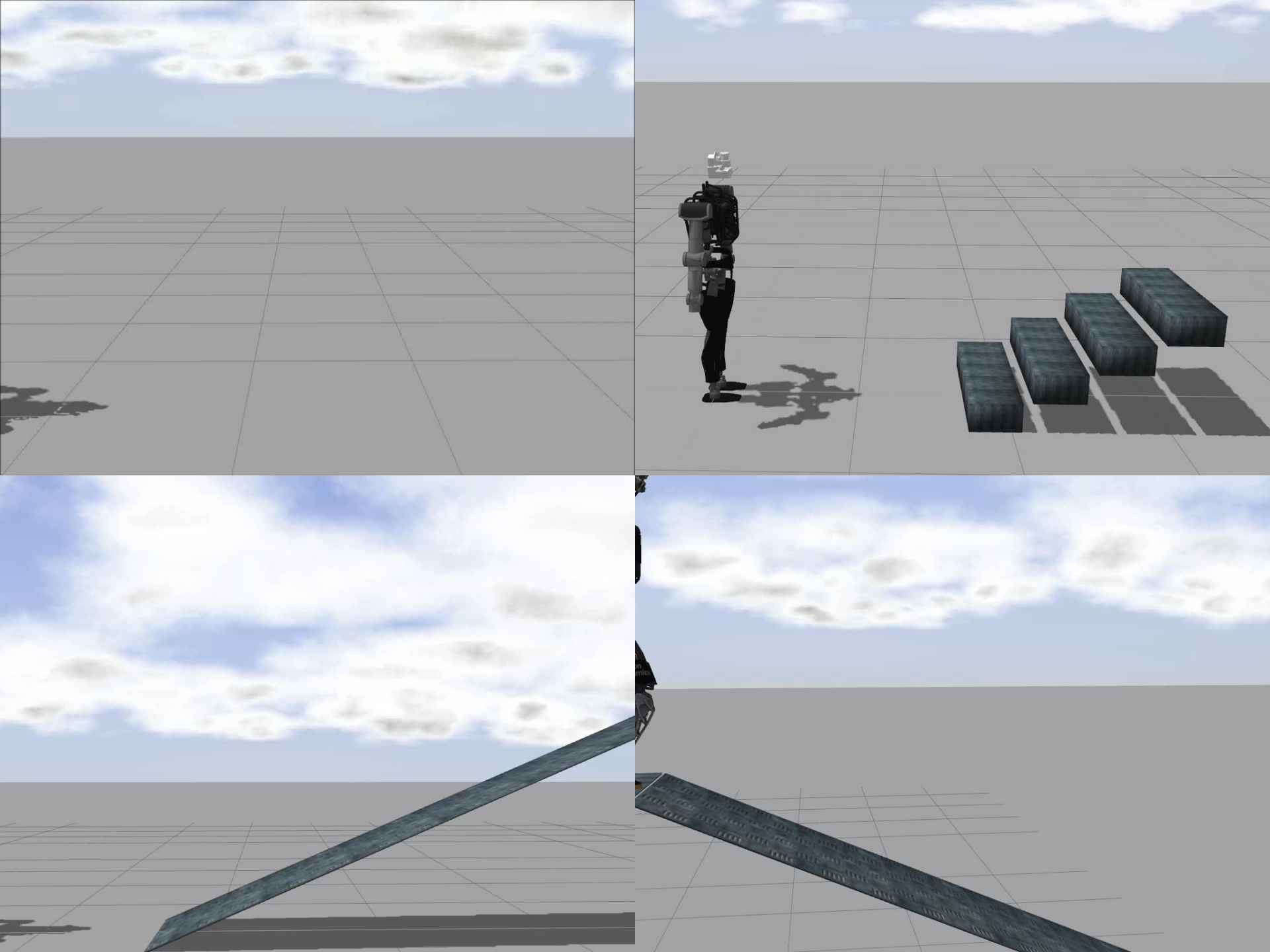
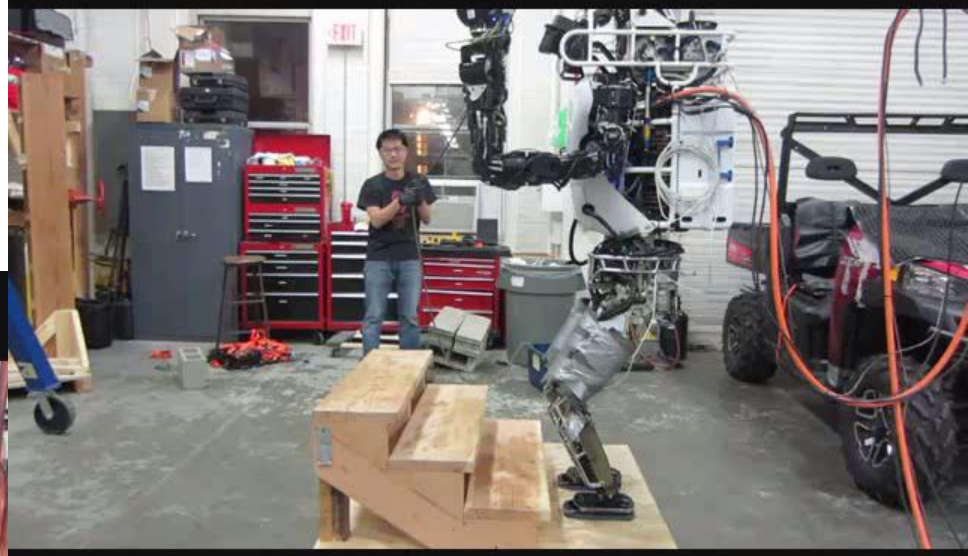
Eric Whitman: Low Dimensional Dynamic Programming

