The Yoyo-Man

Jean-Paul Laumond

Humans are not walking, they are rolling!

- Understand walking…
  … to better design walkers

E.J. Marey, © Cinémathèque Française

- Understand walking…
  … to better design walkers

Etienne Jules Marey
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E.J. Marey, © Cinémathèque Française

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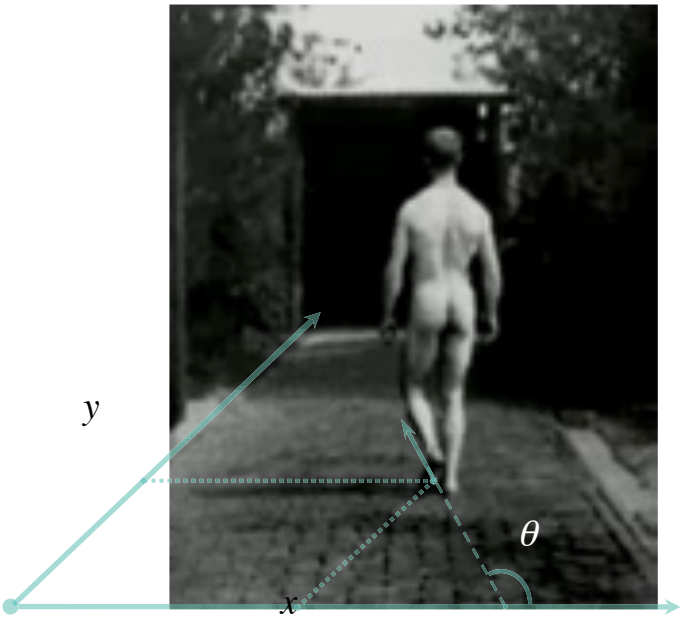

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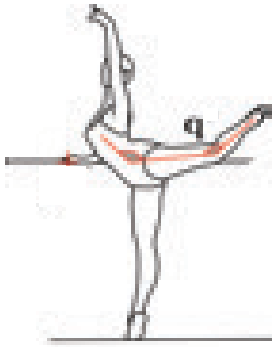
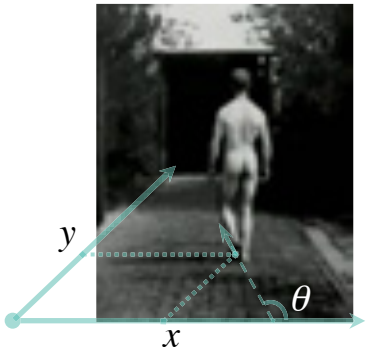
- An underactuation issue





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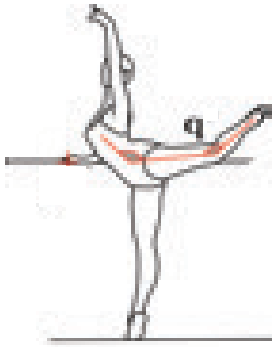
Physical Space

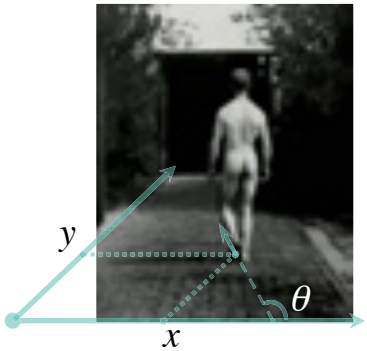
Placement Space × *Posture Space*

Sensory Space

Motor Space

- An underactuation ***complex*** issue





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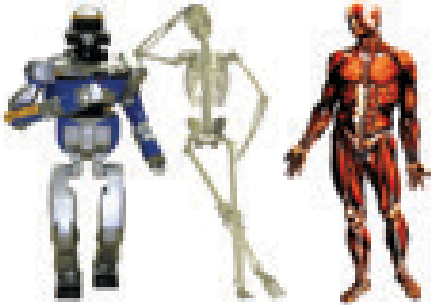
Physical Space

Placement Space × *Posture Space*

Motor Space

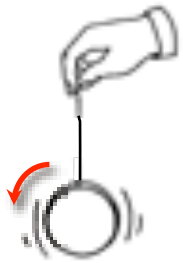


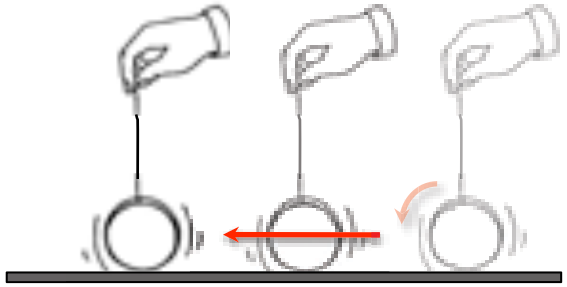
30 motors for the robot, 600 muscles for humans

Synergies:

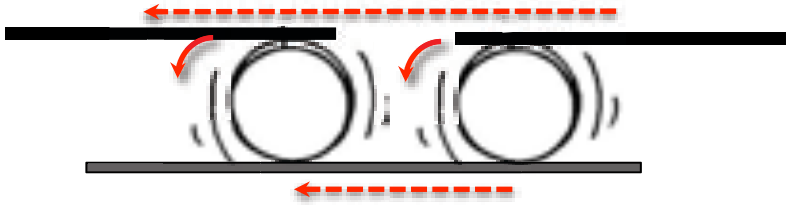
How to reduce the dimension of the search space?

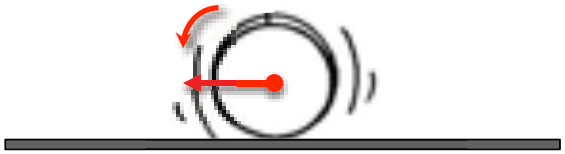
- Rolling





Tribute to the wheel
(-3500)

