Introduction to Course Topics

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Quiz 1 (10 points)

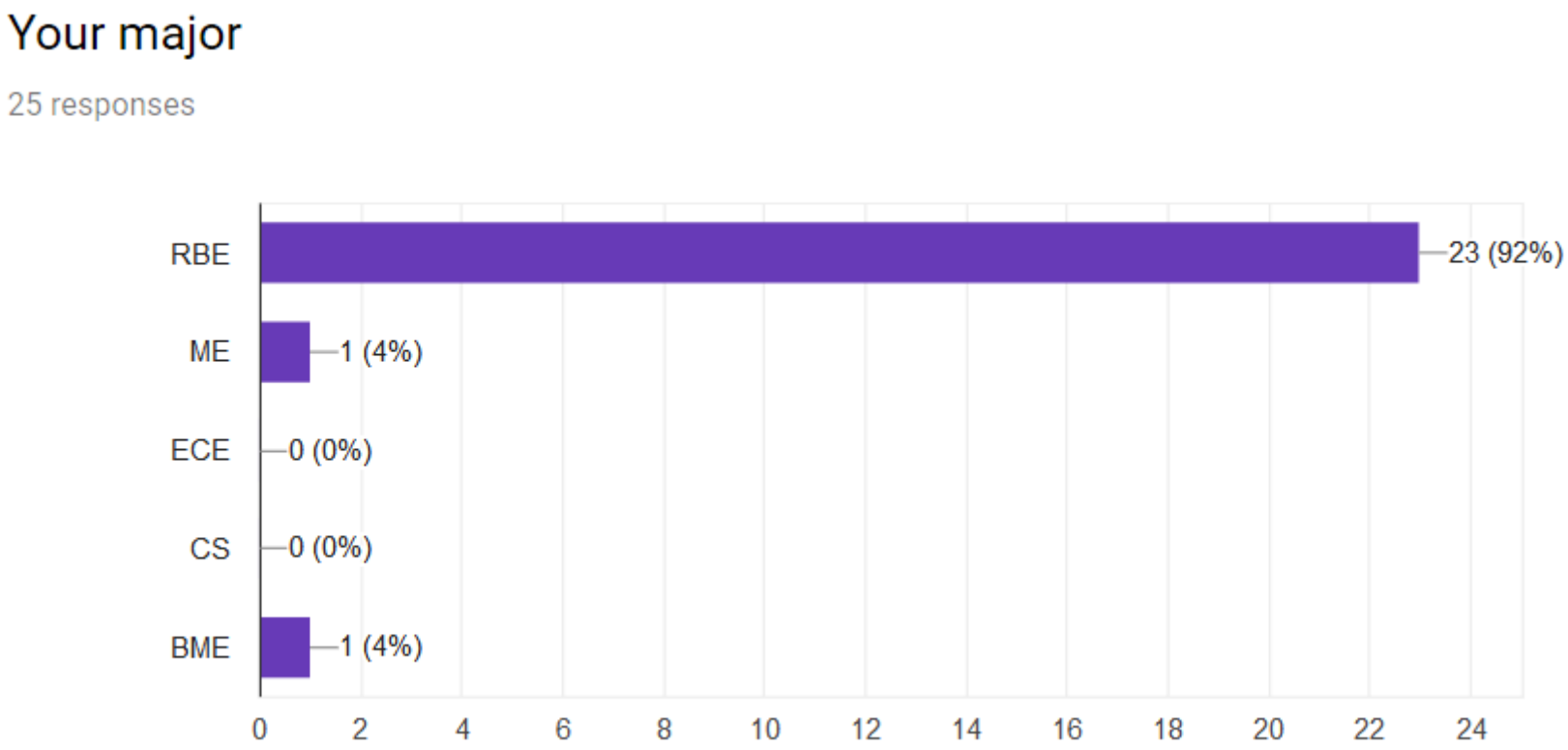
- What are the course topics I am going to introduce today?
  - Hint: there are four topics …

Overview

- A big picture to the fields of
  - Human compatible robots
  - Humanoid robots
  - Teleoperation and haptics
  - Learning from human demonstration

Class statistics

25/32 responses



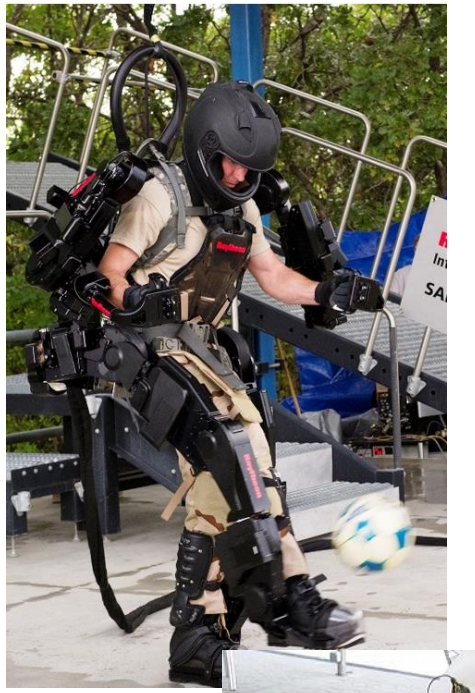
What do you want to learn from this course?

- Breath – Lecture
  - Overview and highlights of the field
  - Fundamental concepts and methods
  - General skills
- Depth – Project
  - Challenge yourself
  - Develop project specific skills

Human compatible robots

What are they?

- Exoskeletons
  - Upper limb
  - Lower limb
  - Hand
  - Whole body
  - …
- Soft exoskeletons





What are they for?

