Real-world robot design using a construction kit and strong experimental methods

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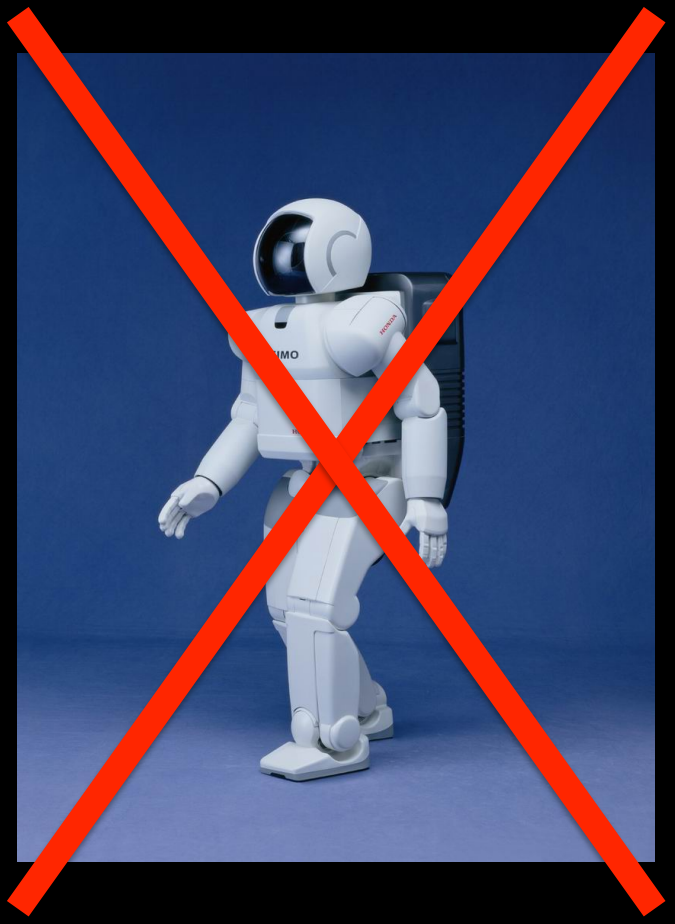
Overview

- Importance of robot morphology
- Approaches to designing complex morphology
- Proposal
  - Model-free, bottom-up
  - Construction kit
  - Strong experimental method
  - Model for analysis
- Conclusion



NO!

Honda, Asimov

MORPHOLOGY

Morphology

- Embodied Artificial Intelligence
  - "Understanding Intelligence", R. Pfeifer, 1999, MIT Press
- Embodiment:
  - Morphology
  - Materials

Morphology

- Not optimized

Honda, Asimov

- Optimized morphology

Steve Collins, Cornell Walker

iRobot, Roomba

Materials

Harvard

Embodiment Important!

- Better choice of embodiment may
  - Reduce control complexity
  - Increase energy-efficiency
  - Increase robustness
  - Increase adaptability
  - Improve interaction with the environment

Problem

- How do you..
  - Systematically
  - Efficiently
- ..design “intelligent” bodies??

