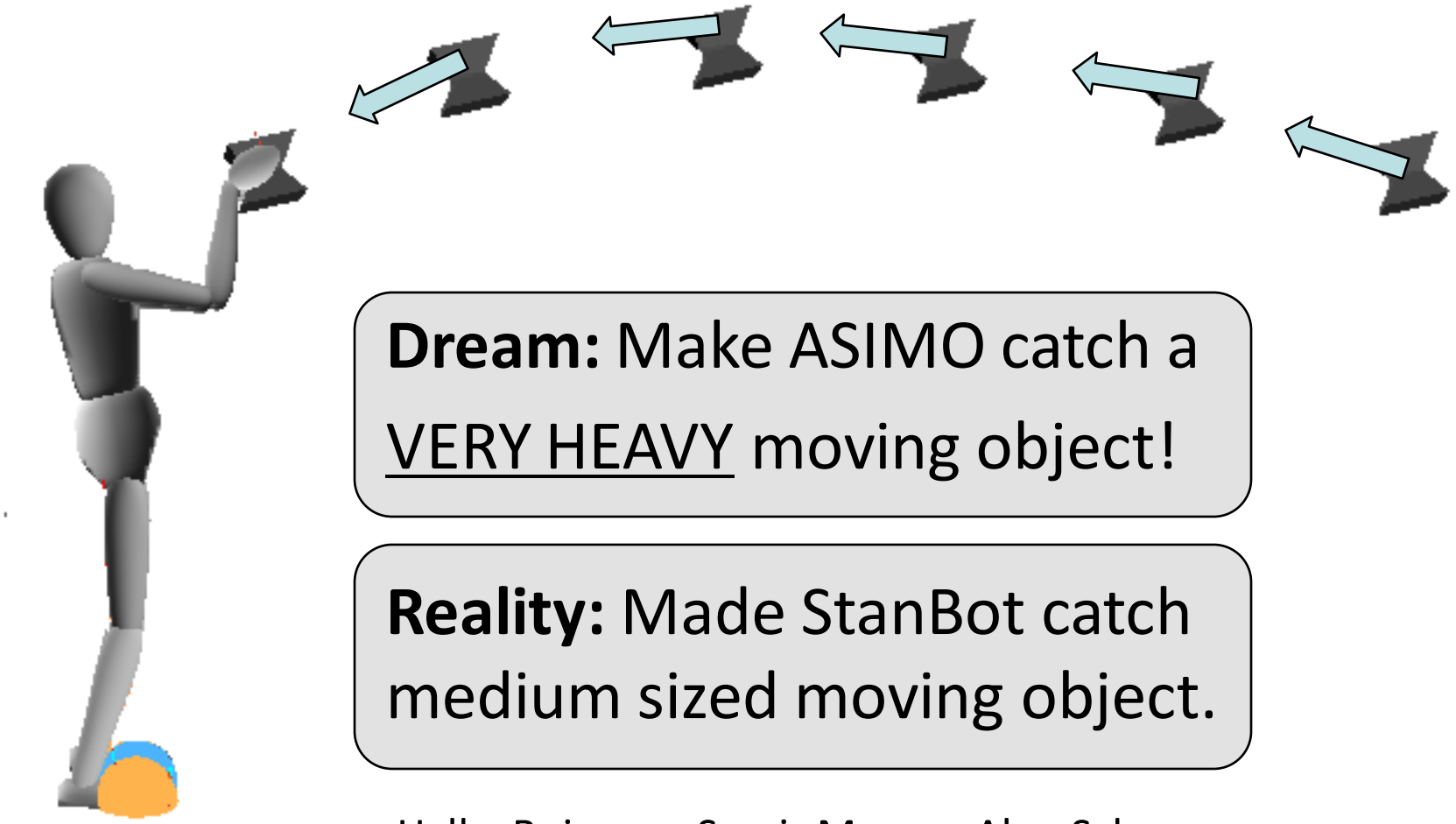
Catching A Moving Mass

catching a moving mass



Dream: Make ASIMO catch a VERY HEAVY moving object!