- Power augmentation
- Rehabilitation
- Teleoperation

Key issues for compatible robots

- Mechatronic design
  - Kinematics, Actuation & power transmission, sensors
- Underlying neuro-mechanisms of human motion
- Control issues
  - Stability, transparency …

Kinematics

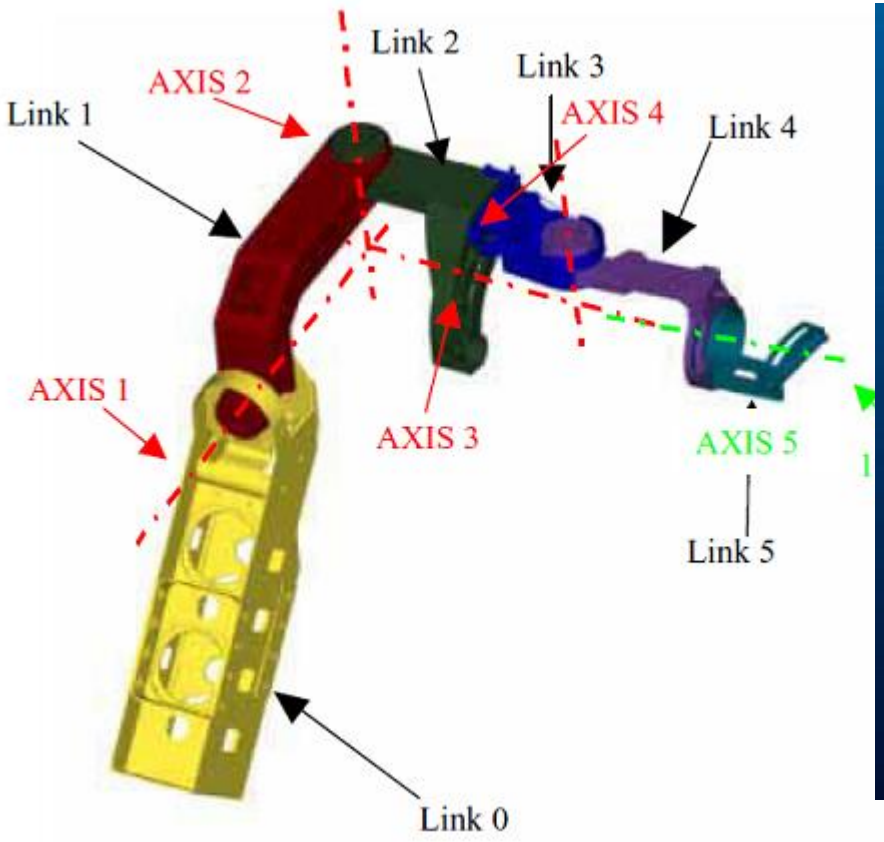
- Which segments to cover?
  - Arm? Hand? Leg? Whole body? Or selected limb segments/joints?
- # of DOFs?
  - Passive / quasi-passive / active?
  - Joint motion ranges?
  - Singularity?

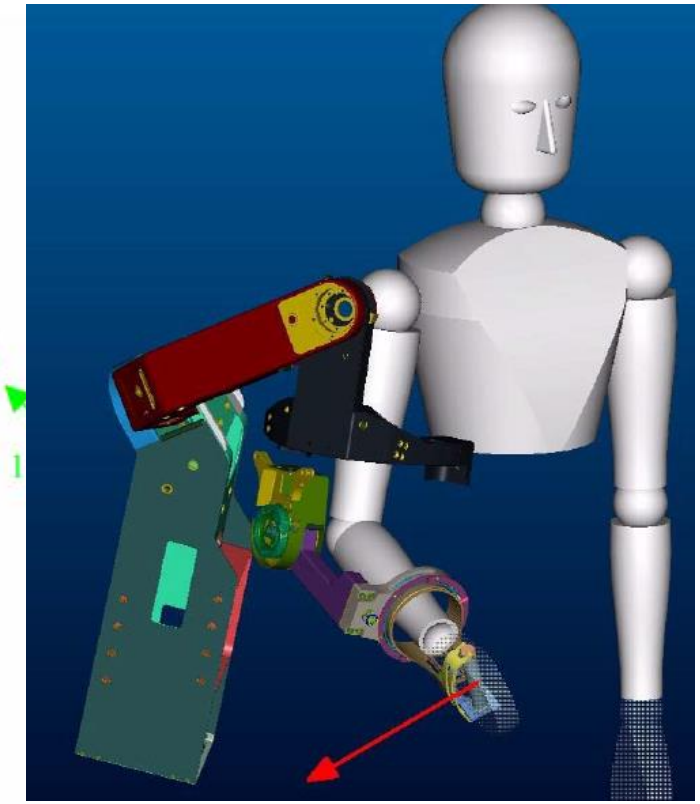
Implementation of Kinematics

- Objectives
  - Compatible to human kinematics
  - Compatible motion range
  - Less bulky structure
  - Singularity-free workspace
- Trade-off