- Taking advantage of
  - Embodiment
  - Materials

MORPHOLOGY DESIGN

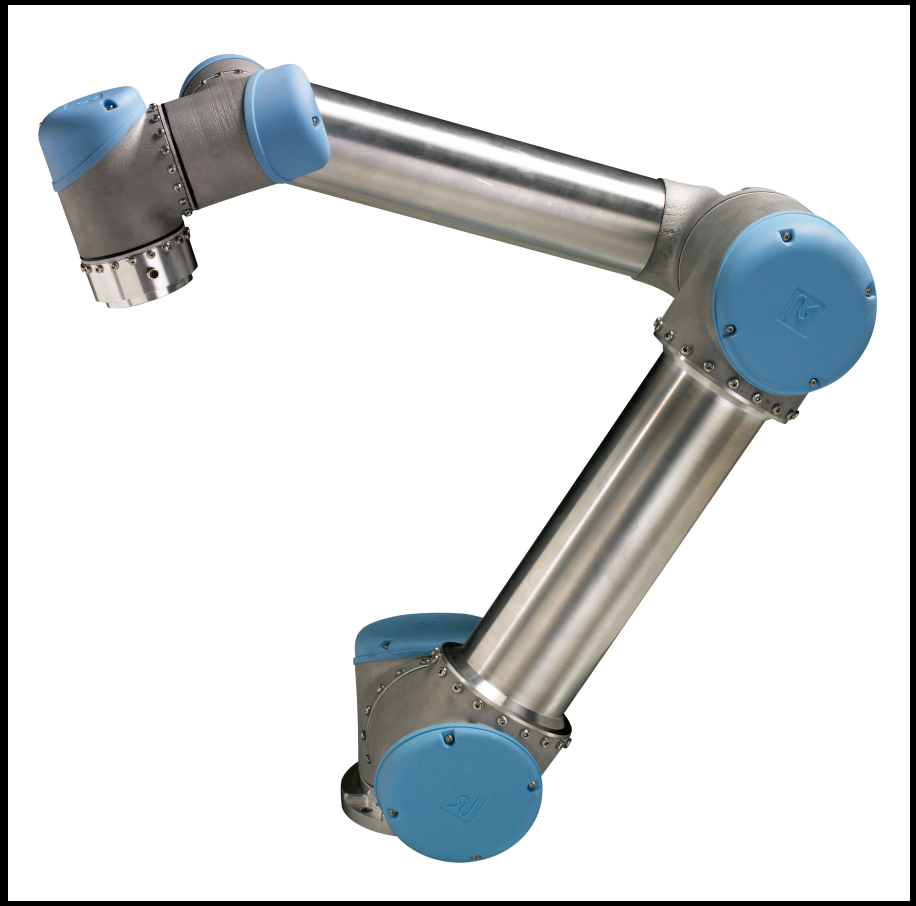
Design approaches

- Model-based
- Top-down

- Model-free
- Bottom-up

Model-based, top-down

- Approach
  - Kinematic model
  - CAD model
  - Prototype
  - Model-based controller
  - Improve model to make it work



Universal Robots, UR5

Model-based, top-down

- Advantages
  - Accepted scientific method
  - Supporting design software (Matlab, CAD)
  - Sound basis for controller

Model-based, top-down

- Disadvantages,
  - Difficult to model and therefore handle…
    - Complex environments
    - Complex morphologies
    - Functional materials
    - Interaction between all of the above

Model-free, bottom-up

- Approach
  - Ad hoc construction based on
    - Intuition
    - Biological inspiration
  - Prototype
  - Ad hoc controller
  - "Tweaking" to work

Steve Collins, Cornell Walker

Model-free, bottom-up

- Advantages
  - Easier, but not easy to handle
    - Complex environments,
    - Complex morphologies
    - Functional materials
    - Their interaction

Model-free, bottom-up

- Disadvantages
  - Not systematic
  - Not efficient
  - No supporting design tools
  - No basis for controller

  - Not really scientific!

Proposal

- Model-free, bottom-up best suited for real-world robotics
- Provide a robot construction kit as a design tool
- Make development systematic and efficient by using strong experimental methods

- Control: you have to wait for Prof. Auke Ijspeert's talk tomorrow!

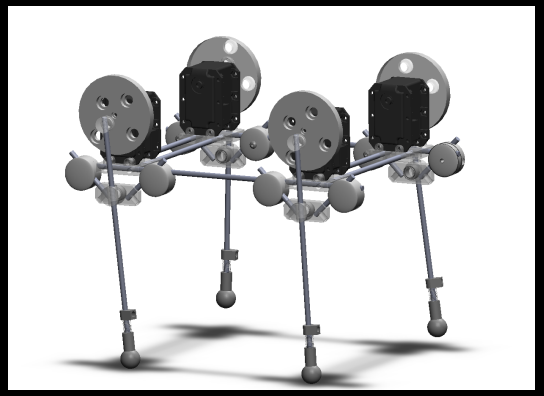
CONSTRUCTION KITS

Motivation

- Construction kits
  - LEGO, Meccano, etc..
- Construction kits facilitate
  - Easy construction
  - Adaptation

Alternatives

Robot type	Development time	Degree of optimization	Openness to morphological exploration
Monolithic	High	High	Low
Modular	Low	Medium	Medium
Construction kit	Medium	High	High



Construction Kit

Jørgen Larsen et al, LocoKit

Modular

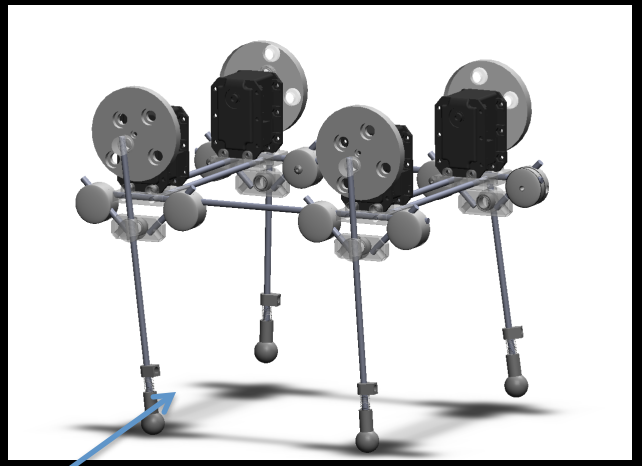
Lyder, Garciá, et al, ODIN

Monolithic

Boston Dynamics, Big dog

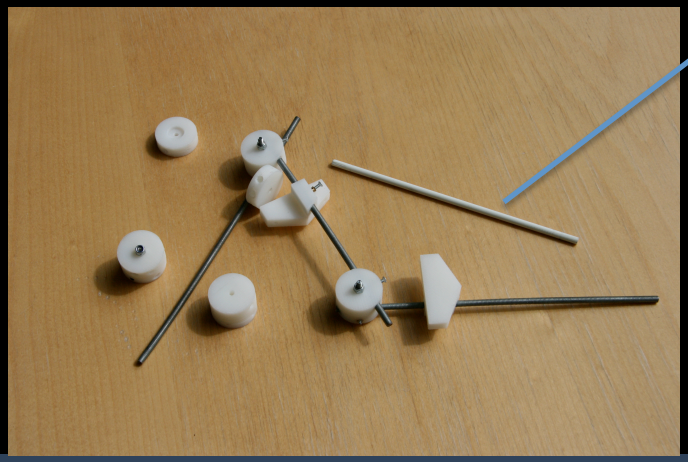
From Kit to Robot

- Broad exploration of morphology and control at several levels
- Many levels of interaction one of which is likely to match the skill and interest of the user