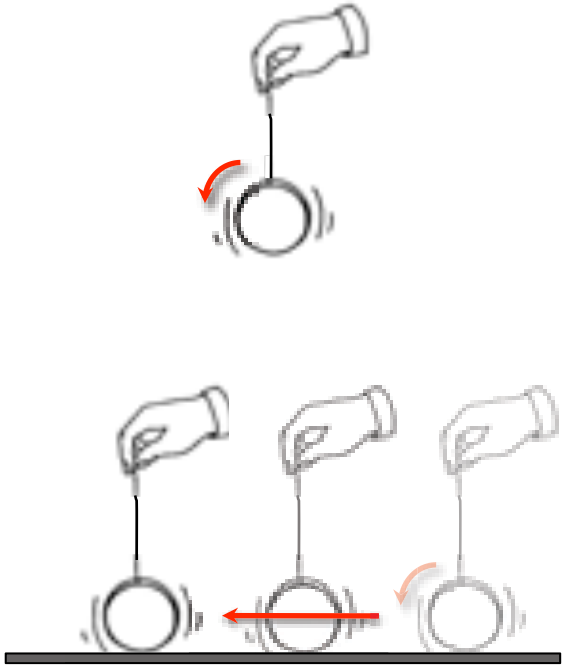




From log to wheel

Displacement

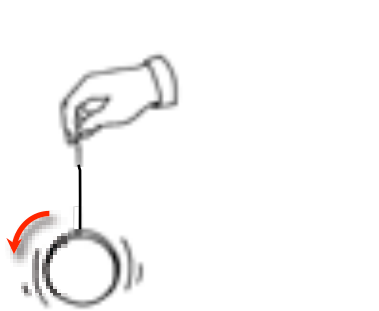
- Rolling

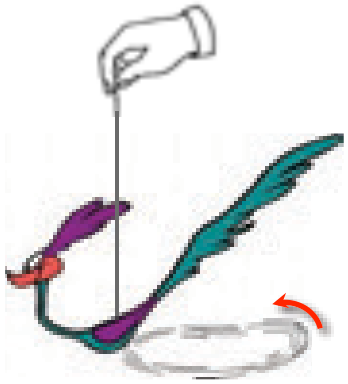


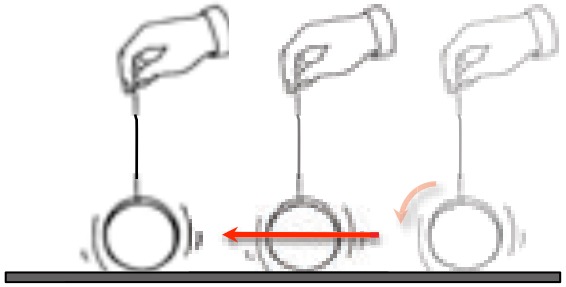
Roadrunner, Chuck Jones © Warner Bross

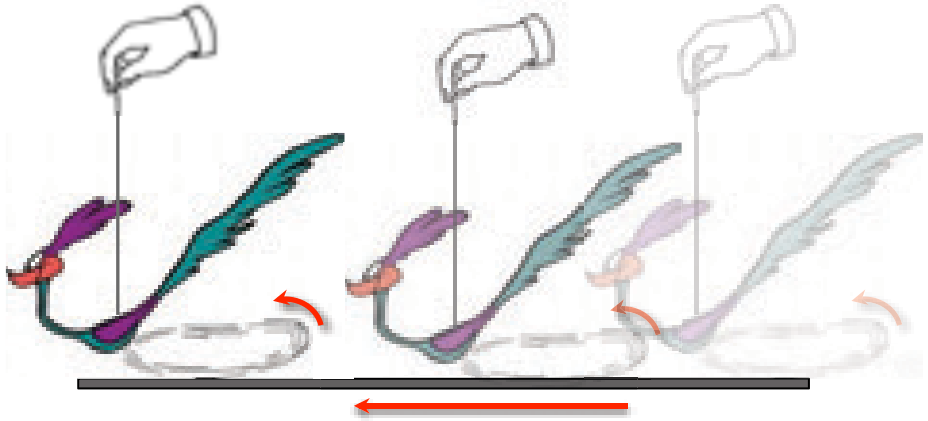
Displacement

- Rolling







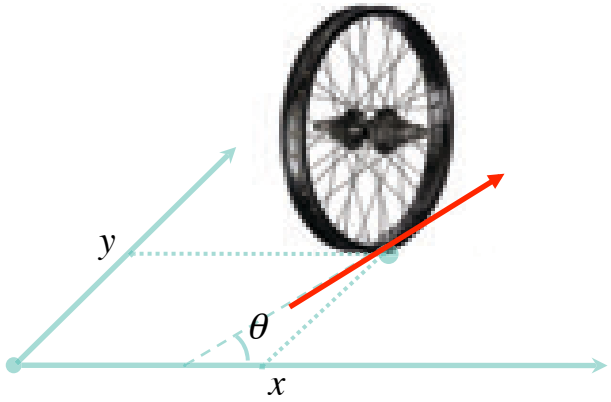


Displacement

- How do you walk?

First intuition: Walkers are nonholonomic

- How do you walk?



$$\dot{x}\,\sin\theta \;-\; \dot{y}\,\cos\theta \;=\; 0$$

First intuition: Walkers are nonholonomic

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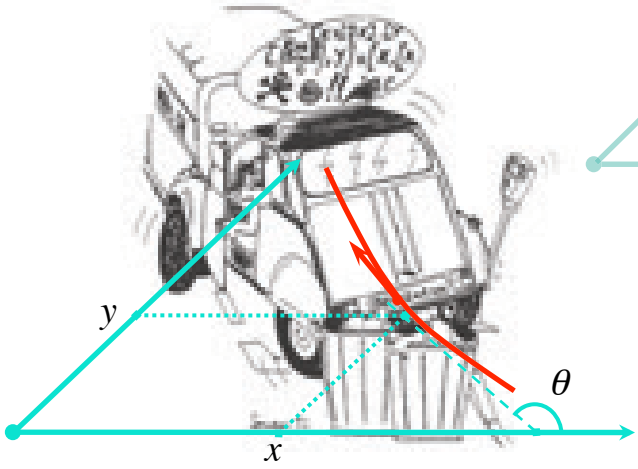

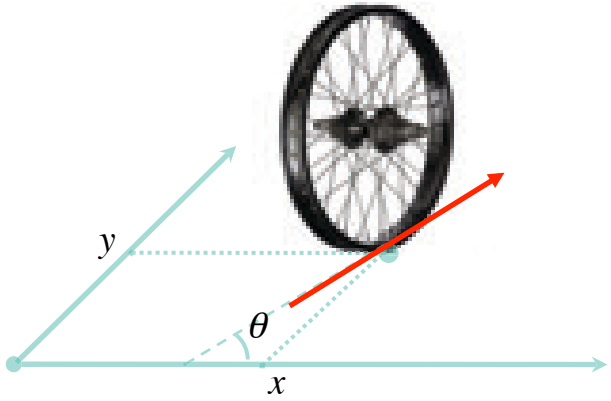

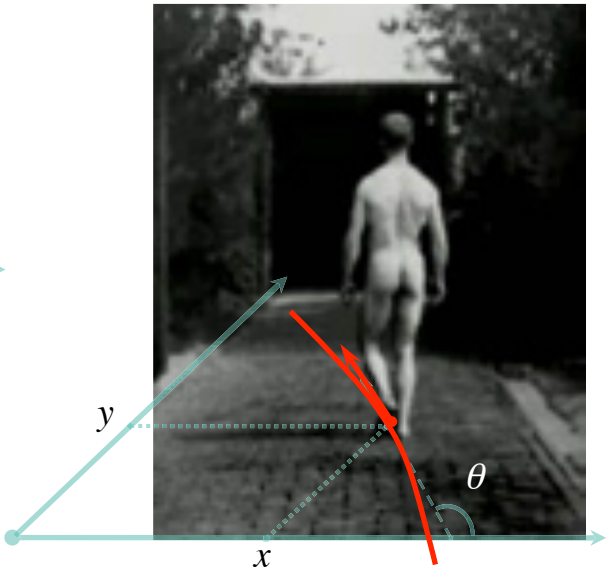

$$\dot{x}\,\sin\theta \;-\; \dot{y}\,\cos\theta \;=\; 0$$

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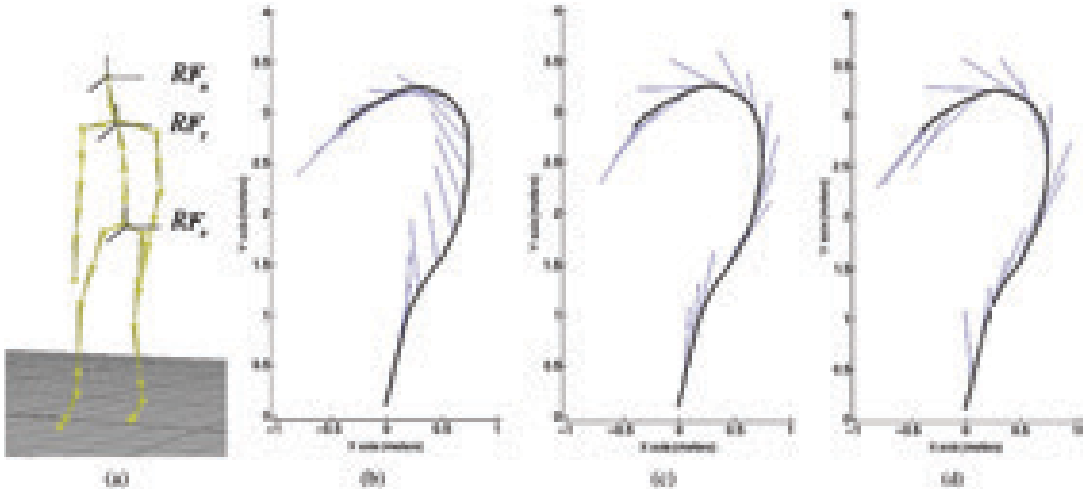
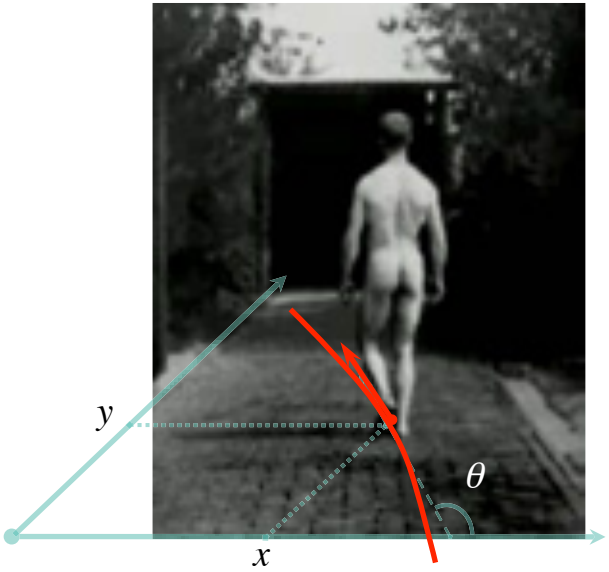
- How do you walk?



G. Arechavaleta, J.P. Laumond, H. Hicheur, A. Berthoz
Autonomous Robots, 2008



$$\dot{x}\,\sin\theta \;-\; \dot{y}\,\cos\theta \;=\; 0$$

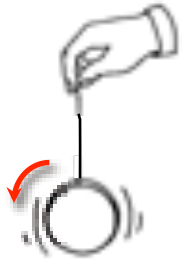
First intuition: Walkers are nonholonomic

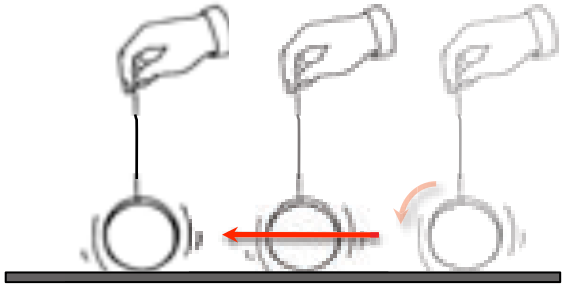
- How do you walk?