Implementation of Kinematics

Implementation of Kinematics





Actuation

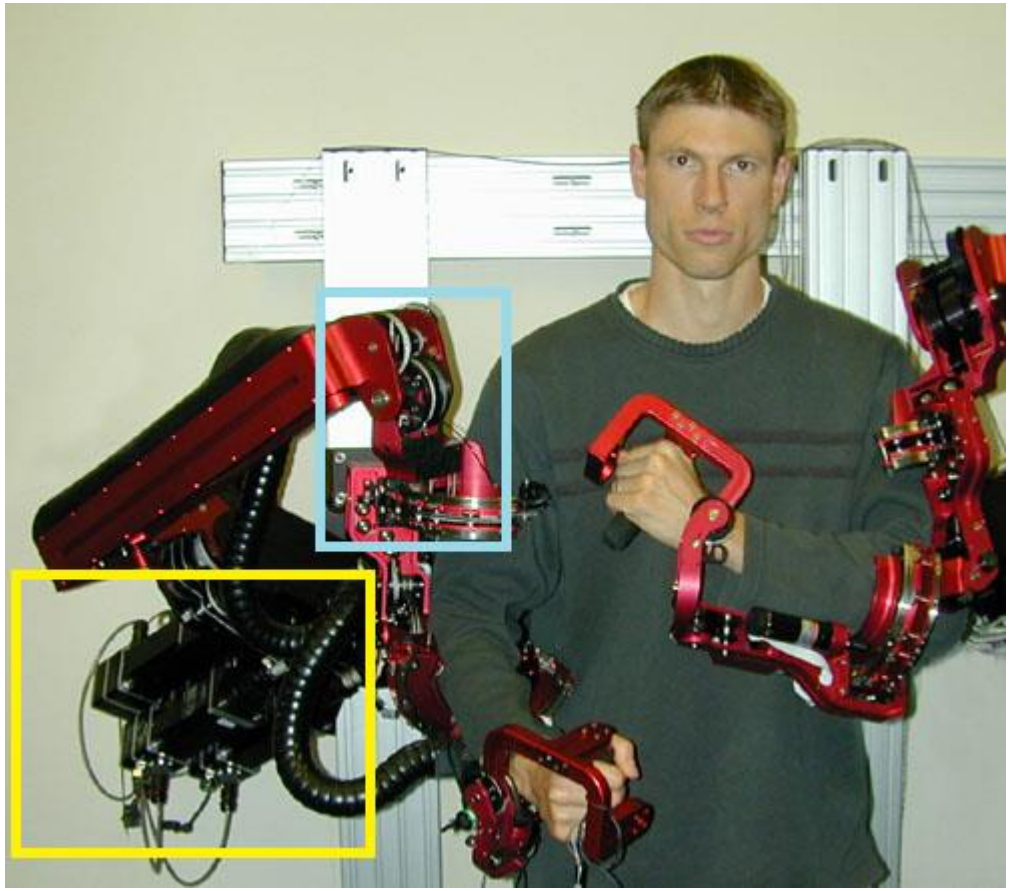
- Options?

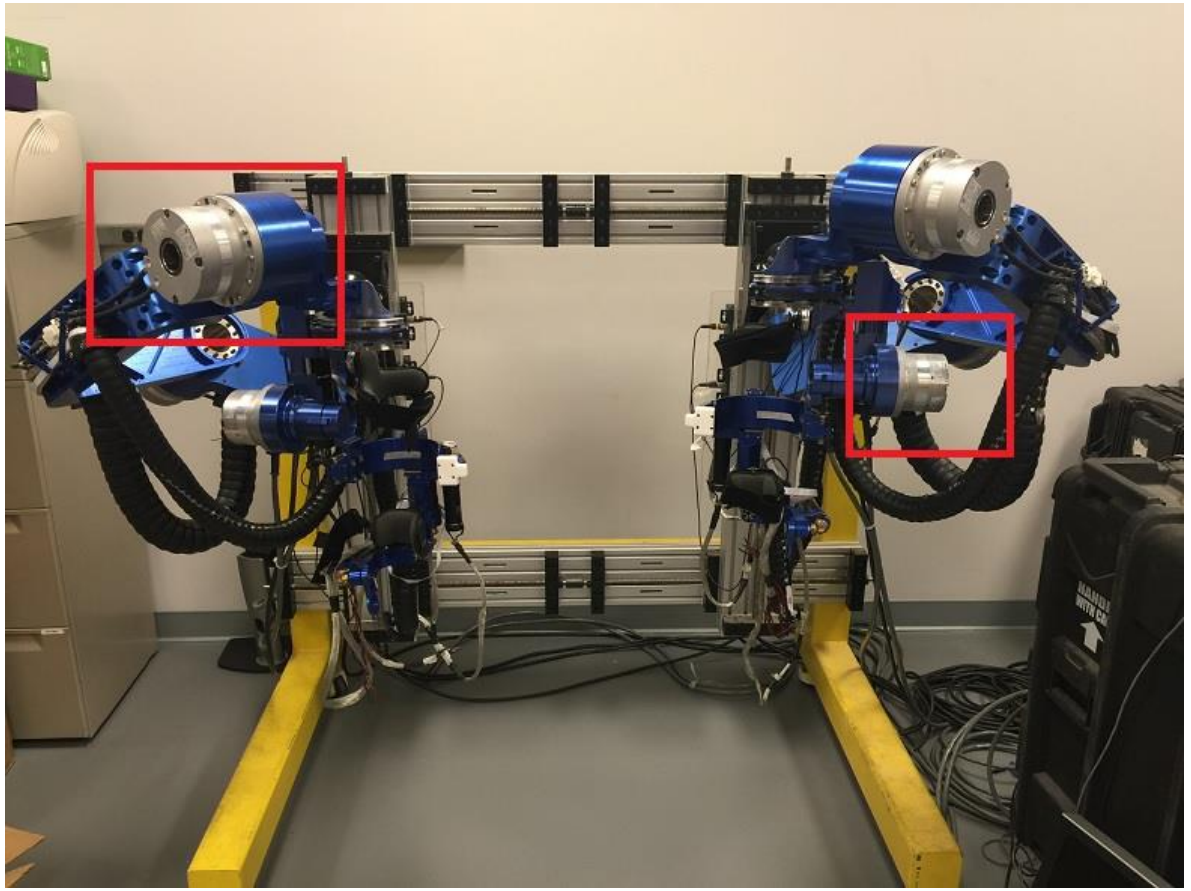
- Passive
  - Springs, elastic band

Marko Popvic – RBE & Physics
Hydro bone for passive lower limb exoskeleton

- Active
  - Hydraulic motors, Pneumatic cylinders, Pneumatic muscles, Electric motors …