Reality: Made StanBot catch medium sized moving object.

Hylke Buisman, Samir Menon, Alan Schoen

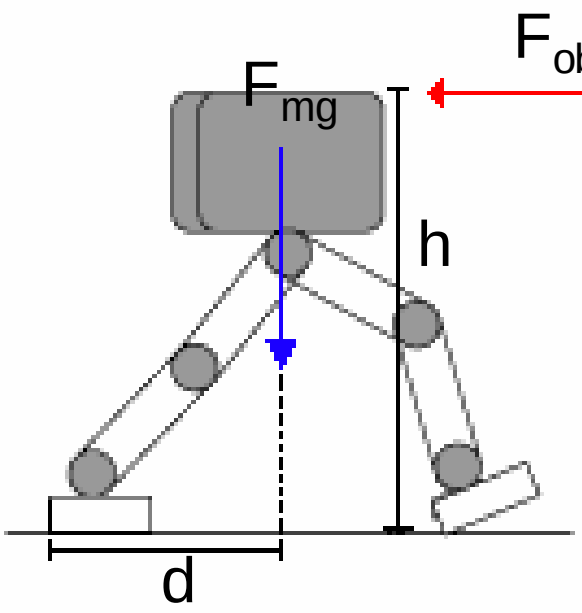
Overview

catching a moving mass

- Catching:
  - Grasping
  - Collision Dynamics
- Stability:
  - Center of mass position
  - Stance Adjustment

Collision Analysis

catching a moving mass



$$F_{obj} \times h \leq F_{mg} \times d$$

Grasping

catching a moving mass

- End-effector mechanical design (friction coefficient adjustments)
- End-effector orientation
- Active grasping

Catch-Impact Dynamics

catching a moving mass

- Feedback methods
  - Low Gains, Potential Field
- Feed-forward methods
  - Velocity Matching, Impact pliability

Passive Methods

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- Analysis of arm inertia:
  $m_1 \times v_1 = (m_1 + m_{arm}) \times v_2$

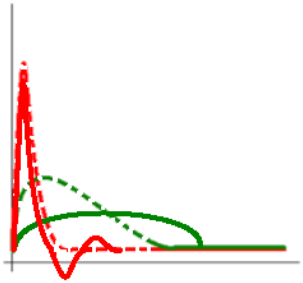
Plastic collision

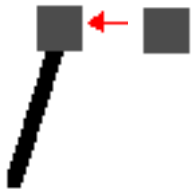
- For small change in time t
  $|F_{obj}| = (|v_2 - v_1| \times m_1) / t$
  $\Rightarrow$We want $v_2 \approx v_1$
  $\Rightarrow m_{arm}$ small
  $\Rightarrow$Effective Inertia should be small