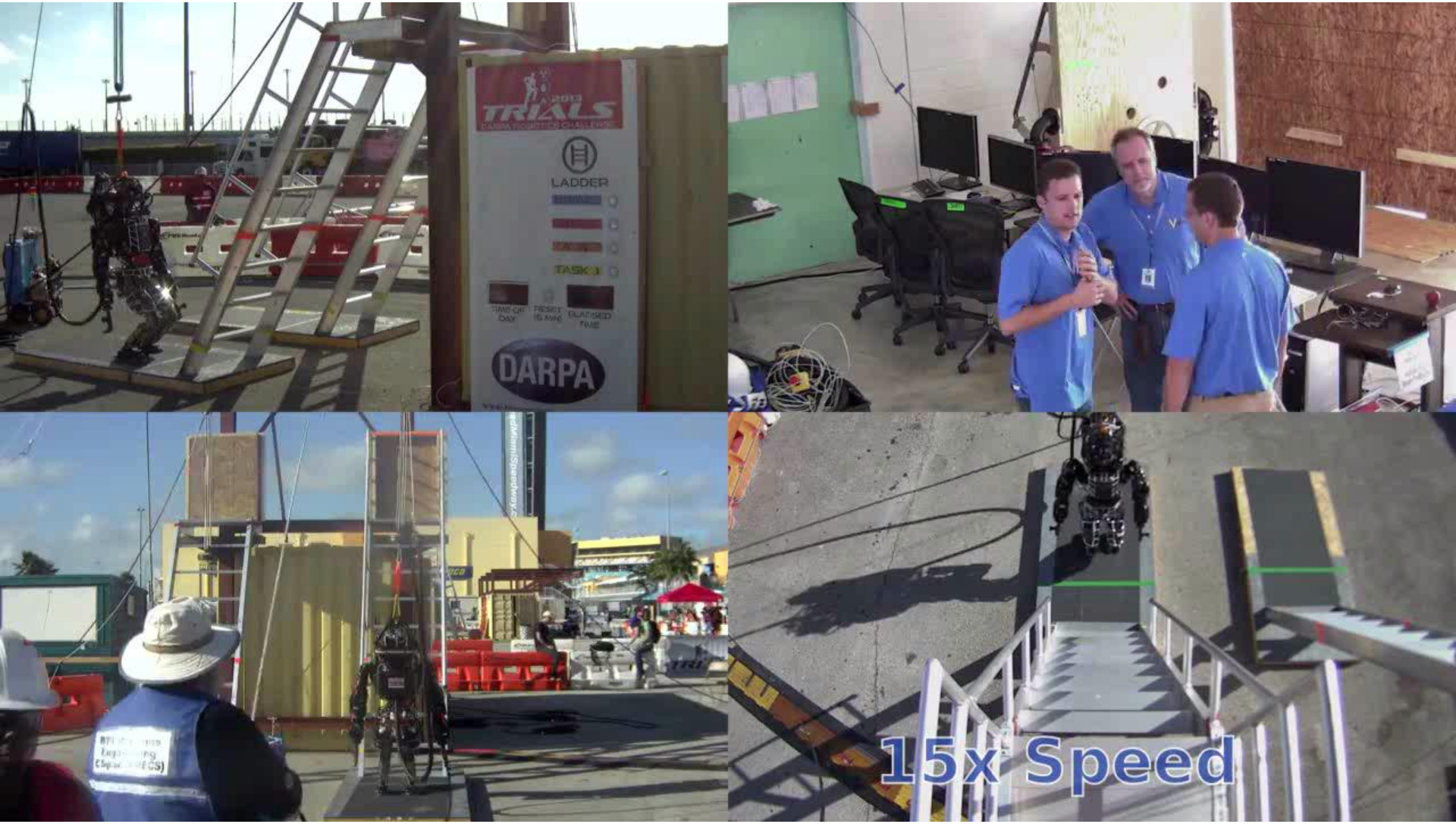
- Dynamic programming applied to multiple simplified and “decoupled” systems: sagittal, lateral, swing, yaw (all low dimensional)
- Couple through coordinating variables (usually touchdown and liftoff timing)
- Once COM trajectory and contact forces determined, use QP to do inverse dynamics and determine joint torques.