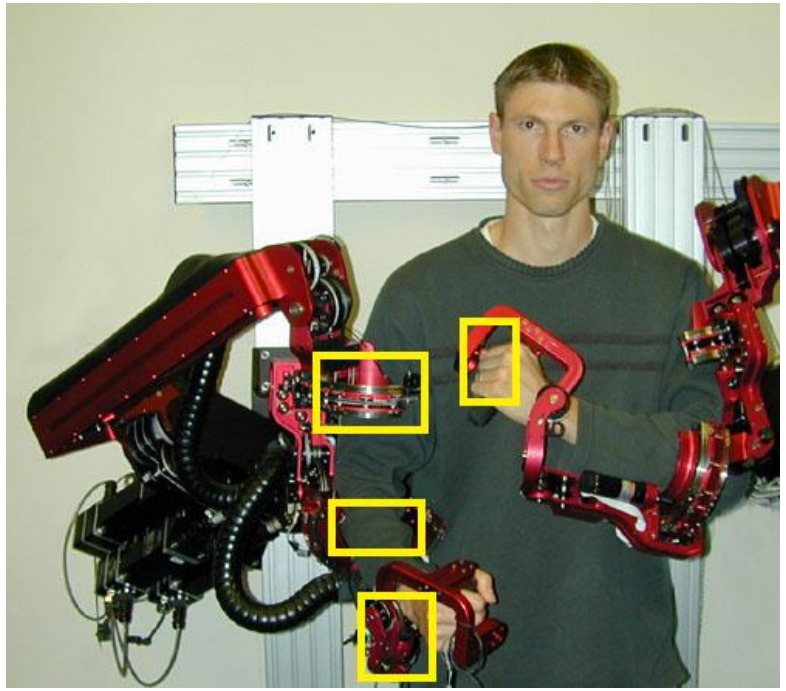
Power and Transmission Systems

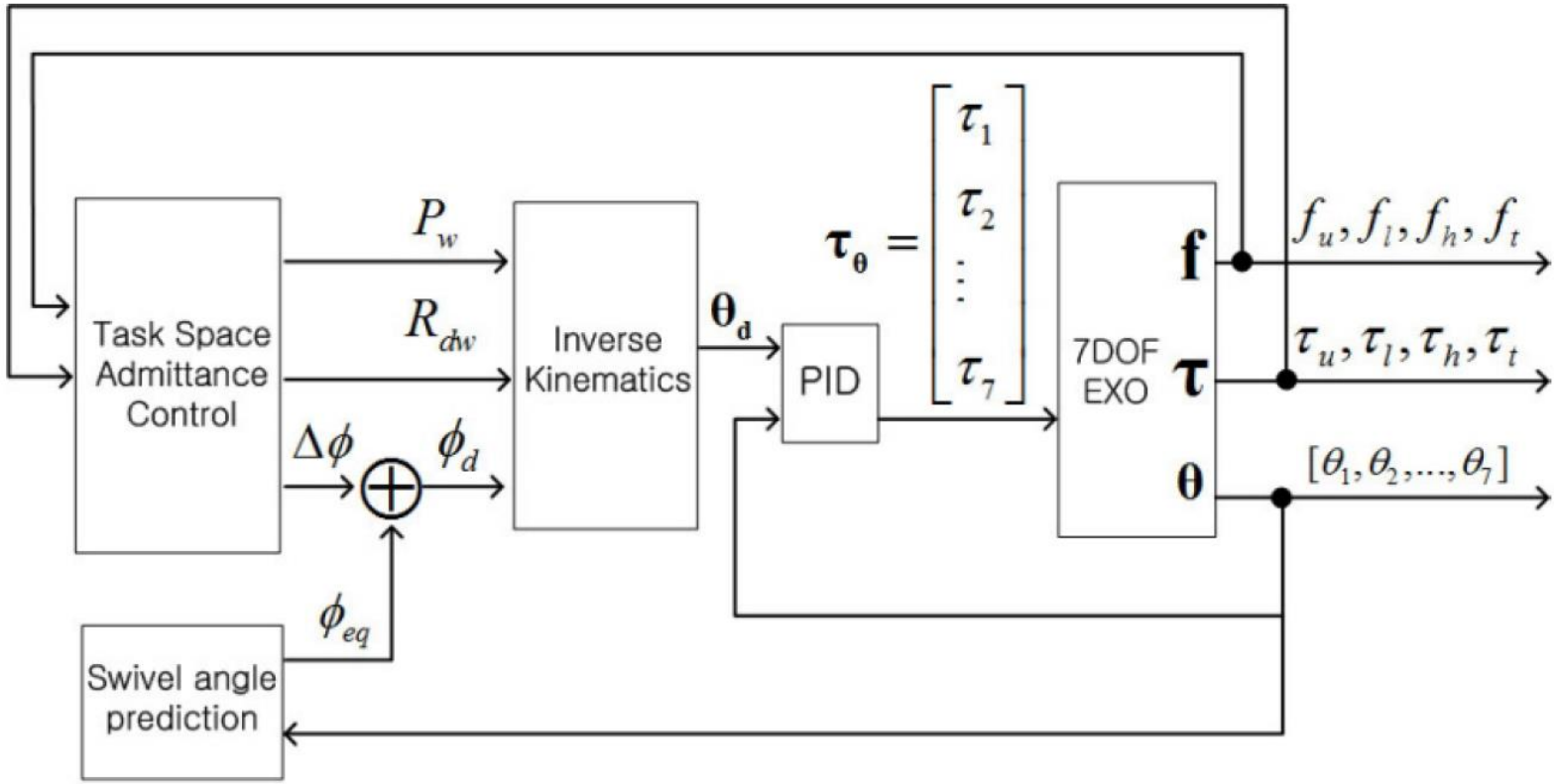




Sensors

- Force/torque sensors for admittance control



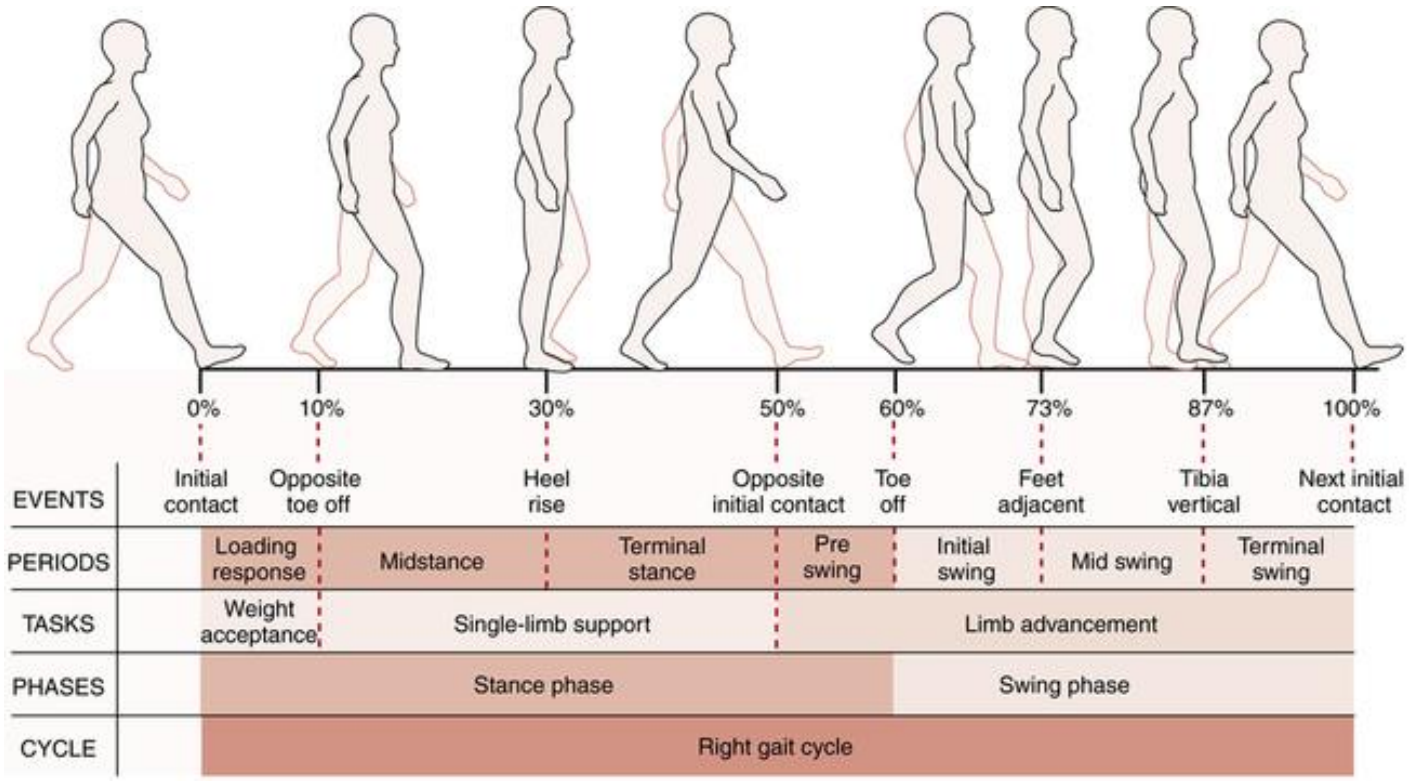


Arm V.S. Hand Exos: what are different?

- Mechanical design
  - Light-weighted, many DOFs
- Actuation and transmission
  - Under-actuated, cable-driven …
- Sensors
  - EMG, to capture muscle synergy in dexterous manipulation

Arm V.S. Leg: What are different?