Post-catch Control

catching a moving mass

- Control using the block / use of the robot as a filter



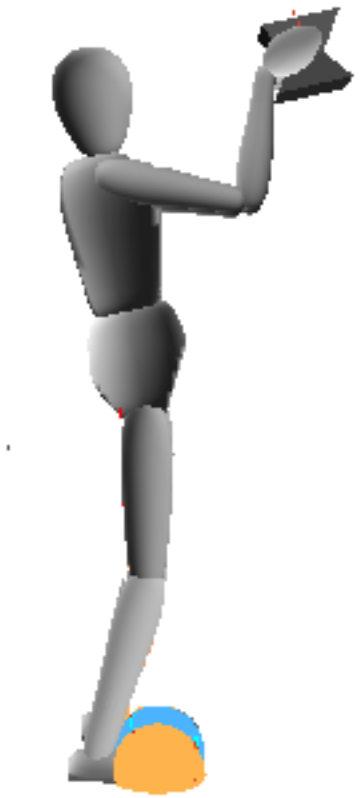


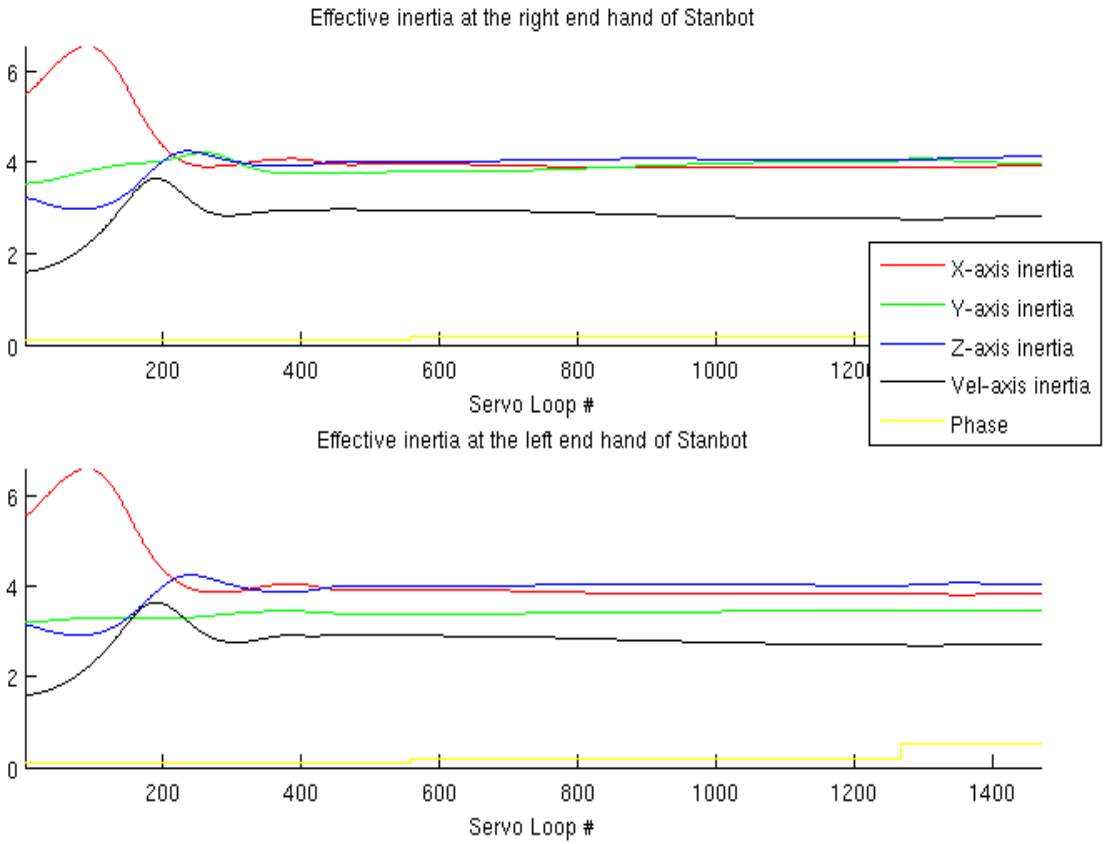
- $F_{obj} = (v_{obj} / t) \times m$
- $t = 2 \times (d_{catch} / v_{obj})$

- $\boxed{v_{obj}^2 \times m = 2 \times d_{catch} \times F_{obj}}$

Inertial property at hands

catching a moving mass





- The effective inertial property was minimized along the velocity axis to reduce impact forces.

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Overview

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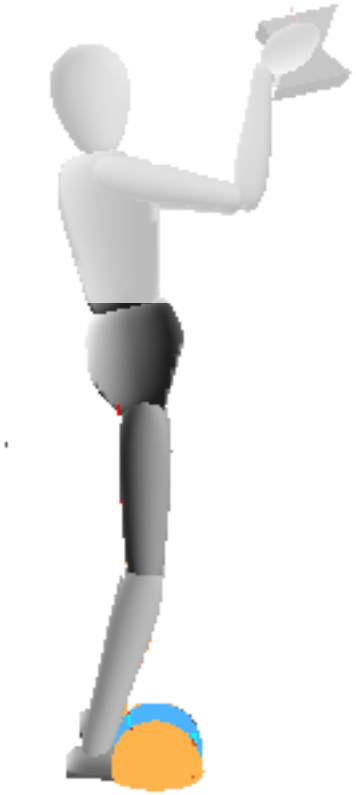