Atlas Locomotion

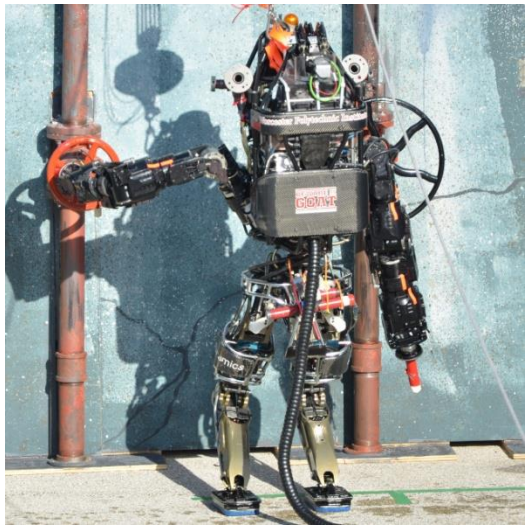


Manipulation = Locomotion



DRC: Siyuan Feng

- A*-based footstep planning (kinematic and low dimensional)
- COM trajectory optimization using DDP and LIPM+Z model. (low dimensional)
- Once COM trajectory and contact forces determined, use QP to do inverse dynamics and determine joint torques.
- Locomotion and manipulation use same controller.



NOW

$$[\dot{q}_T], \begin{bmatrix} \ddot{q}_T \\ F_T \\ \tau_T \end{bmatrix}$$

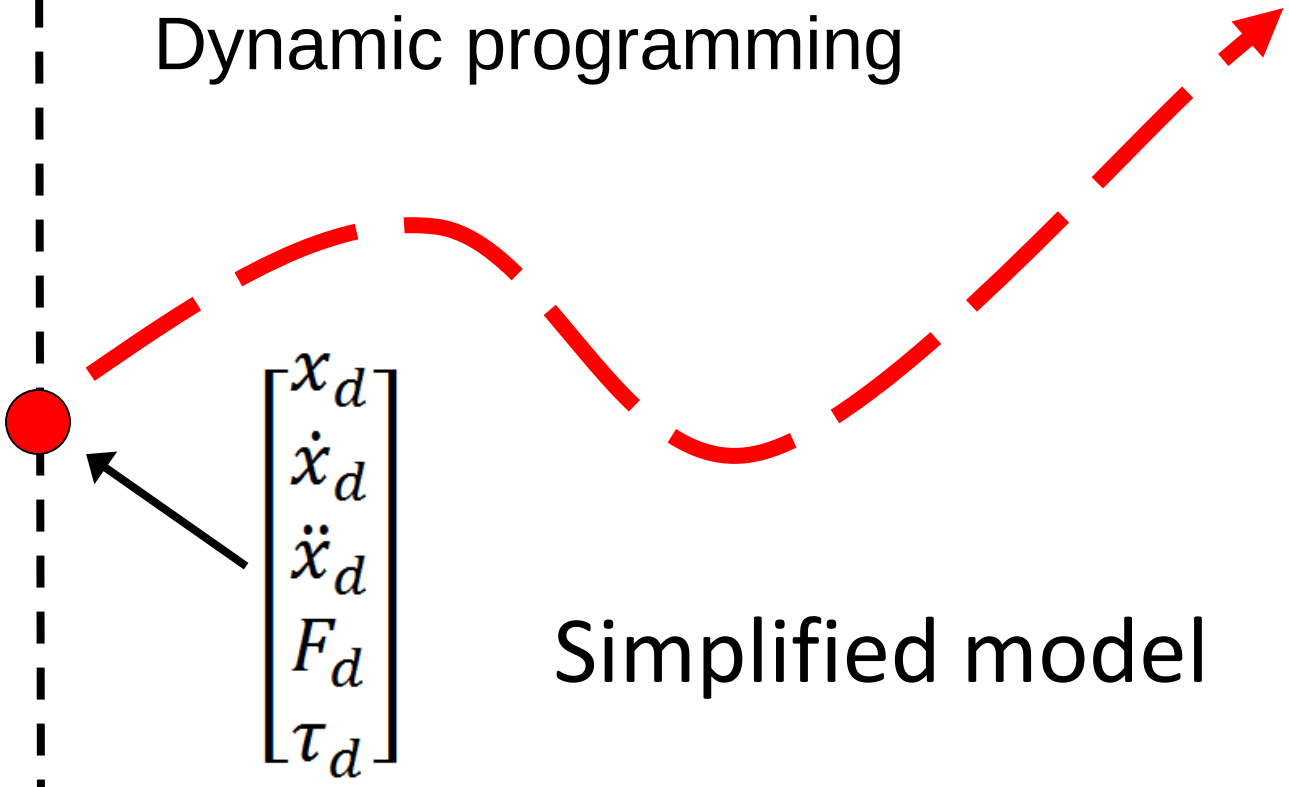