- Leg motion regularity
  - Gait cycle
  - Gait phases
  - Anti-phase symmetry

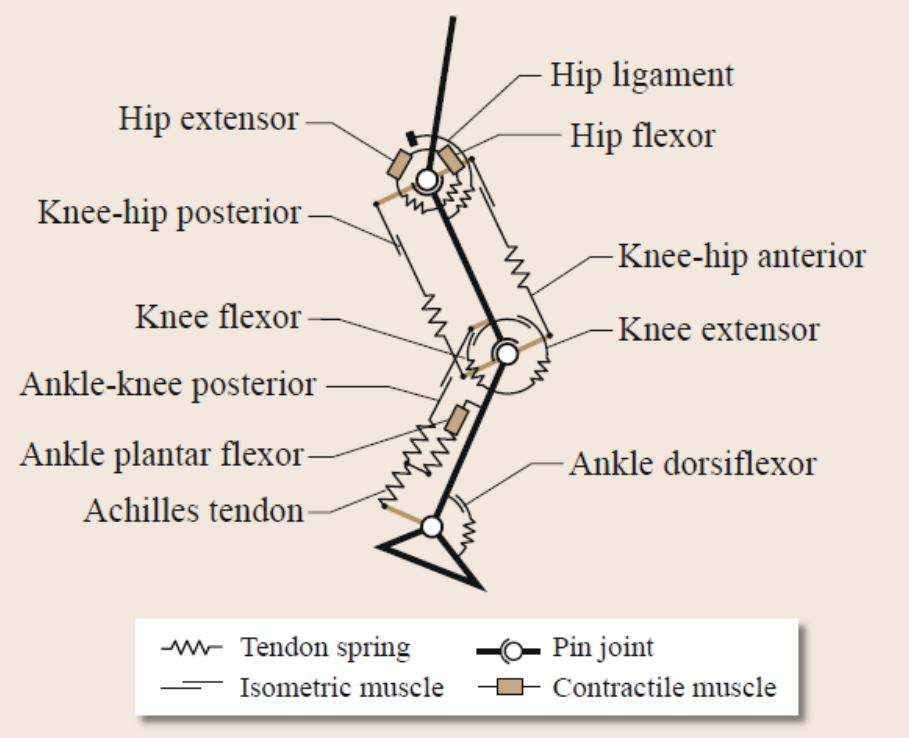


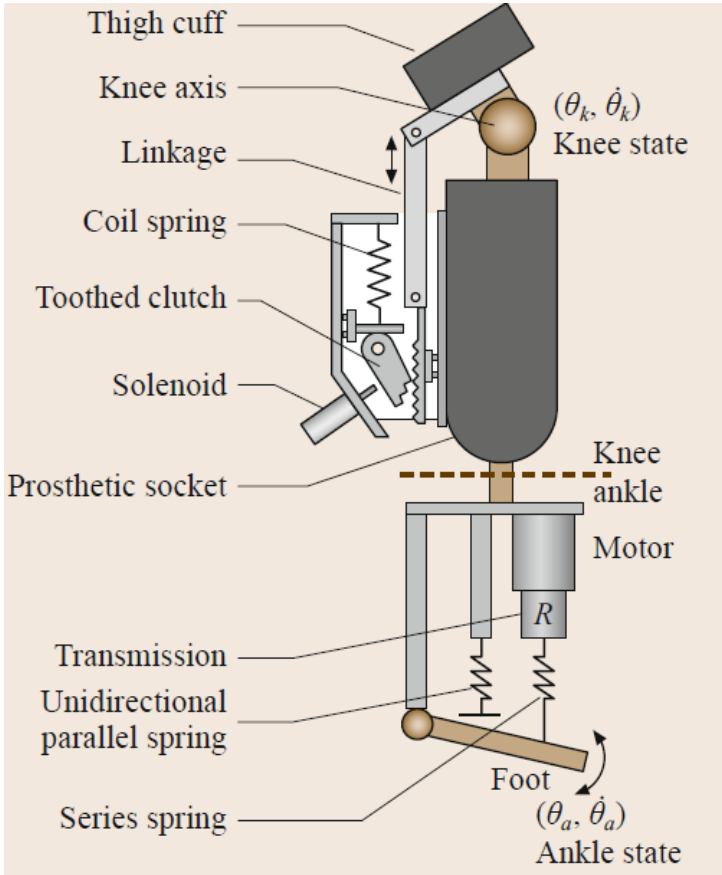
To address these differences?

- Mechanical structure?
- Actuation?
- Motion control?

Mechanical structures

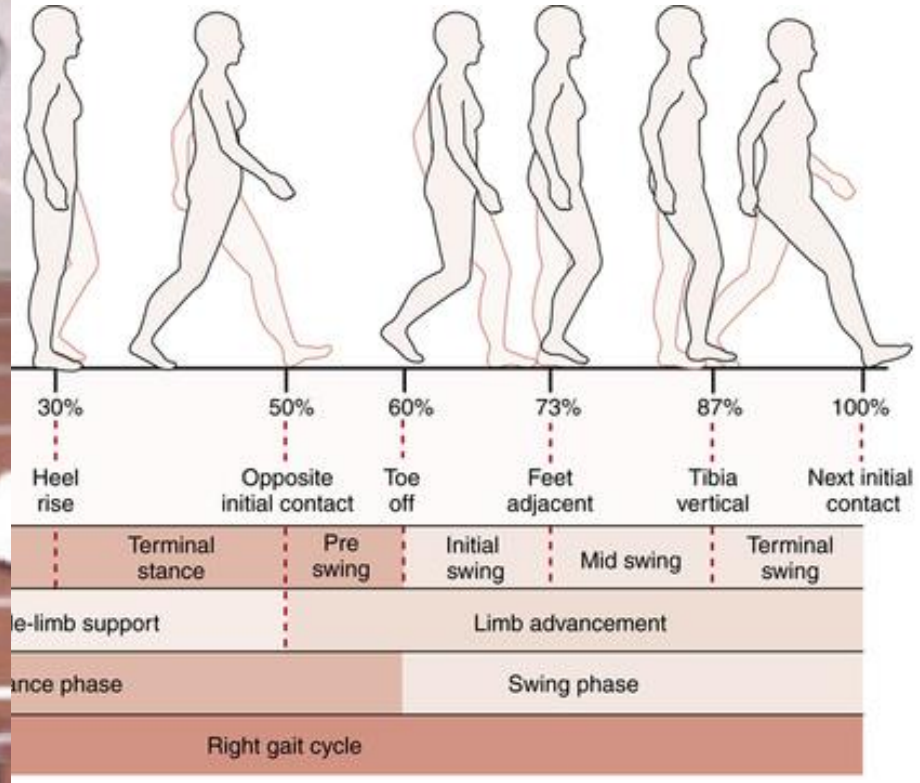
- Bio-mechanical compatibility





Actuation

- Actuation phase
- Quasi-passive design
- Energy recycling



Control issues

- Stability
- Transparency
- Operation frequency

Technology trend

- Lighter
- Softer
- Energy-efficient
- Customized
- Adaptable to human user

Humanoid Robots

Motivation

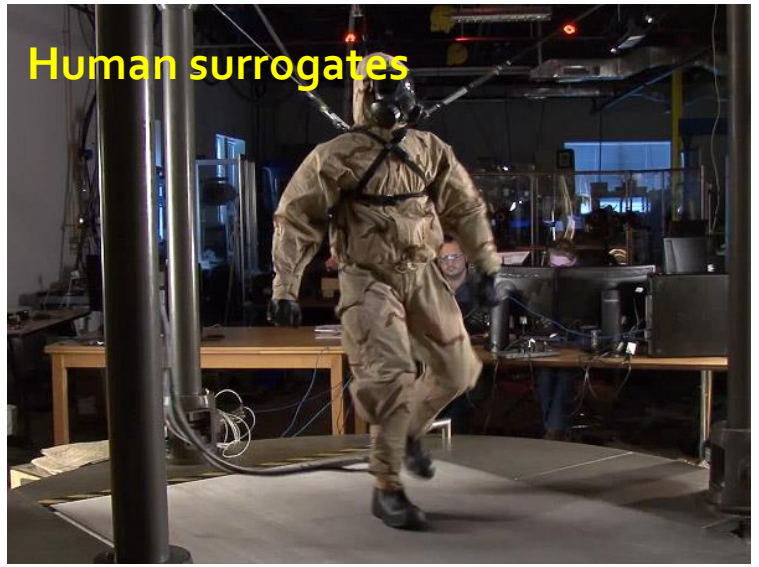
- Human surpasses current robots for overall performance
- Build robotic embodiment to imitate human characteristics
- Use humanoids as a tool for better understanding of human