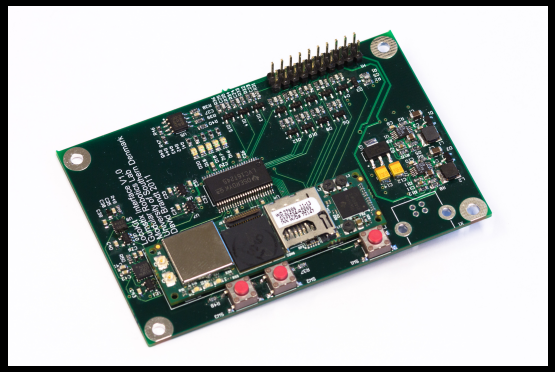
Robot

Modules for building robots



Construction kit for building modules

LocoKit - Electronics



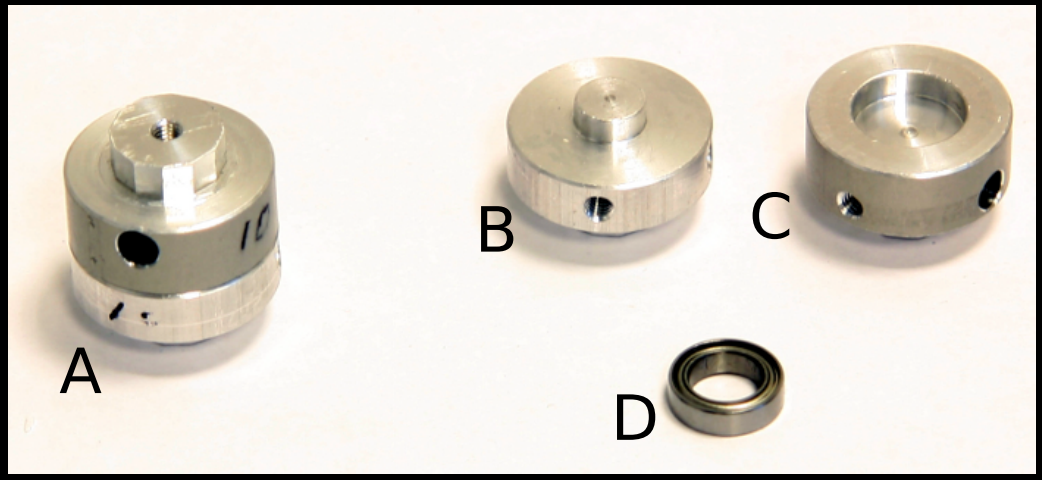
GumStix

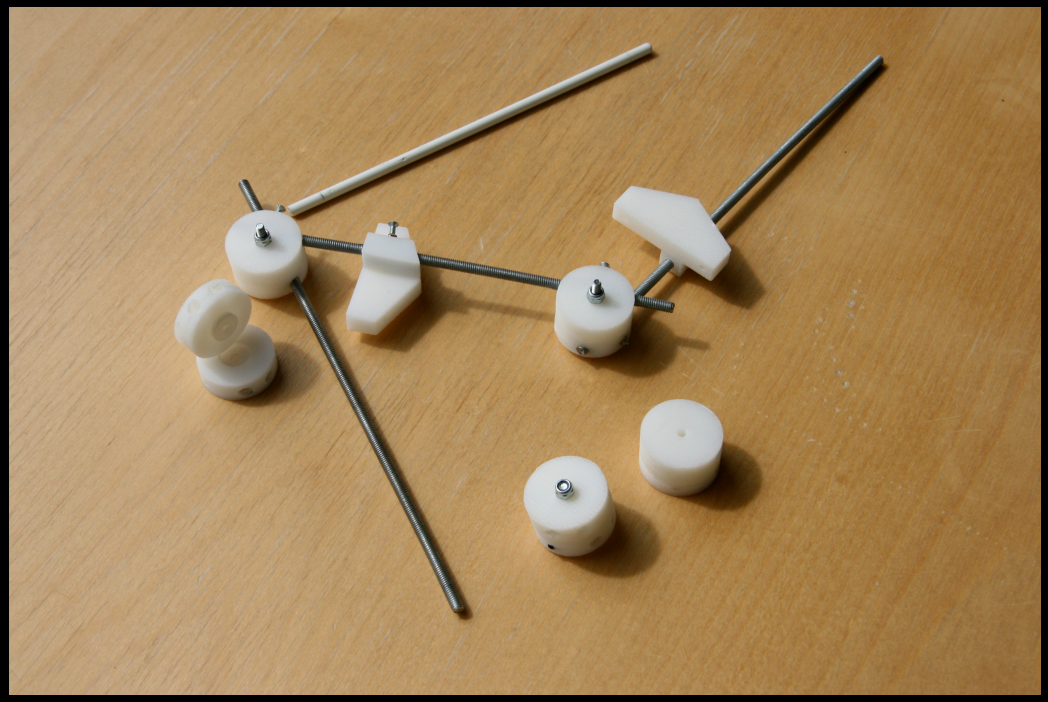
David Brandt

LocoKit - Mechanics

- Basics
  - Joints
    - Rotary
    - Fixed
  - Off-the-shelf 6mm rods
    - Glass-fiber enforced plastic
    - Aluminum
    - Carbon-fiber
    - Rubber