Inverse Dynamics

QP

Full model

FUTURE

Preview control
Capture point
Trajectory optimization/MPC/RHC
Dynamic programming



Simplified model

50 DOF?

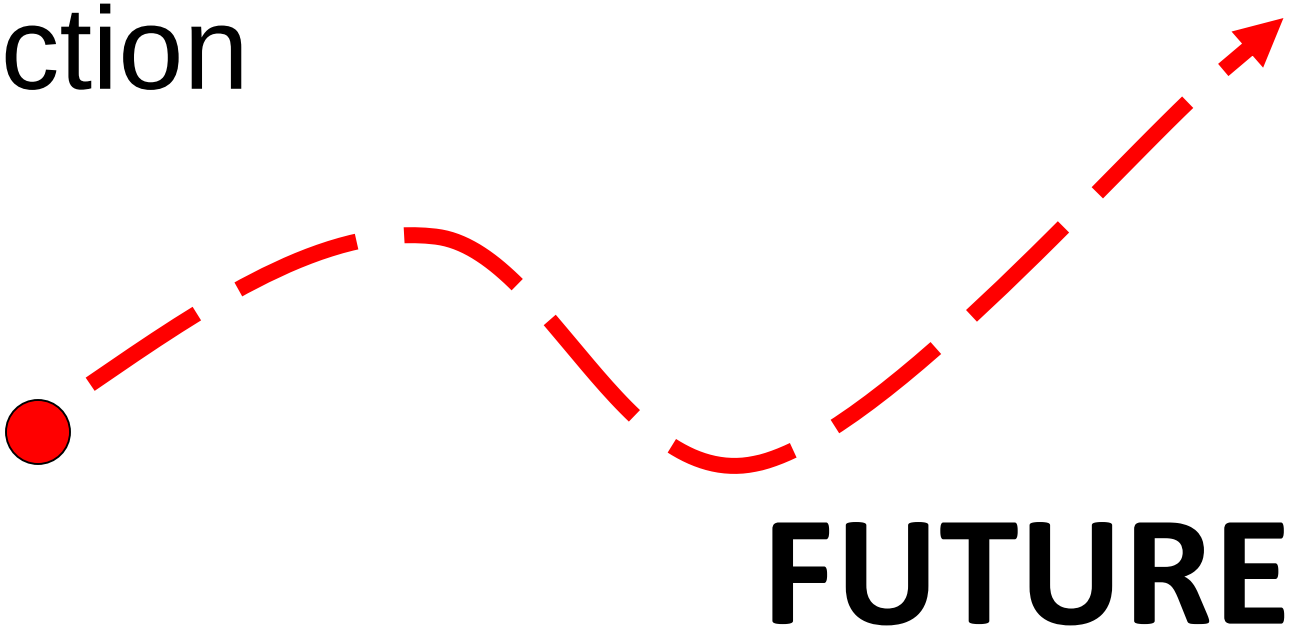
- The part of the controller that considers the future is low dimensional in both these systems.
- Our inverse dynamics QP considers around 30 DOF, but that is NOT what makes the system work.
- We would need to increase the dimensionality of the receding horizon portion of the controller to really say we could handle 50 DOF.