Advantages of Humanoids

- Convenient to co-exist and co-work with human
- Simplified and enhanced human-robot interaction
- Easy to transfer knowledge and skills from human to robot

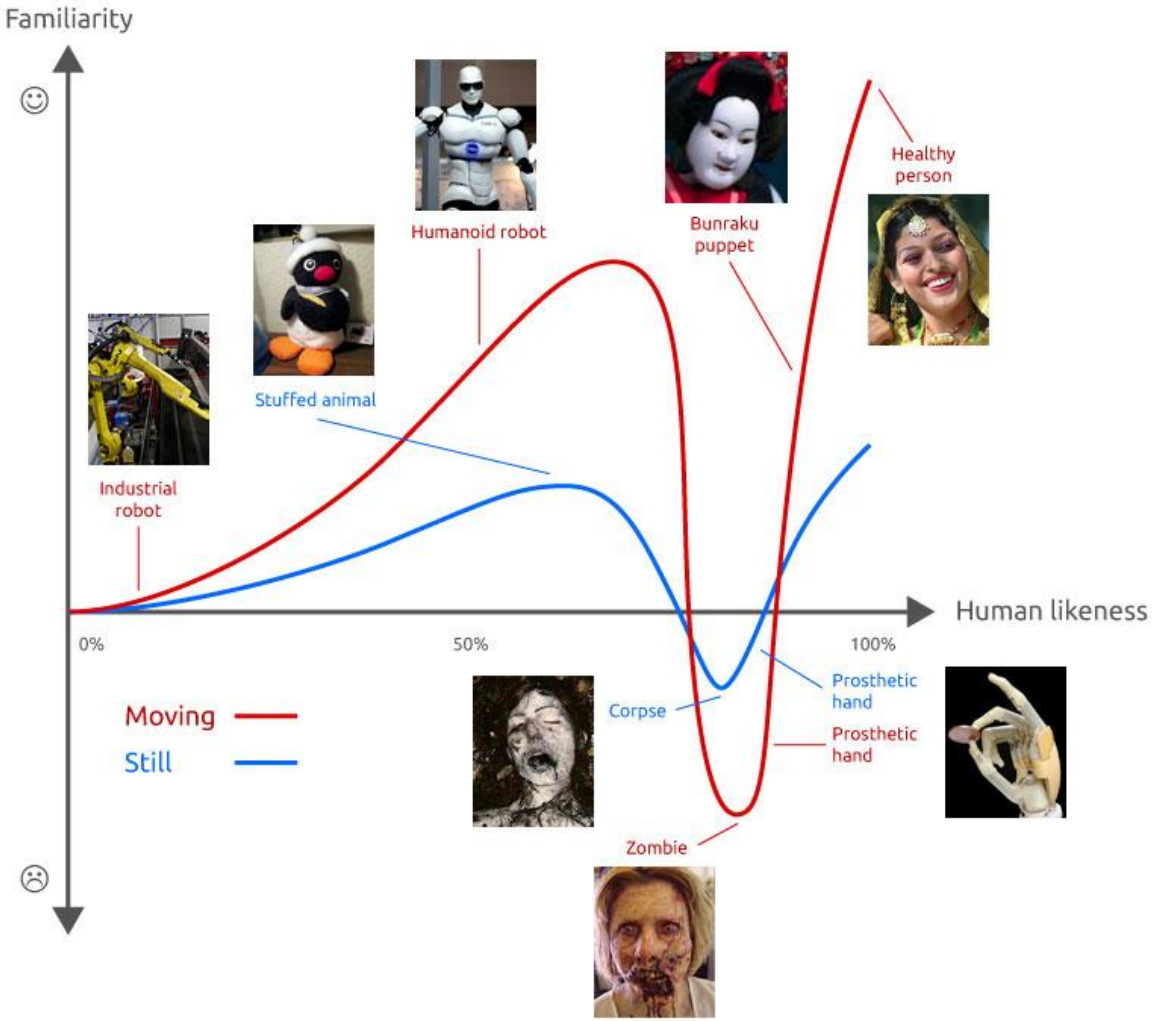
Application

- Humanoids are inherently appropriate for many applications:



What can be imitated from human?