- Catching:
  - Grasping
  - Collision Dynamics

- Stability:
  - Center of mass position
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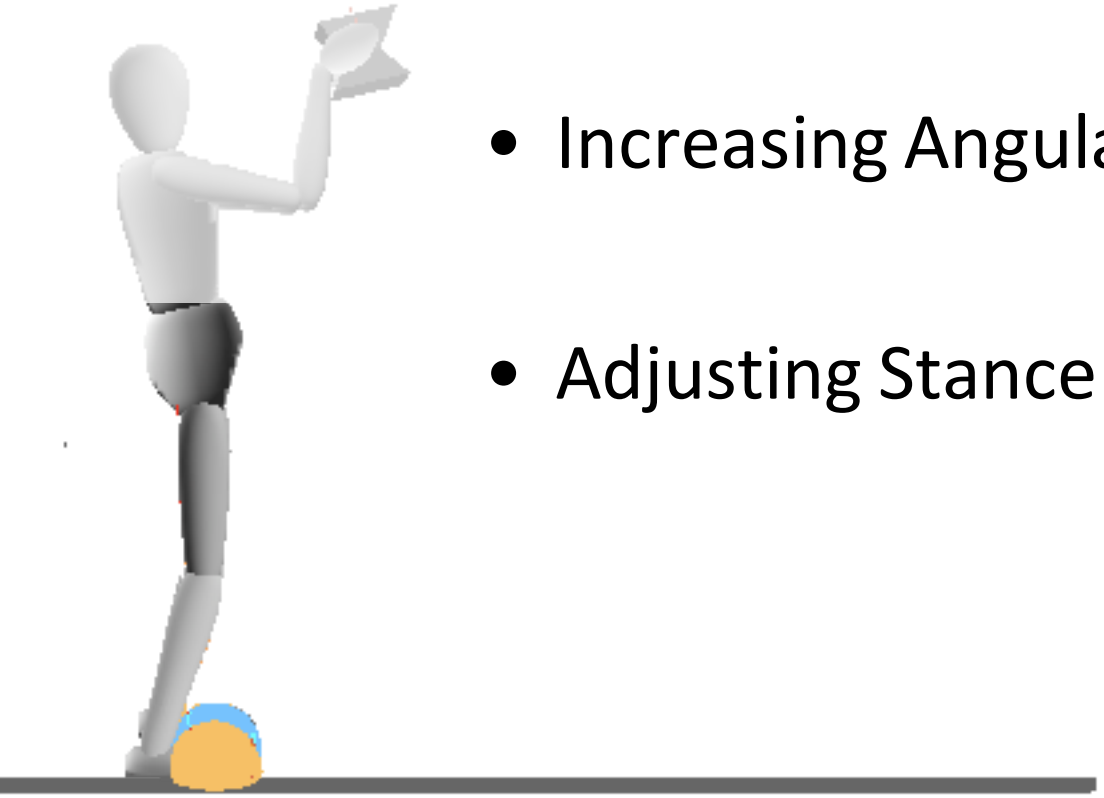
Maintaining Stability

catching a moving mass



- Attaching Skis
- Increasing Angular Inertia
- Adjusting Stance

Dynamic Stance Adjustment

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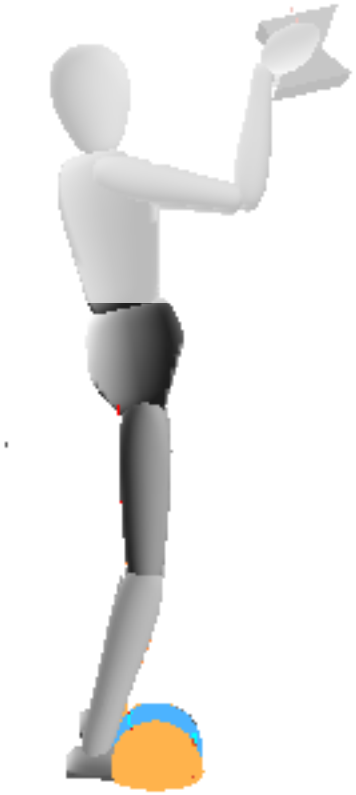