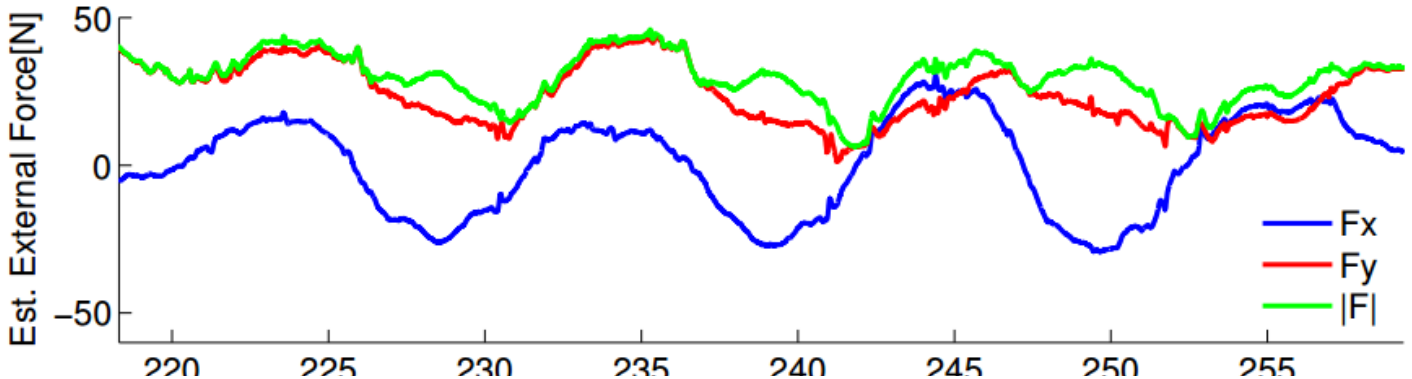
Only full model?