A. Berthoz, T. Pozzo, Posture and Gaits, Elsevier, 1988

Second intuition: Walkers stabilize the head direction

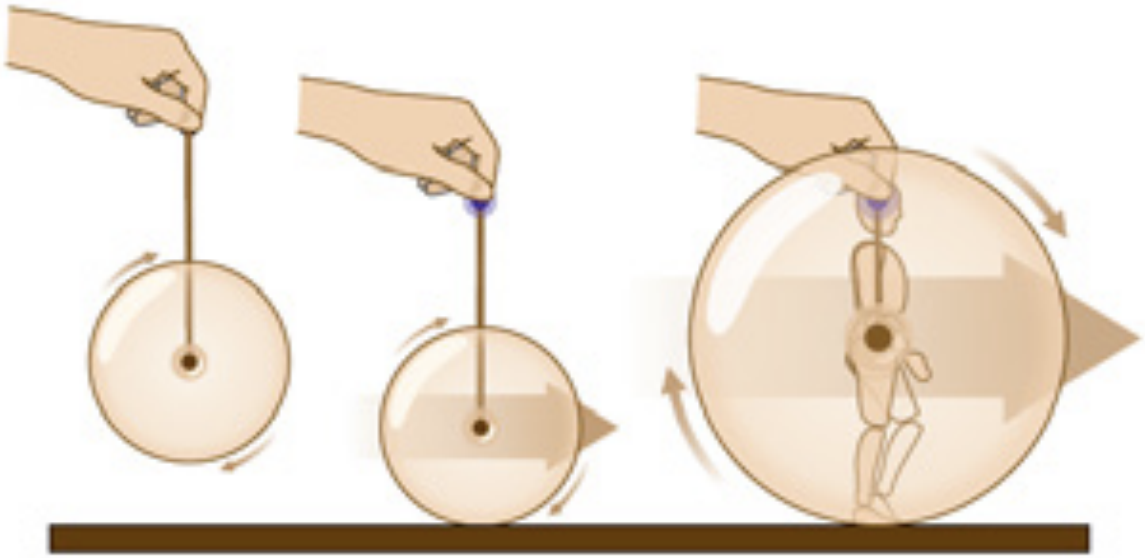
- How do you walk?





Displacement

The Yoyo-Man: the quest of walking « centers »

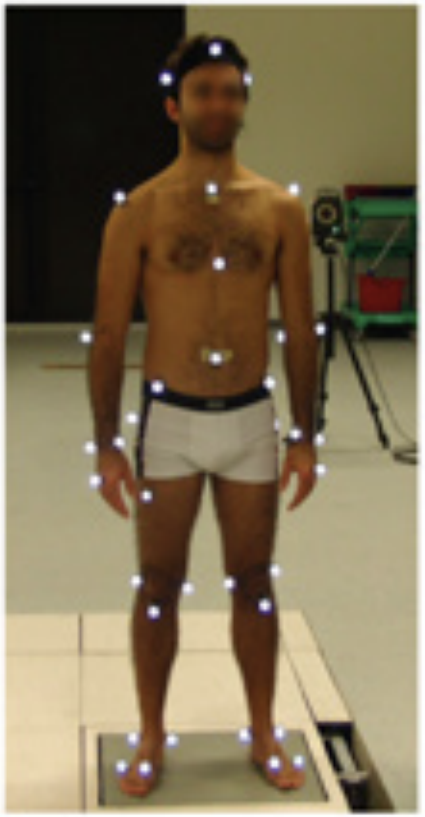


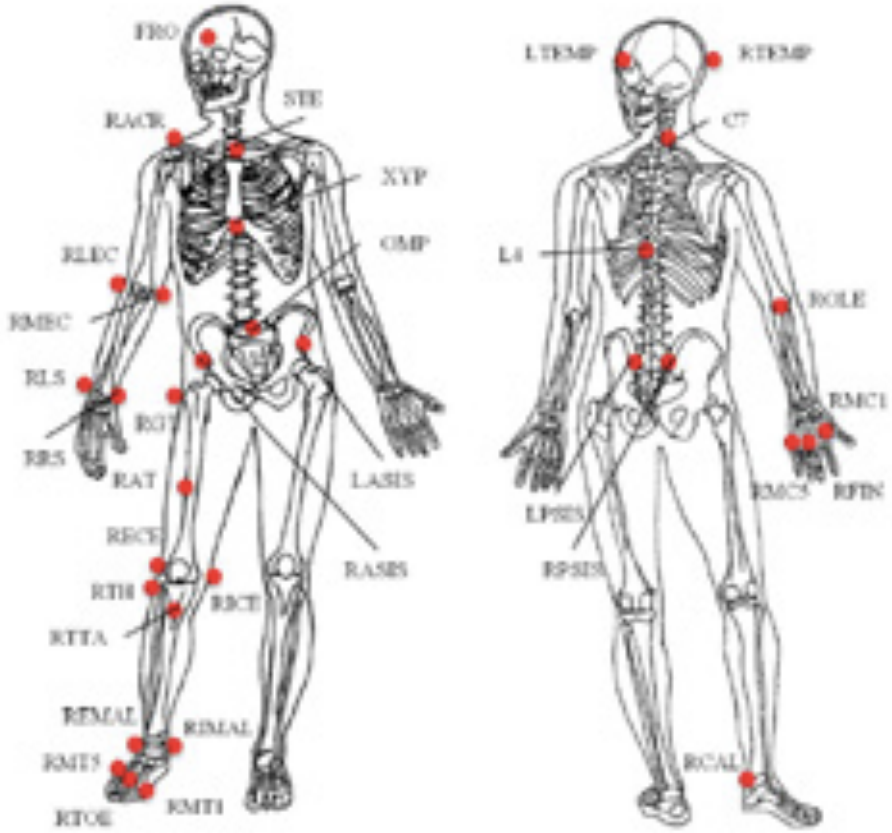
J.P. Laumond, J. Carpentier, M. Bennalegue, A. Berthoz