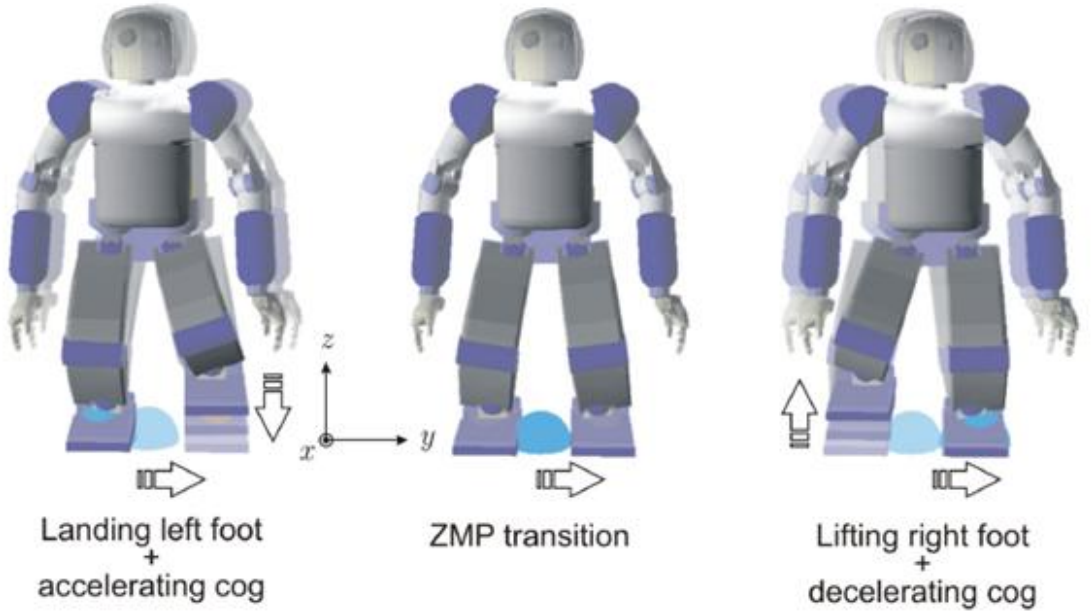

Advantage: Faster, more realistic

Disadvantages: Complex

Static Stance Adjustment

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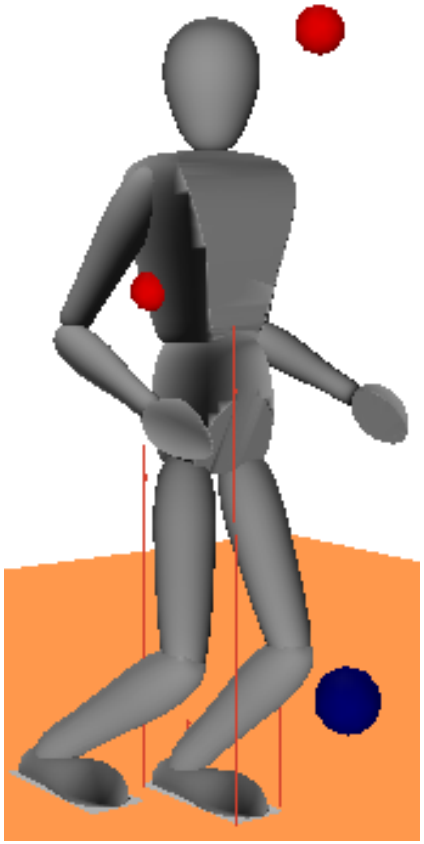

Advantage: Simple

Disadvantages: Artificial, slow

Two behaviors:

- Step backwards
- Rotating step

Our option of choice!