Trajectory optimization/MPC/RHC

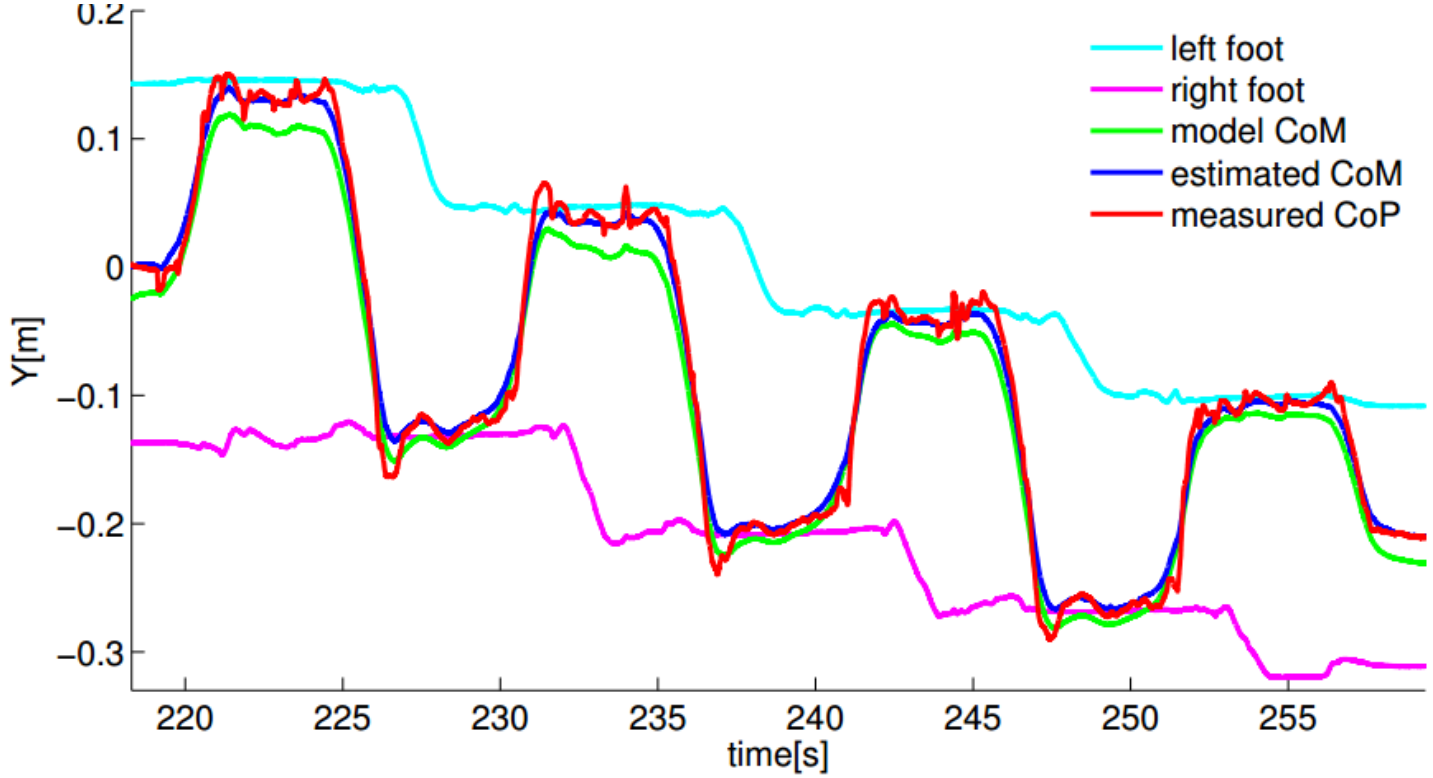
Value function

$$[\dot{q}_T], \begin{bmatrix} \ddot{q}_T \\ F_T \\ \tau_T \end{bmatrix}$$





For force controlled robots:
DRC will be won by good models



High Dimensional Manipulation

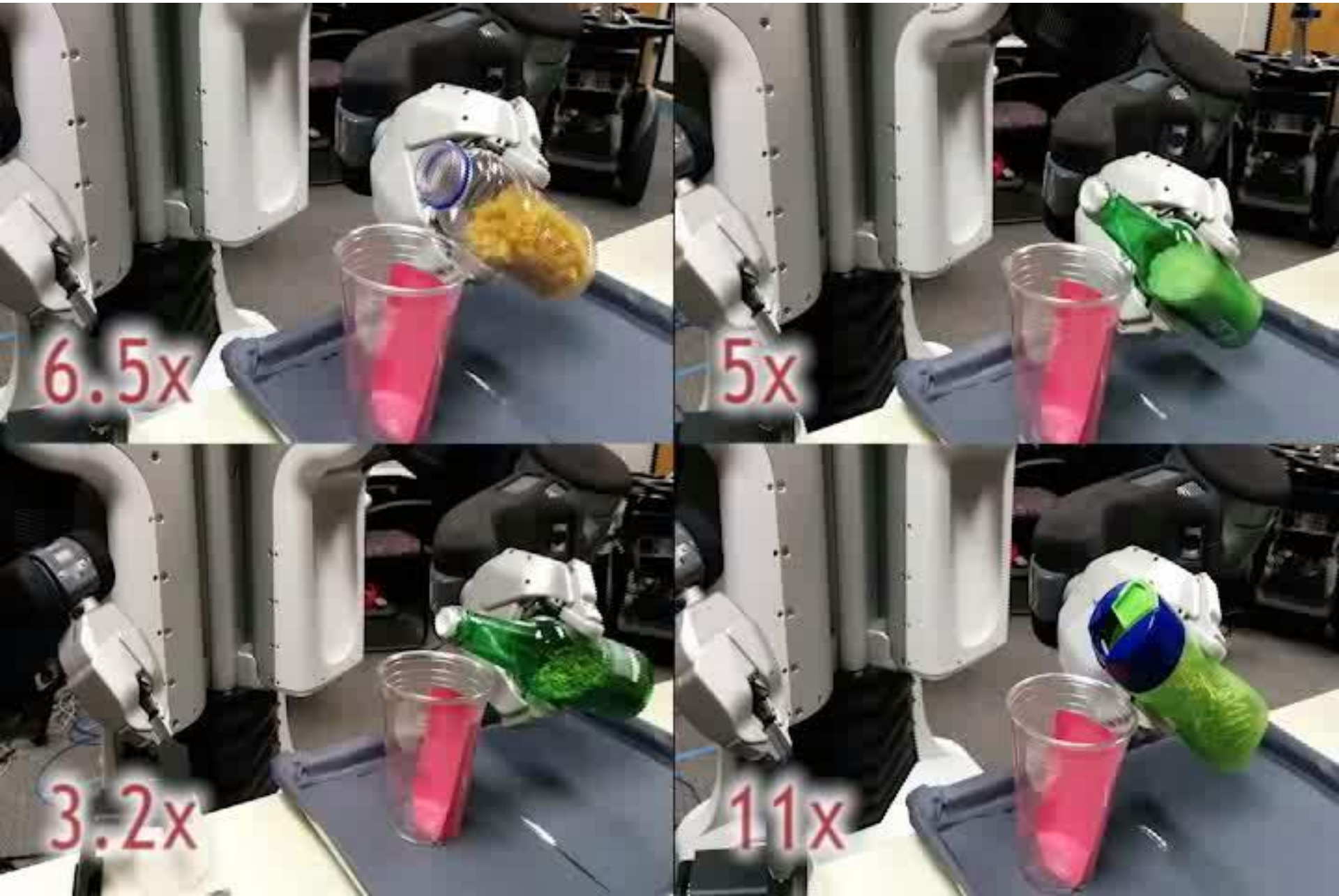
- How can we manipulate liquids and granular materials?
- Where models are expensive to compute or hard to identify or whose form is not known?

High DOF Task: Pouring

Yamaguchi and Niekum

Baby Steps: Robot Pouring I

Baby Steps: Robot Pouring II



Robot “Tapping”

Our Approach

- Learn from observation: task “topology”.
- Learn from practice: task “parameterization” and how to generalize across objects and situations.
- We are still in the exploratory phase.
- Well behaved high DOF system: damping, containers/constraints, controllable initial conditions.
- Low DOF actions/policies/behaviors.
- Mostly low bandwidth actions/policies/behaviors
- Eventually: Qualitative Physics -> Theory Driven Exploration And Learning

High DOF Animations

- Big Hero 6
- Google joke first

Google patents system that could one day download the personality of a celebrity or even a deceased loved one to a ROBOT

- Google says robot could replicate a deceased loved one or a celebrity
- Firm has already developed the 6.2 foot Atlas robot
- Robot personalities can be downloaded like apps online