Int. Symp. on Robotics Research, 2015

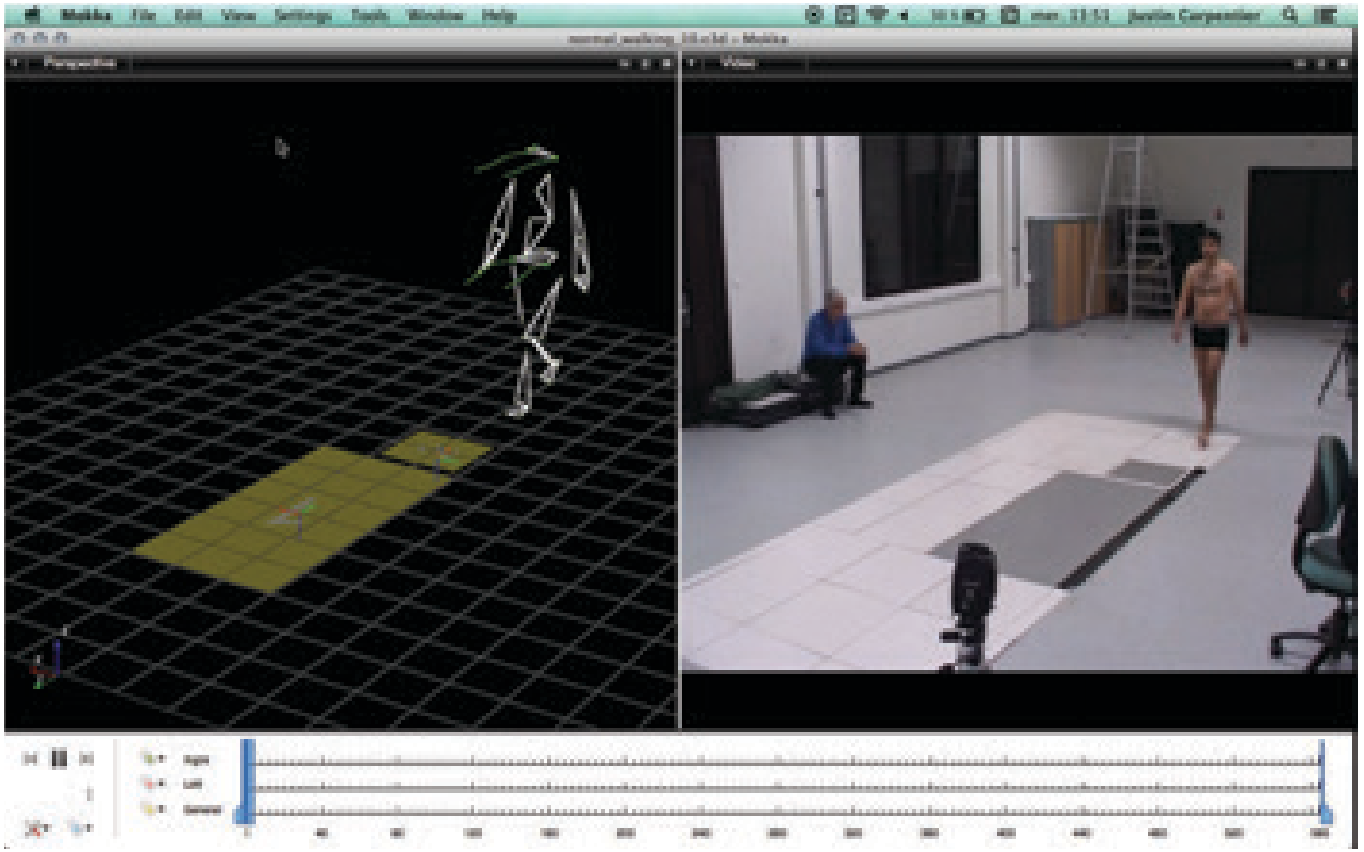
Geometric center

Geometric center of walking

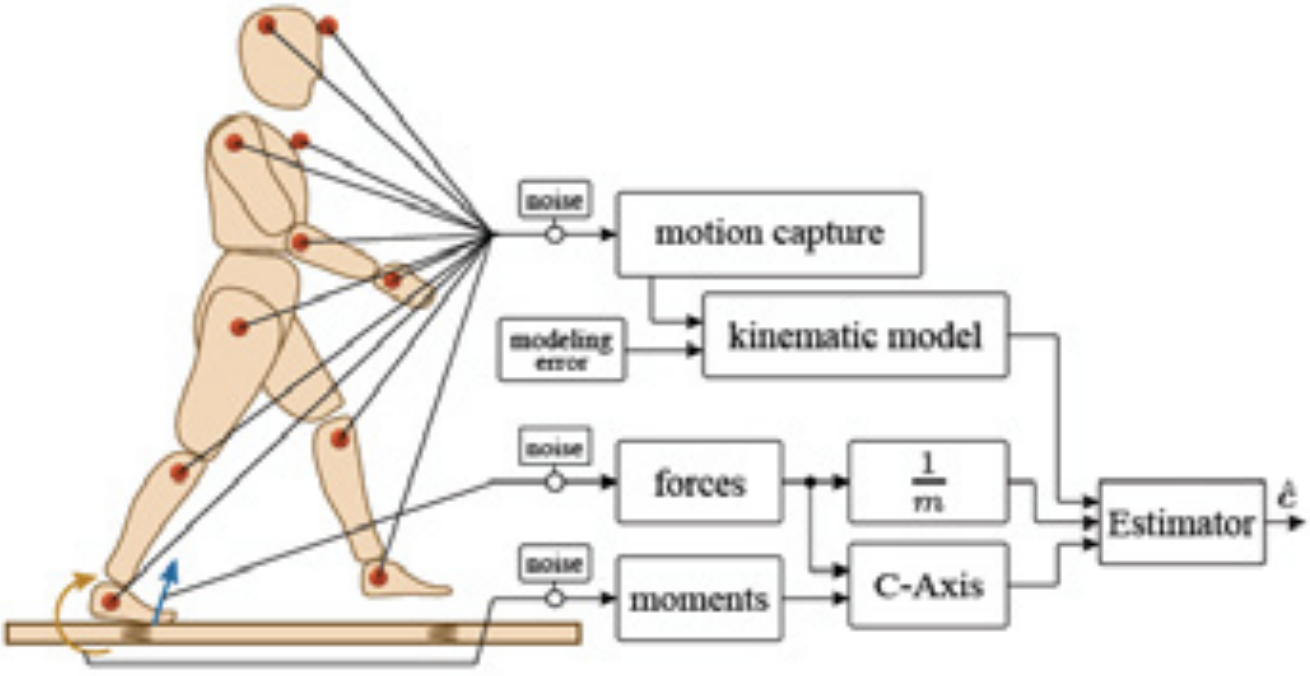




Apparatus

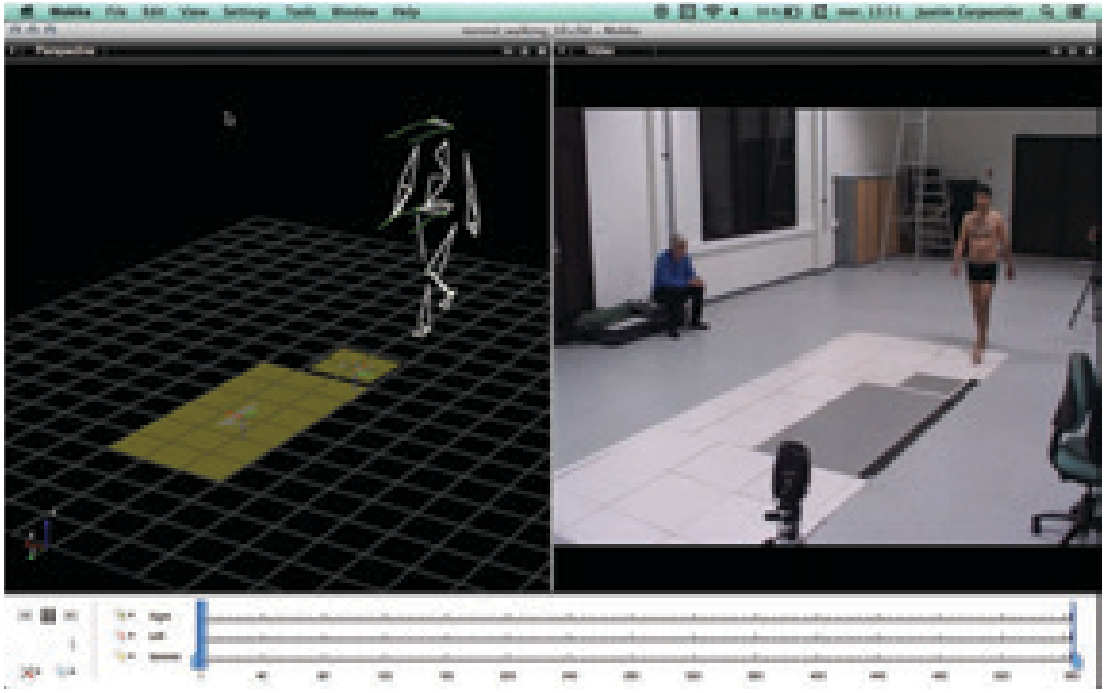


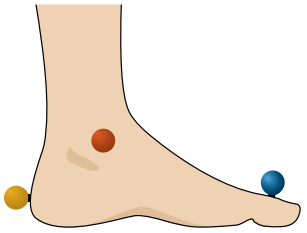
Center of Mass computation

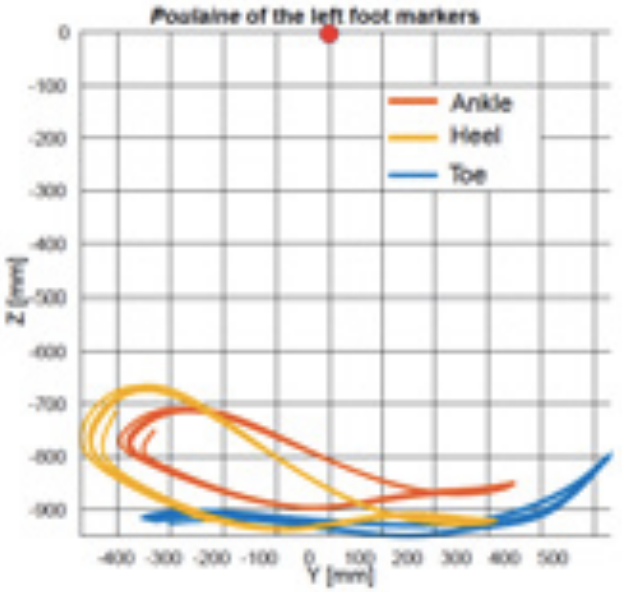


J. Carpentier, M. Bennalegue, J.P. Laumond
IEEE Trans. on Robotics, 2016

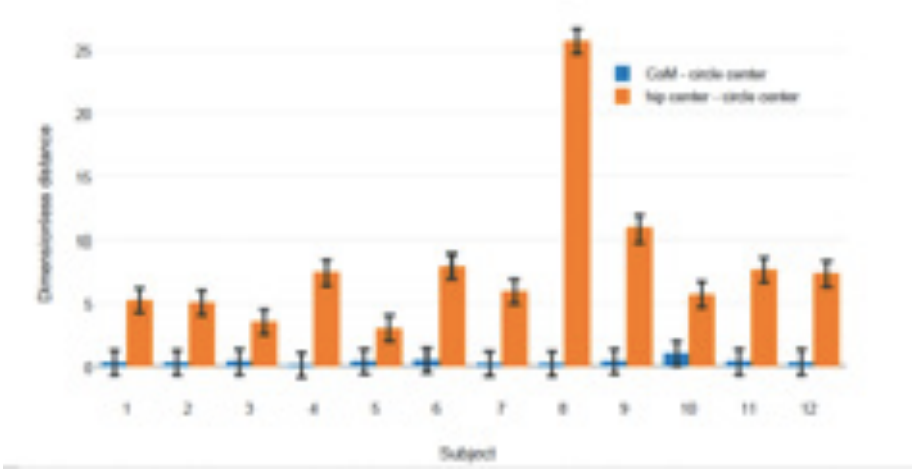
Geometric center of walking

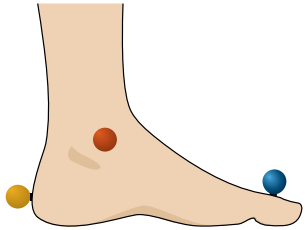