Learning to catch a block

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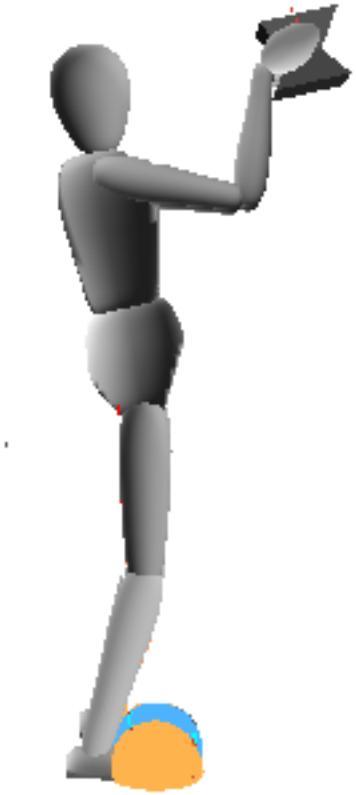
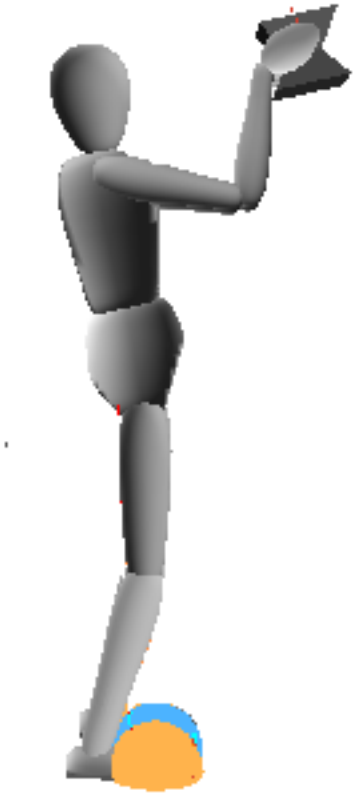
- Please open this link



Final video

catching a moving mass

- Please open this link



Conclusions

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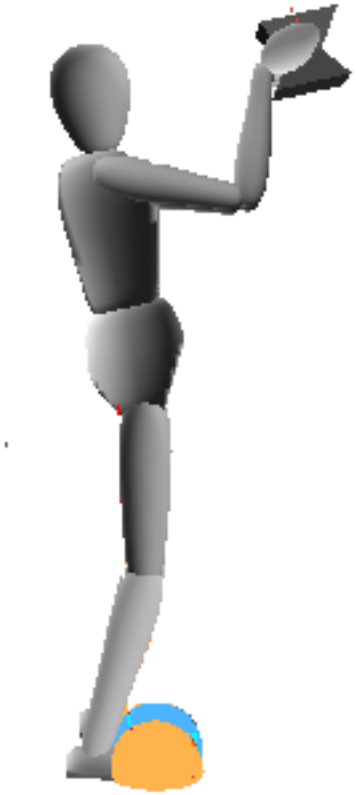
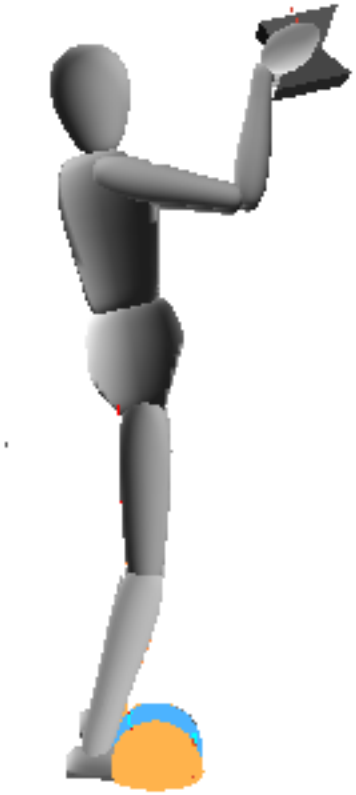


- **Caught blocks of up to 3kg!**
- Temporal resolution of servo loop strongly affects performance
- Rigid design causes higher collision impulses

Future Directions

catching a moving mass



- Integration of dynamic walking
- Implementation of novel sensing
- Exploration of robustness with respect to uncertainty