Uncanny valley

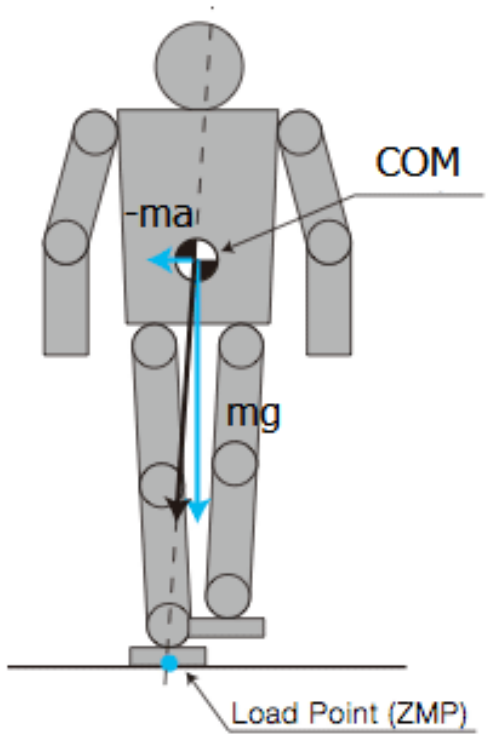


Key issues

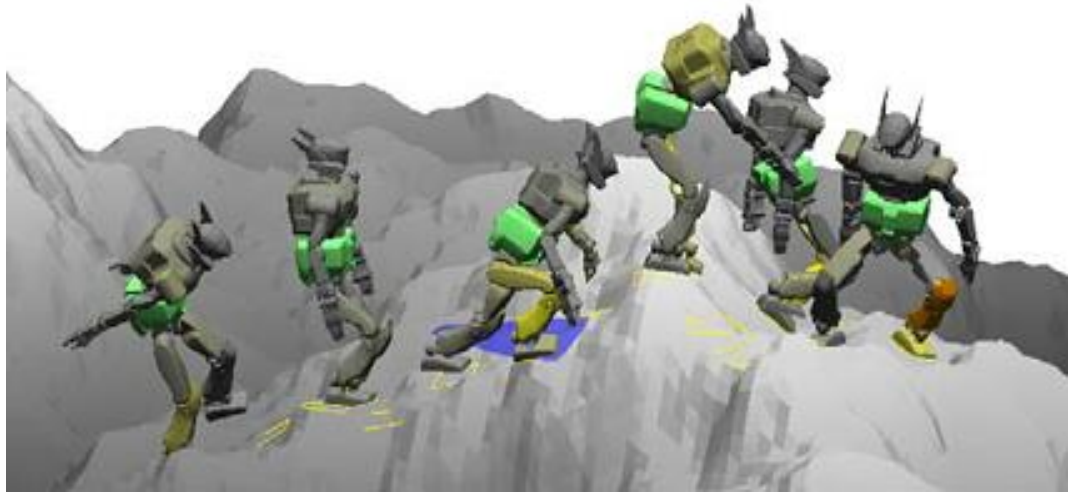
- Bipedal locomotion
- Whole-body coordination
- Coordinating arm, hand, fingers in dexterous manipulation
- Morphological Communication

Bipedal locomotion

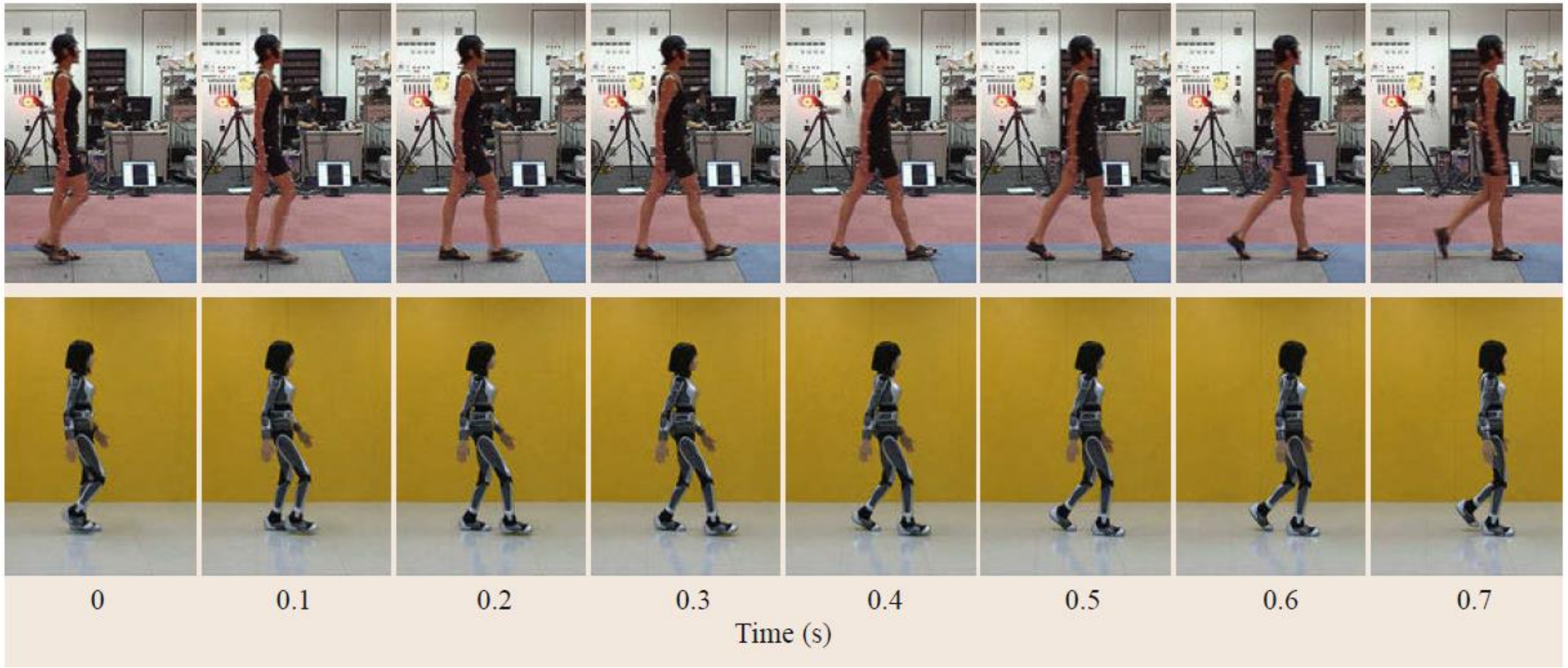
- ZMP= zero moment point
- Assumptions
  - Planar contact area
  - High-enough friction



Other locomotion styles



Rendering human-like motions



Motion Coordination in Dexterous manipulation