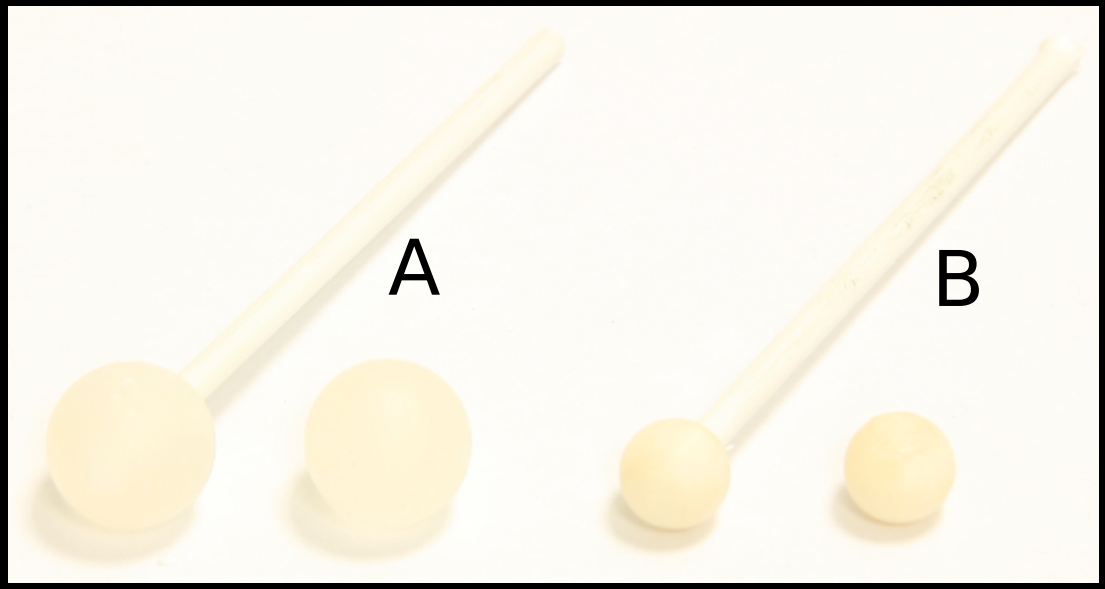
Jørgen Larsen

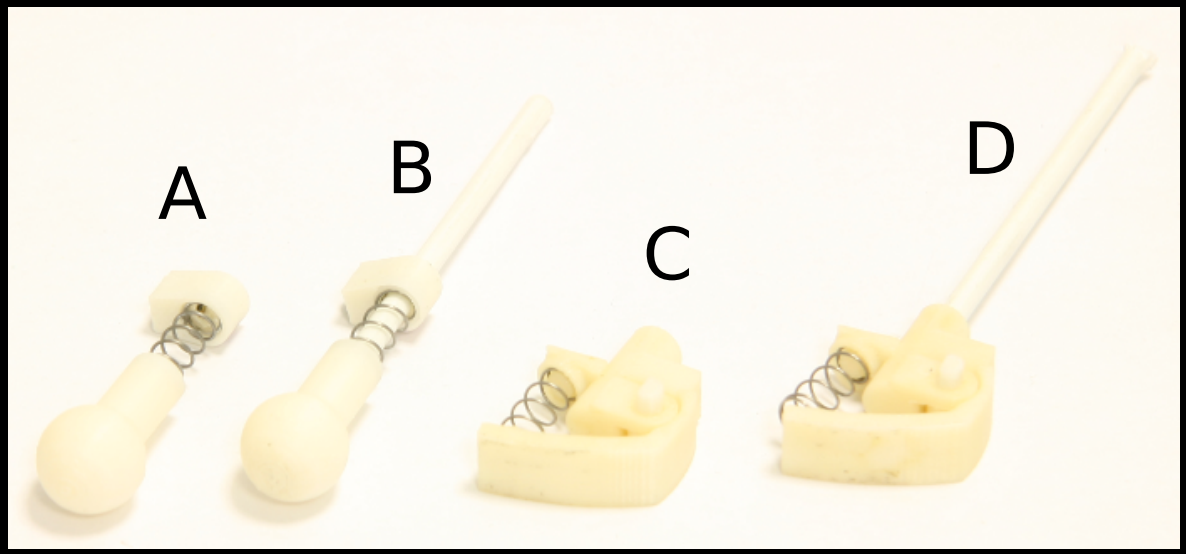




LocoKit - Mechanics

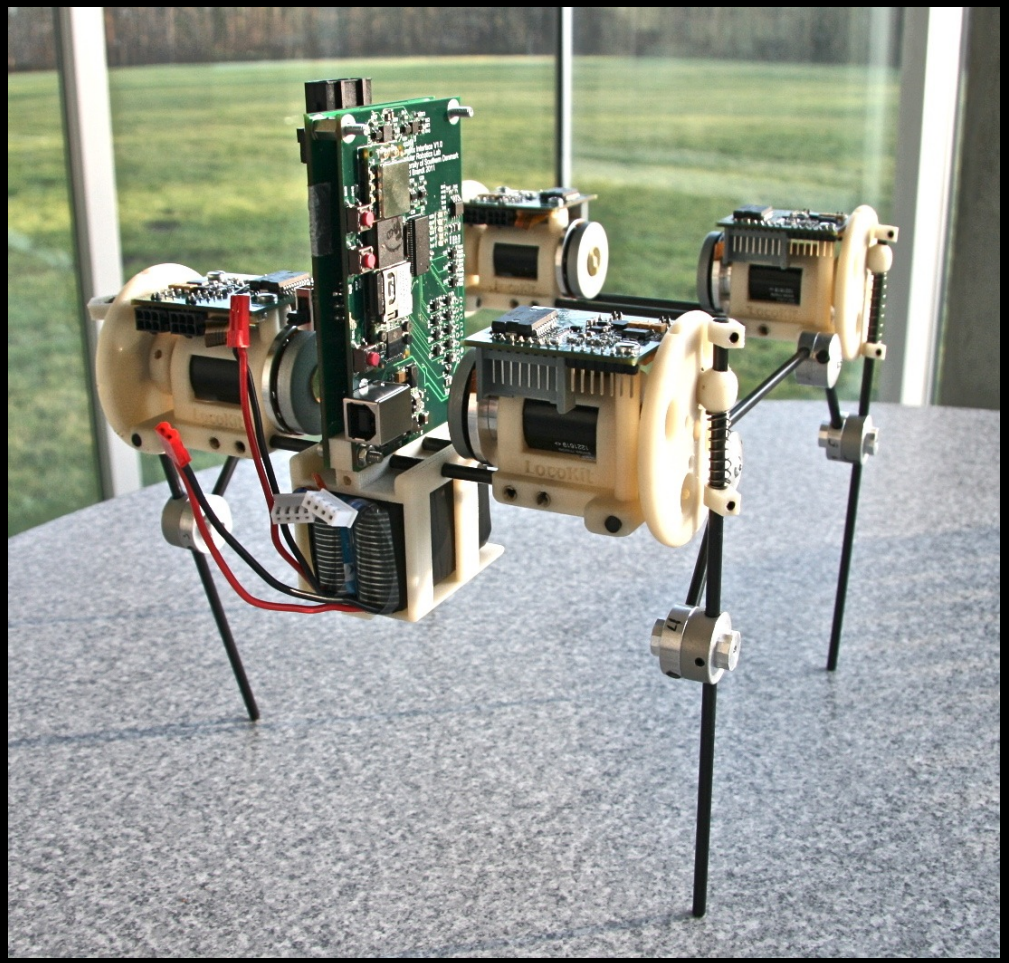
- Additional
  - Electronics mounts
  - Actuator mounts
  - Transmissions
  - Lots of feet!