By MARK PRIGG FOR DAILYMAIL.COM

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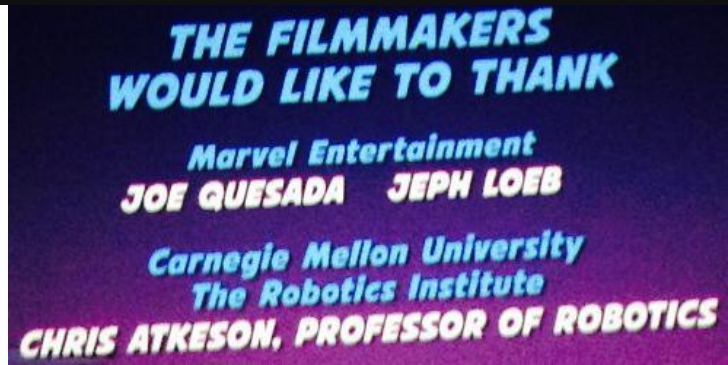
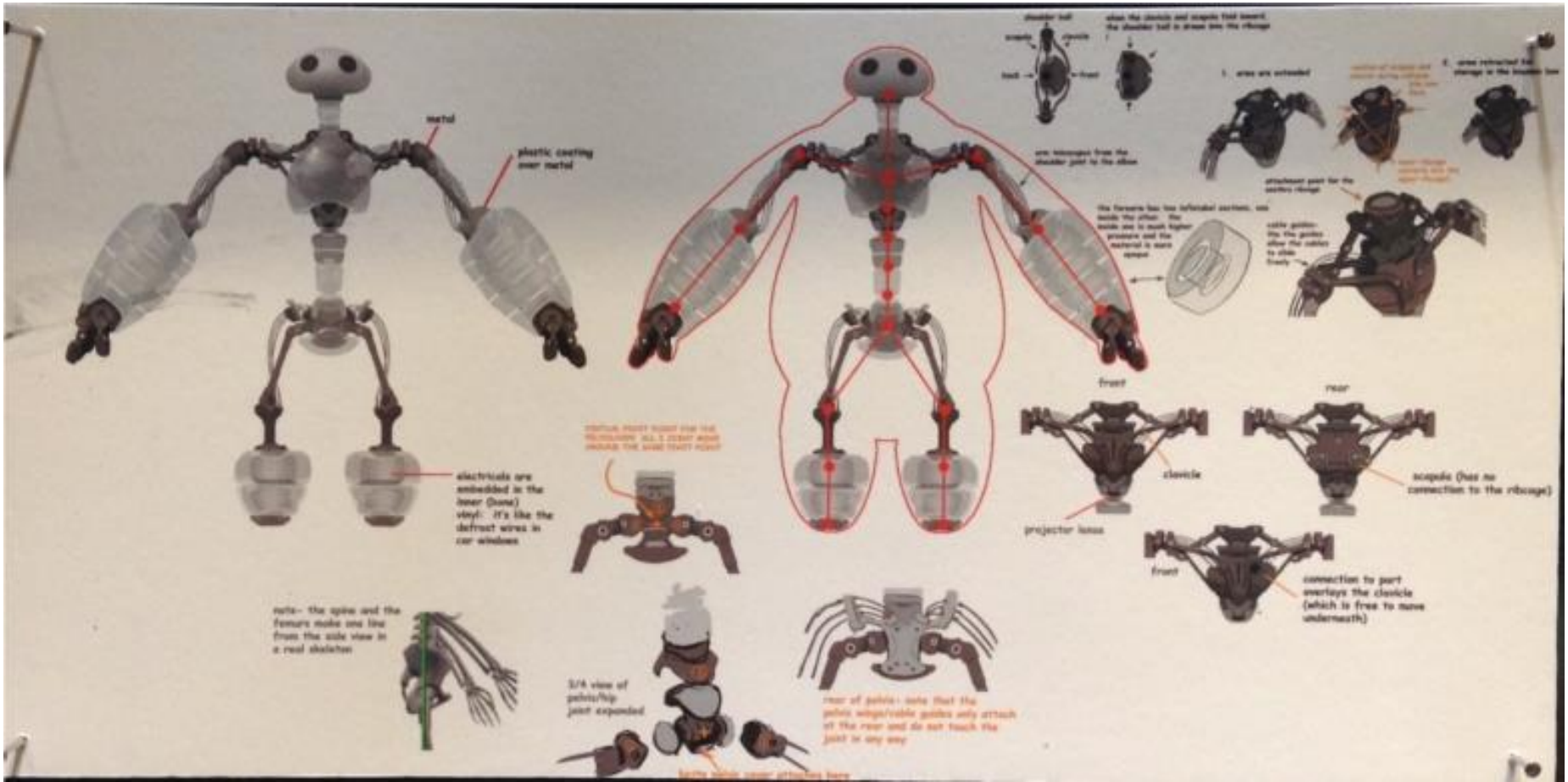
Safe and soft: Inflatable robots

Big Hero 6


THE FILMMAKERS
WOULD LIKE TO THANK
Marvel Entertainment
JOE QUESADA
JEPH LOEB
Carnegie Mellon University
The Robotics Institute
CHRIS ATKESON, PROFESSOR OF ROBOTICS

Low DOF Skeleton

- Animators created skeleton to pose robot.
- Body shapes were interpolated.
- No physical simulation



High Dimensional Locomotion and Manipulation

- Low dimensional models useful for control.
- Underactuated high DOF systems can be controlled by low DOF and mostly low bandwidth actions/policies/behaviors.
- Damping, constraints, and controllable initial conditions help.
- DEMO