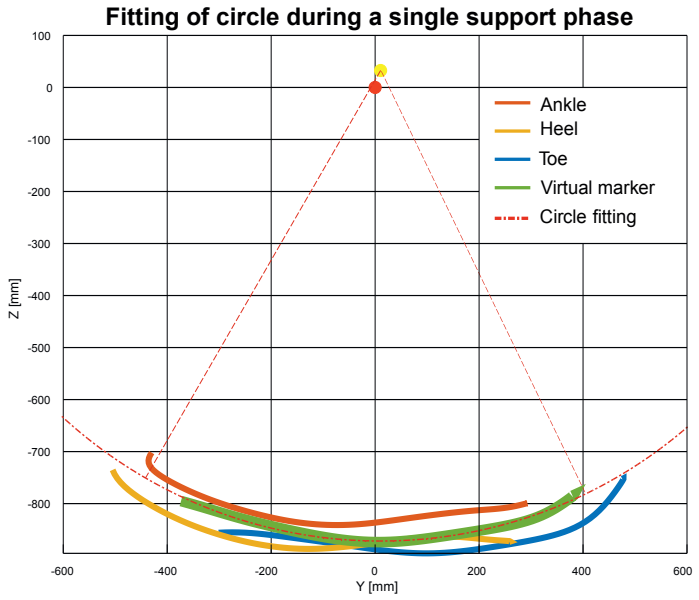




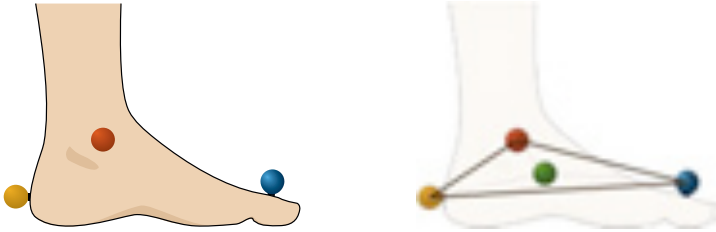
Geometric center of walking

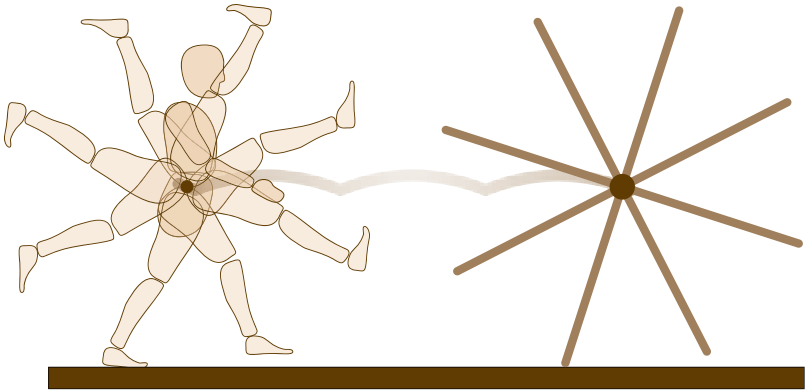


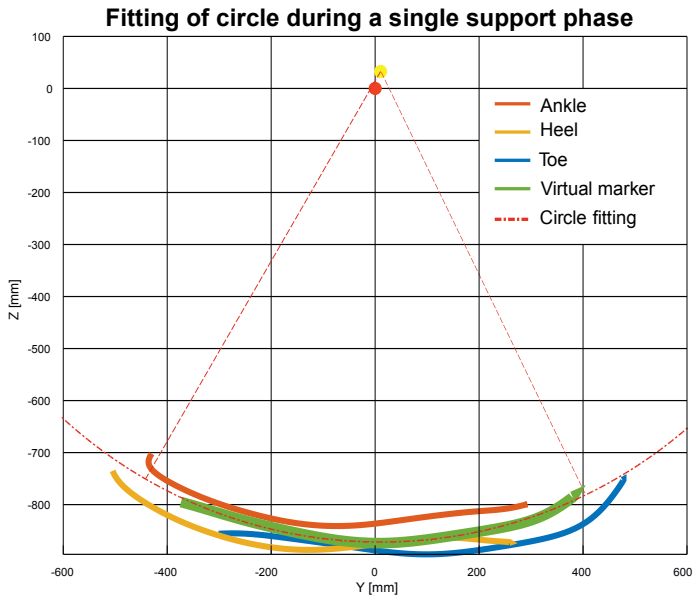




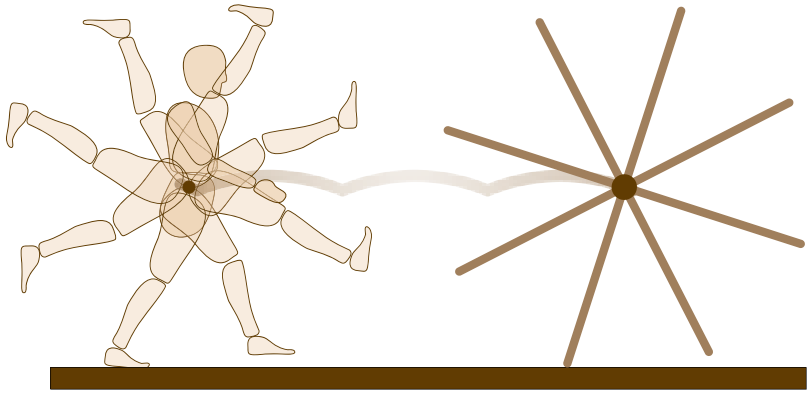
Geometric center of walking







Corollary: translation does not exist!

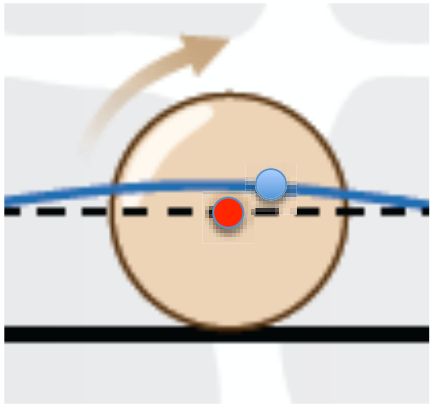


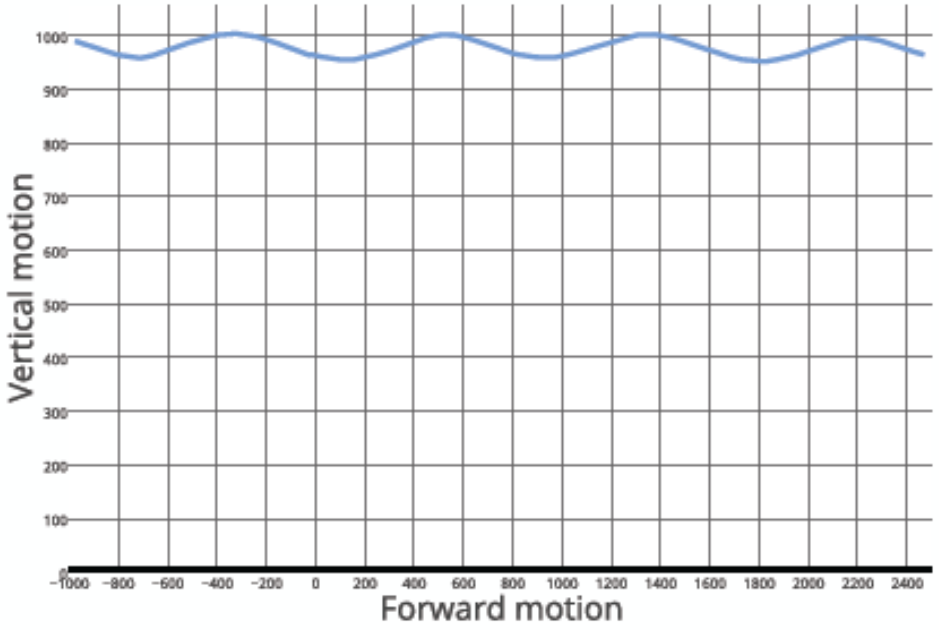
Humans do not walk

They roll

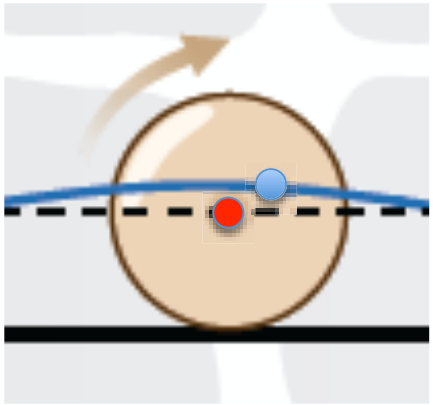
(1 km = 476 turns)