LocoKit

- Construction kit message:
  - Rapid construction
  - Rapid adaptation



STRONG EXPERIMENTAL METHODS

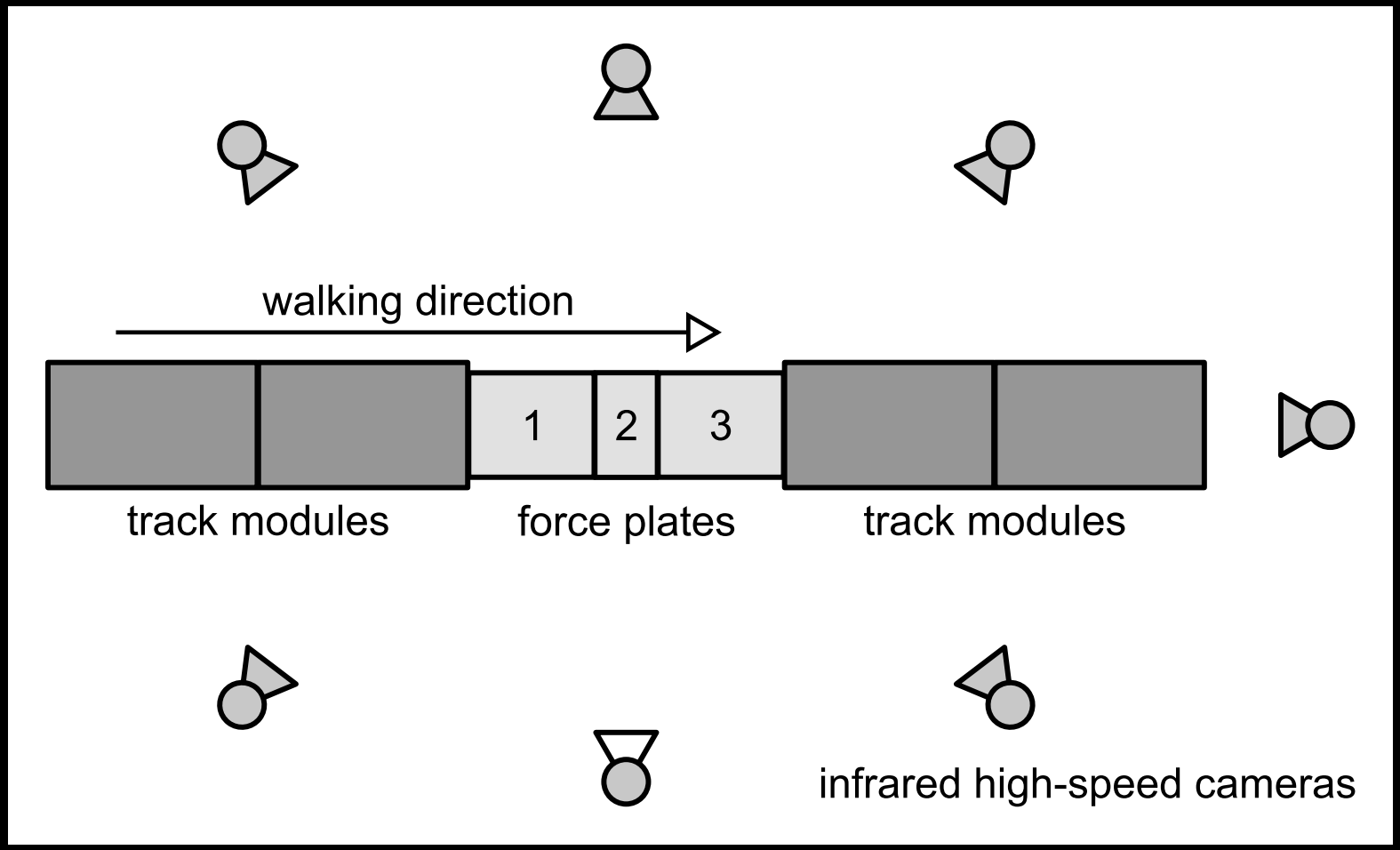
Motivation

- Need to measure the robot's behavior properly to close design loop
- Methods borrowed from biomechanics/functional morphology

Jørgen Larsen

Case-study: locomotion

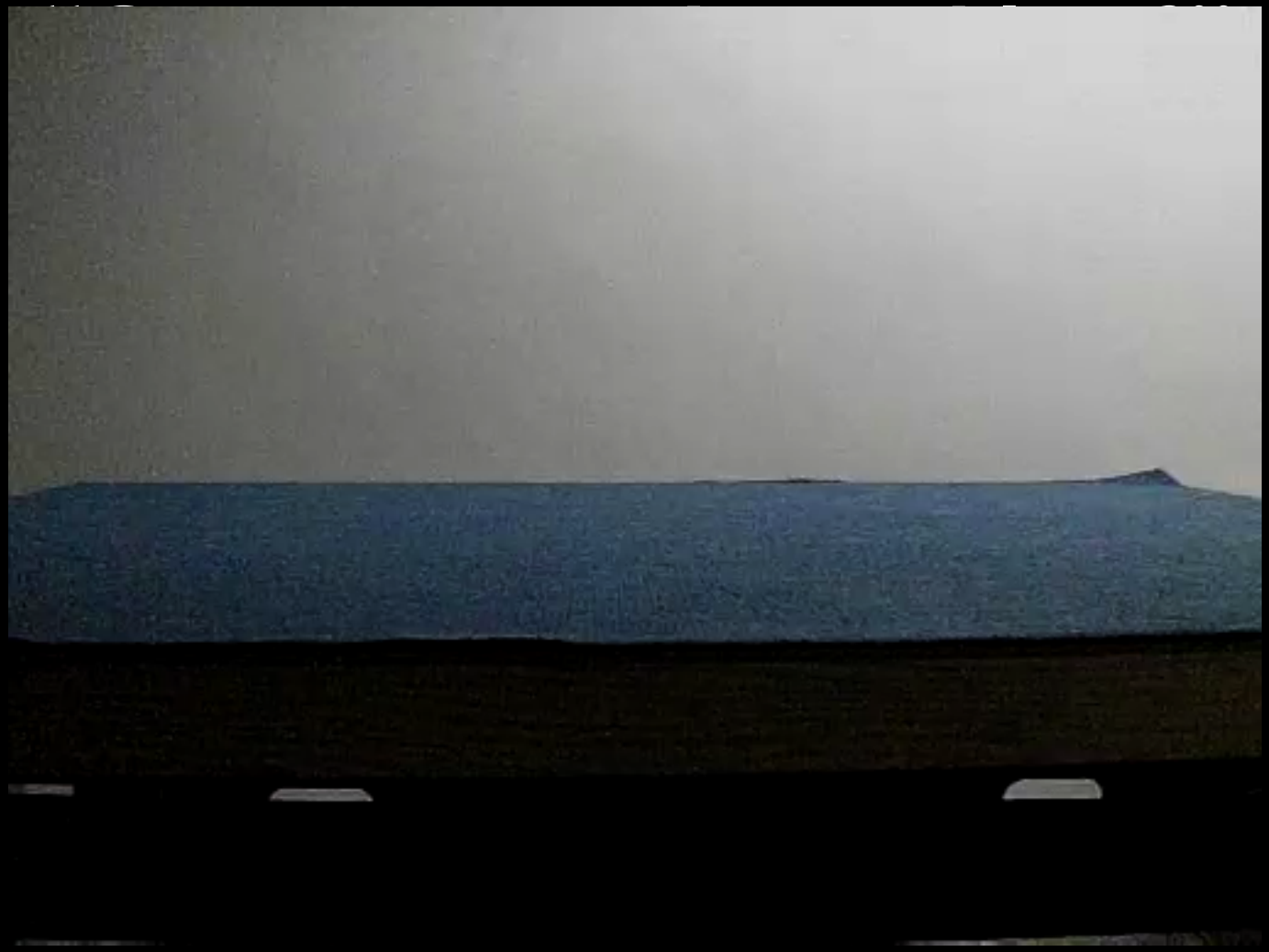
Experimental Setup



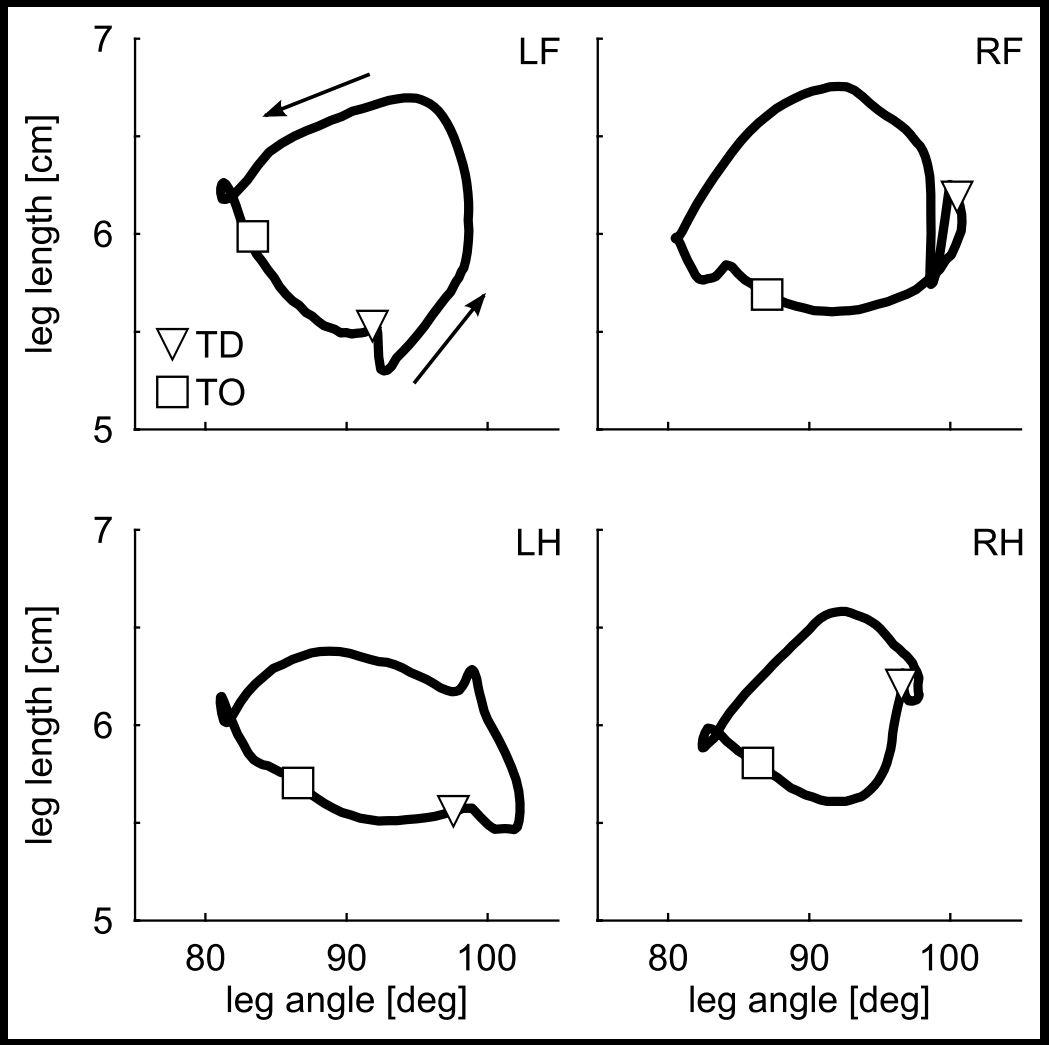
Experimental data

- Synchronized
  - Motor control outputs
  - High-speed video
  - Three-dimensional motion capture of key points on the morphology
    - allowing for calculation of relative position, speed, and acceleration
  - Output of transducers both internal and external registering mechanical variables
    - Forces, velocity, acceleration, pressure