Geometric center of walking

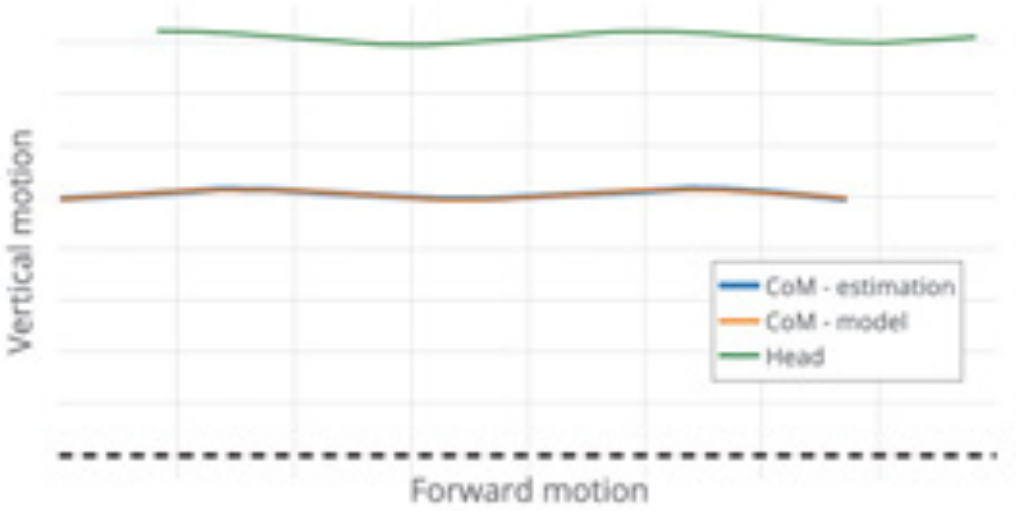


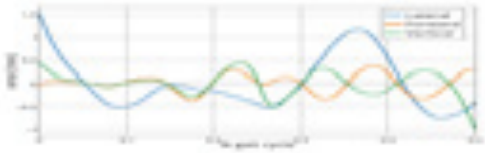


Geometric center of walking

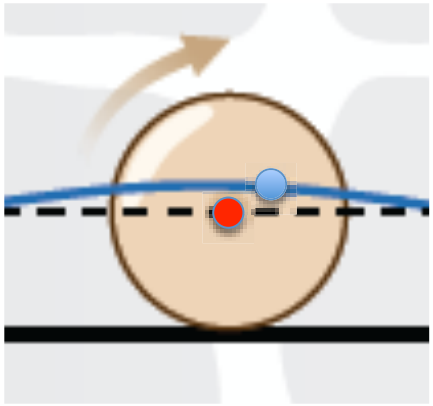


Tronchoïd





Geometric center of walking



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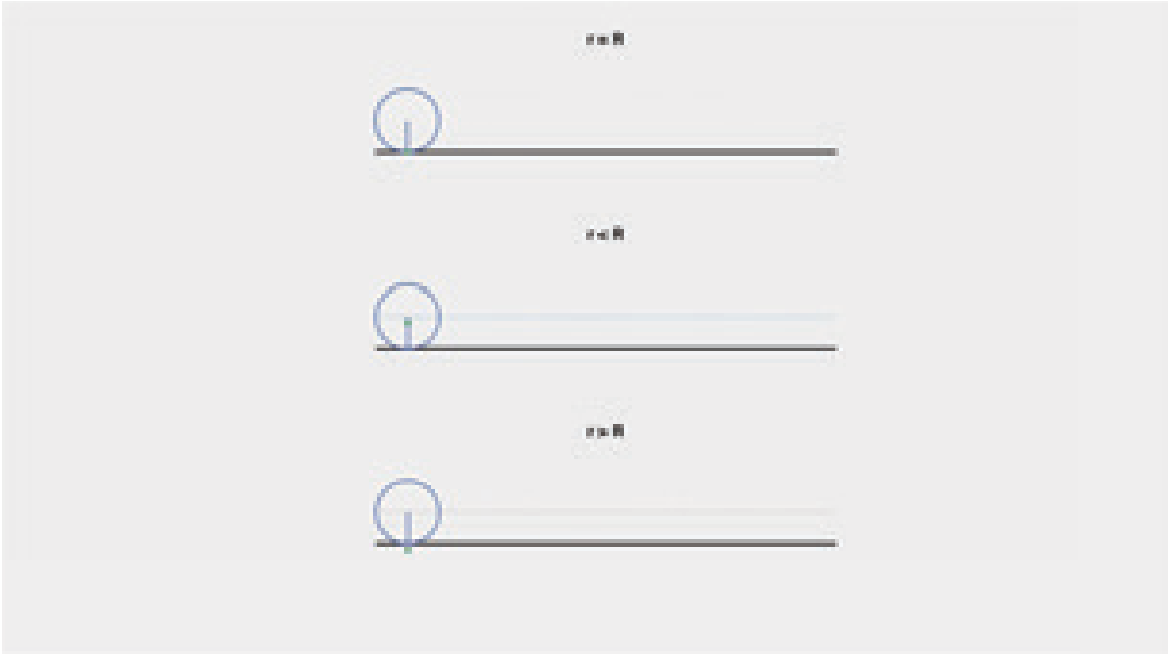

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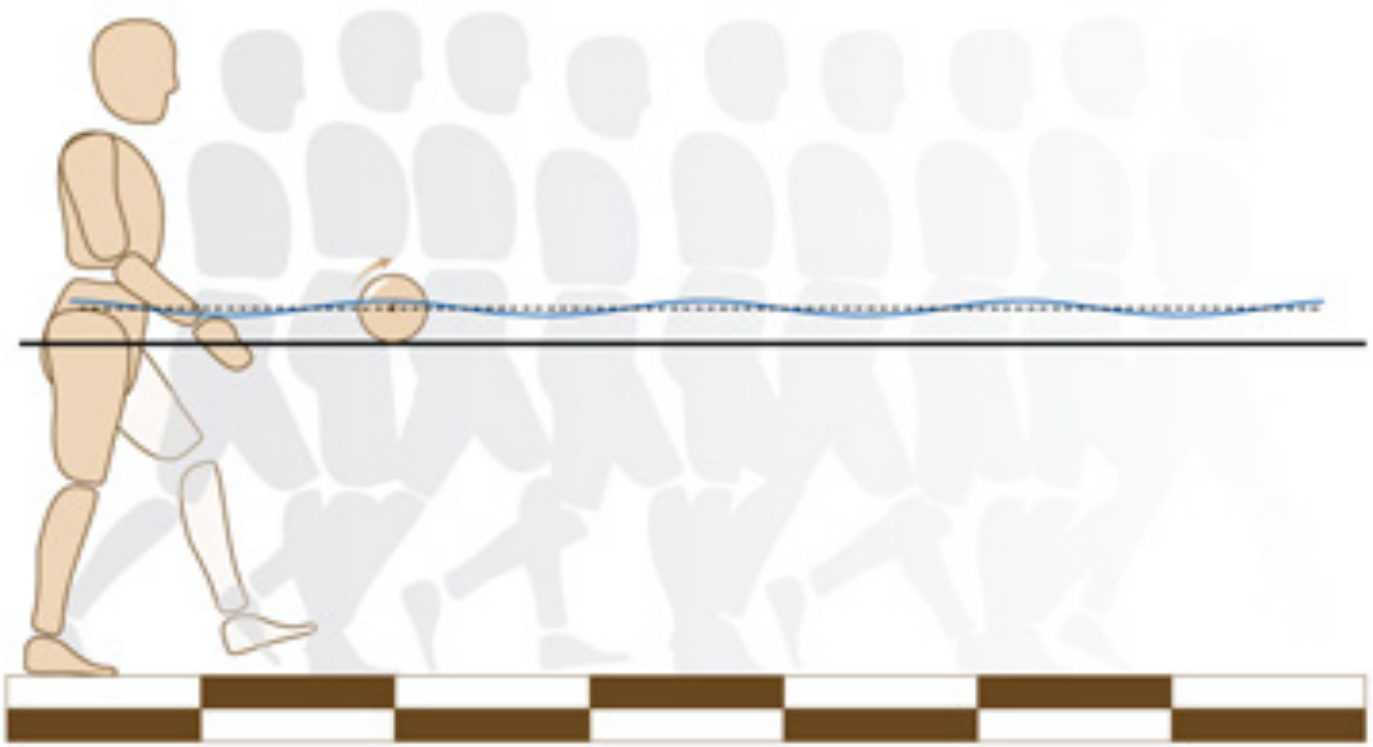
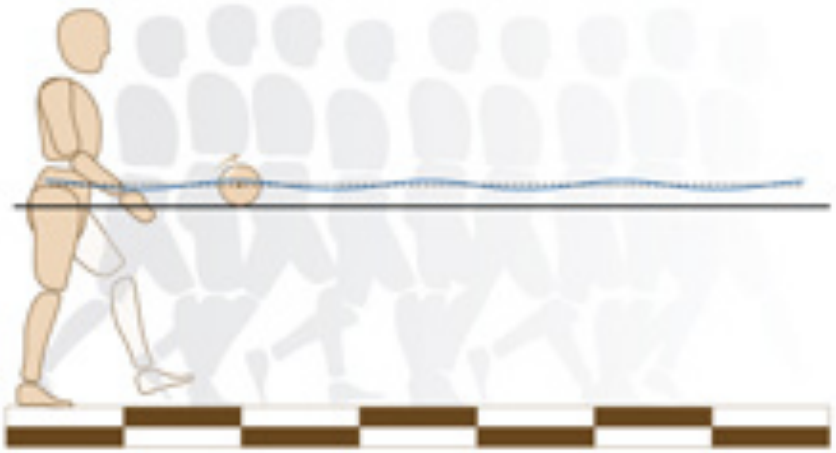