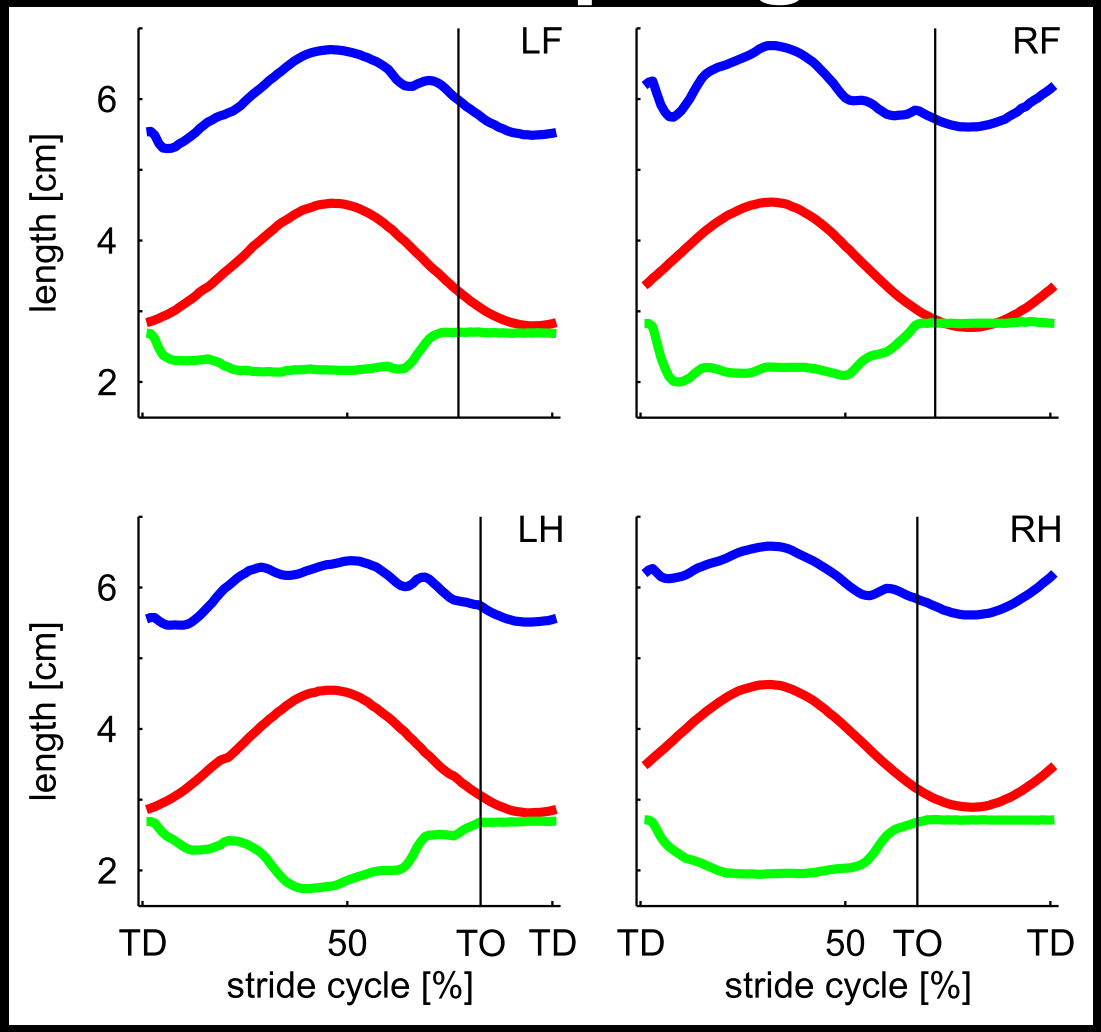
Data example: high-speed video

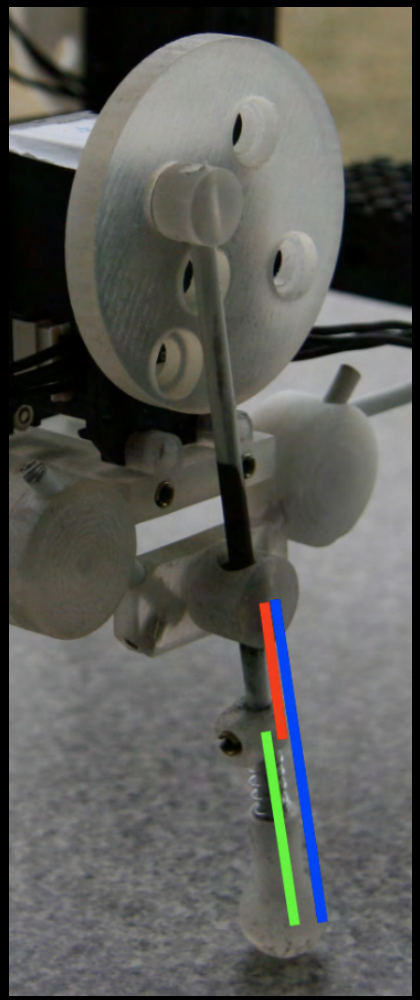


Data example: path of each leg



Stride cycle
Foot spring – too weak!





Experimental methods discussion

- No distinction between functionality of
  - Morphology
  - Materials
  - Actuation/Control
- Once a problem has been located it can often be addressed at any of these levels

Models useful?

- Models are not suited as a basis for design
- Models are great for analyzing designs!
  - Insights
  - Generalization

Conclusion

- Embodiment crucial for real-world robots
- Model-free approach allows us to handle complex
  - Environments
  - Morphologies
  - Materials
  - Their interaction
- A construction kit, such as LocoKit, accelerates development
- Strong experimental methods closes design cycle efficiently and systematically

Thank you

http://modular.mmmi.sdu.dk

http//youtube.com/usdmrl

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