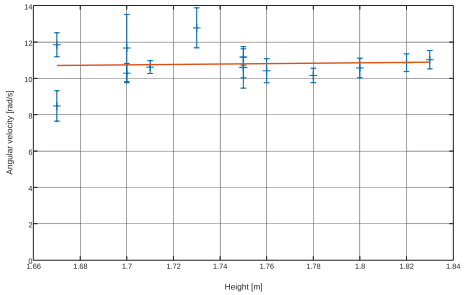
Geometric center of walking

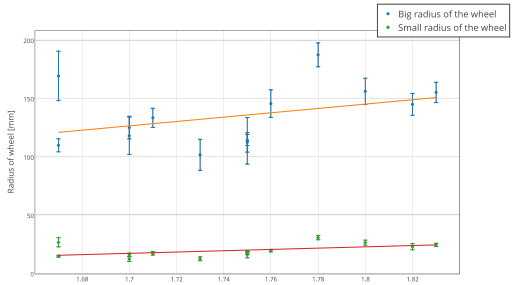


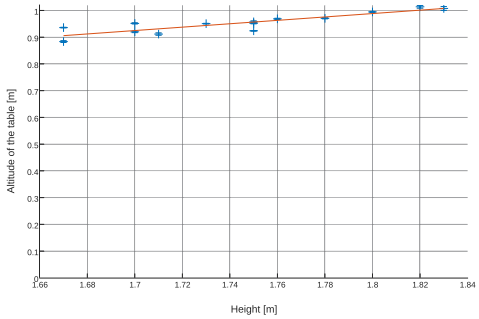
3 parameters :

- Table altitude
- Wheel radius
- Distance between CoM and wheel center

Geometric center of walking







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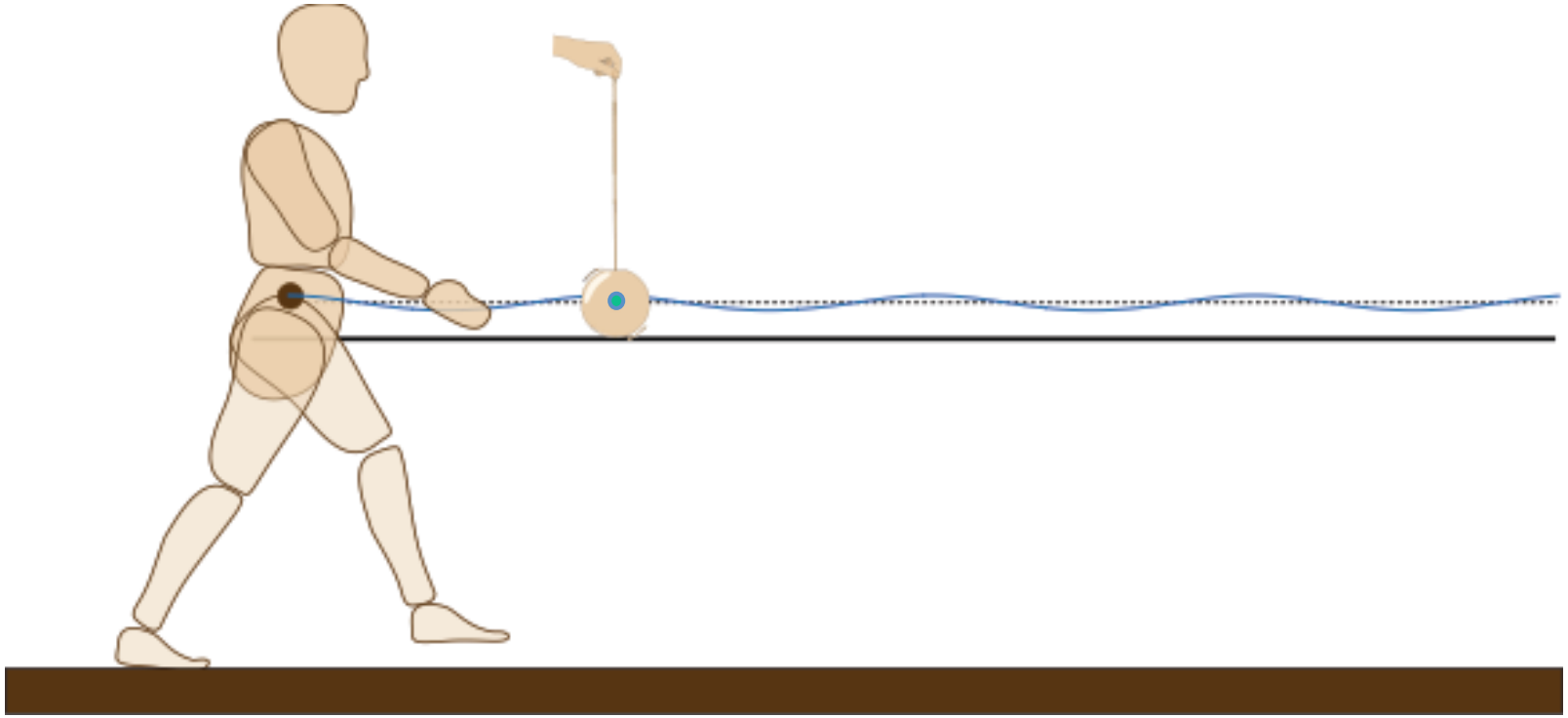
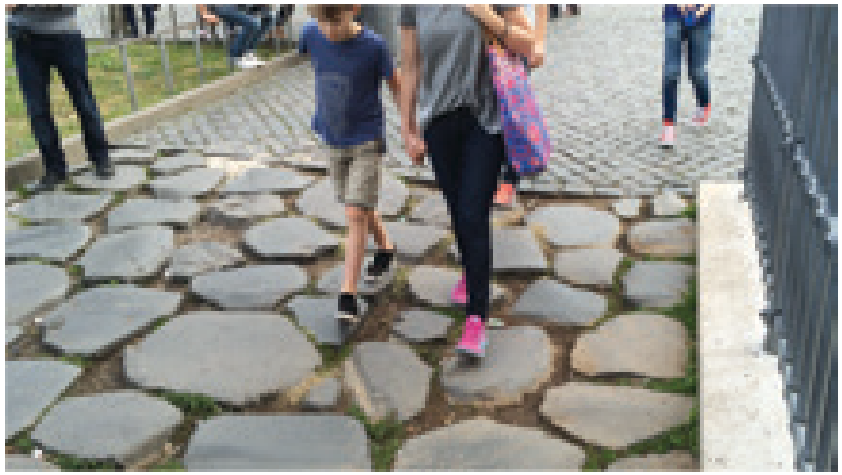
Geometric center of walking



Control center



Pavements in Roma:

Walking without thinking.
Reflex-based walking is stereotyped and robust enough to absorb slightly textured pavements.

Two exemples of stumble.
Transiting from slightly to significantly textured pavements requires attention.

Passivity intuition

Cornell Ranger, © Ruina's lab., Cornell University

Passivity intuition

Walking with the head

No neck

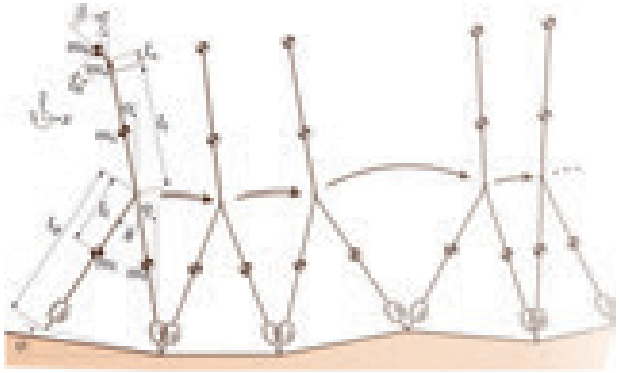
Neck

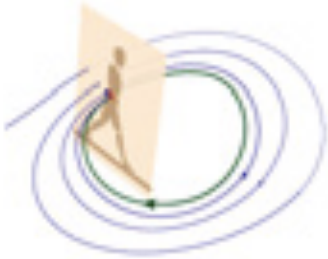
Giacometti

Passivity intuition

No neck

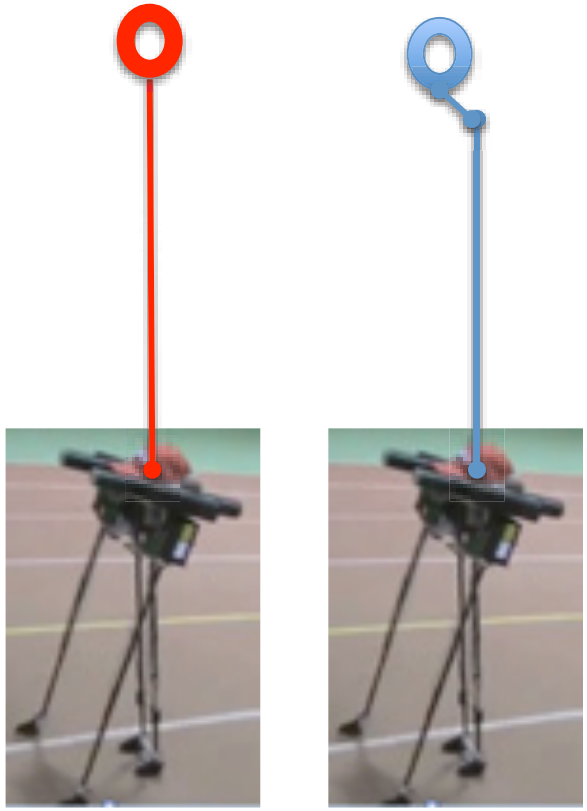
Neck



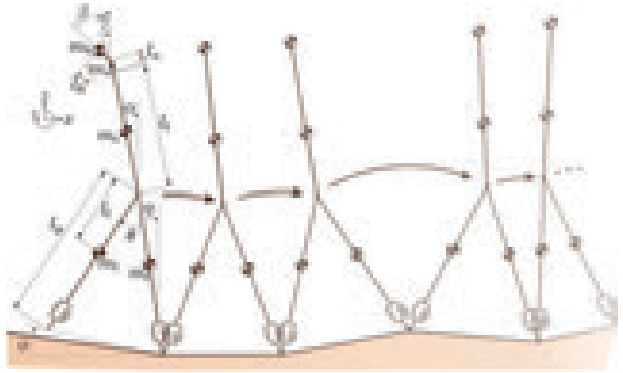


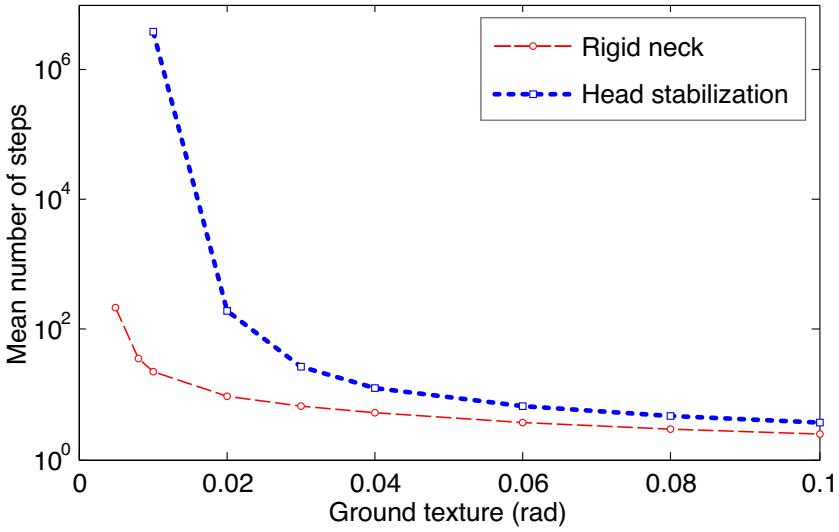
Dynamic simulation

Passivity intuition



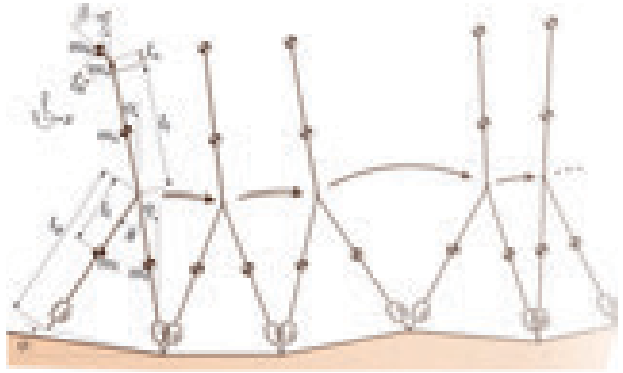
No neck Neck

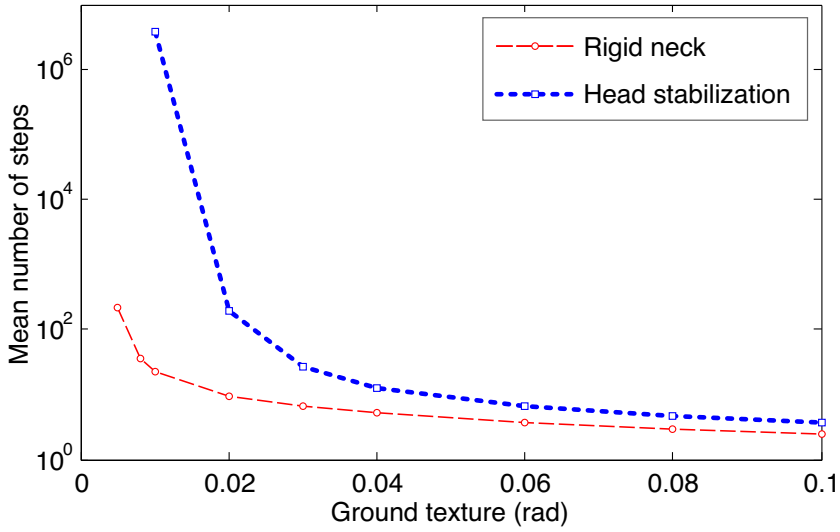




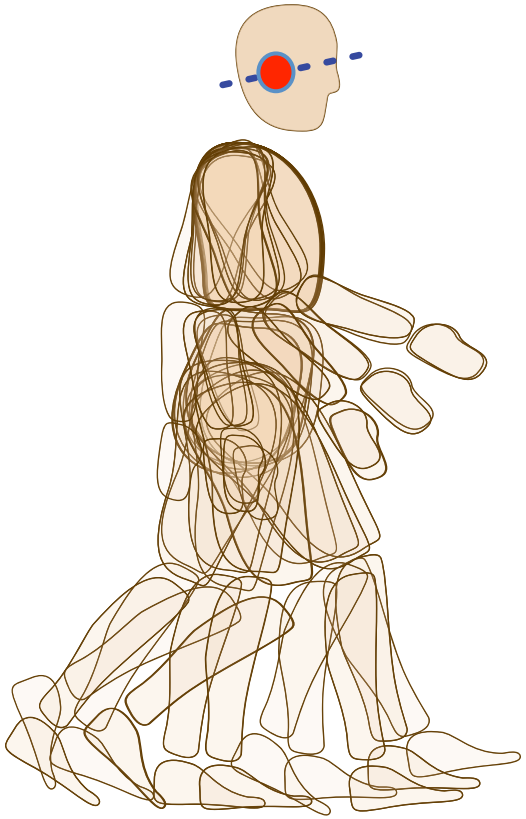
Passivity intuition

Ground texture

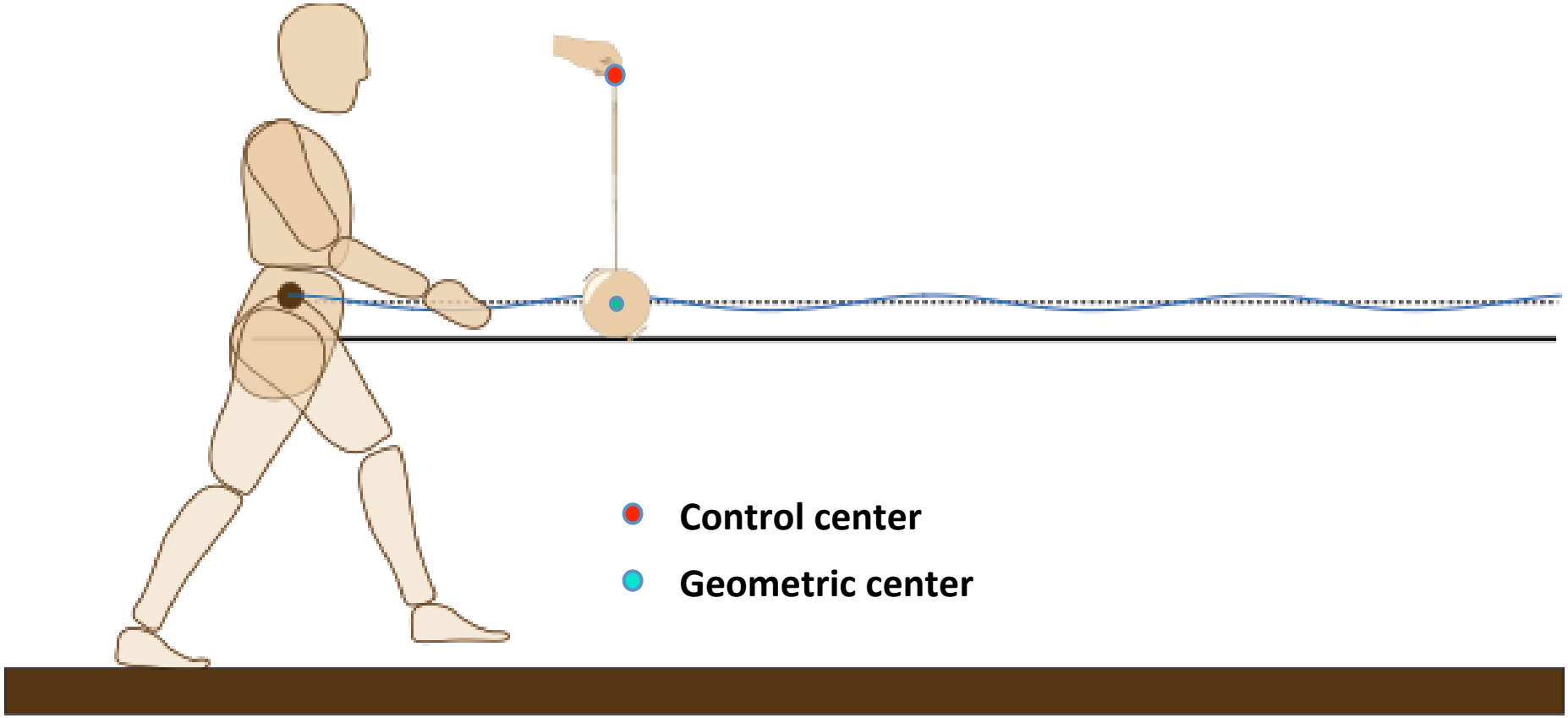




Control center

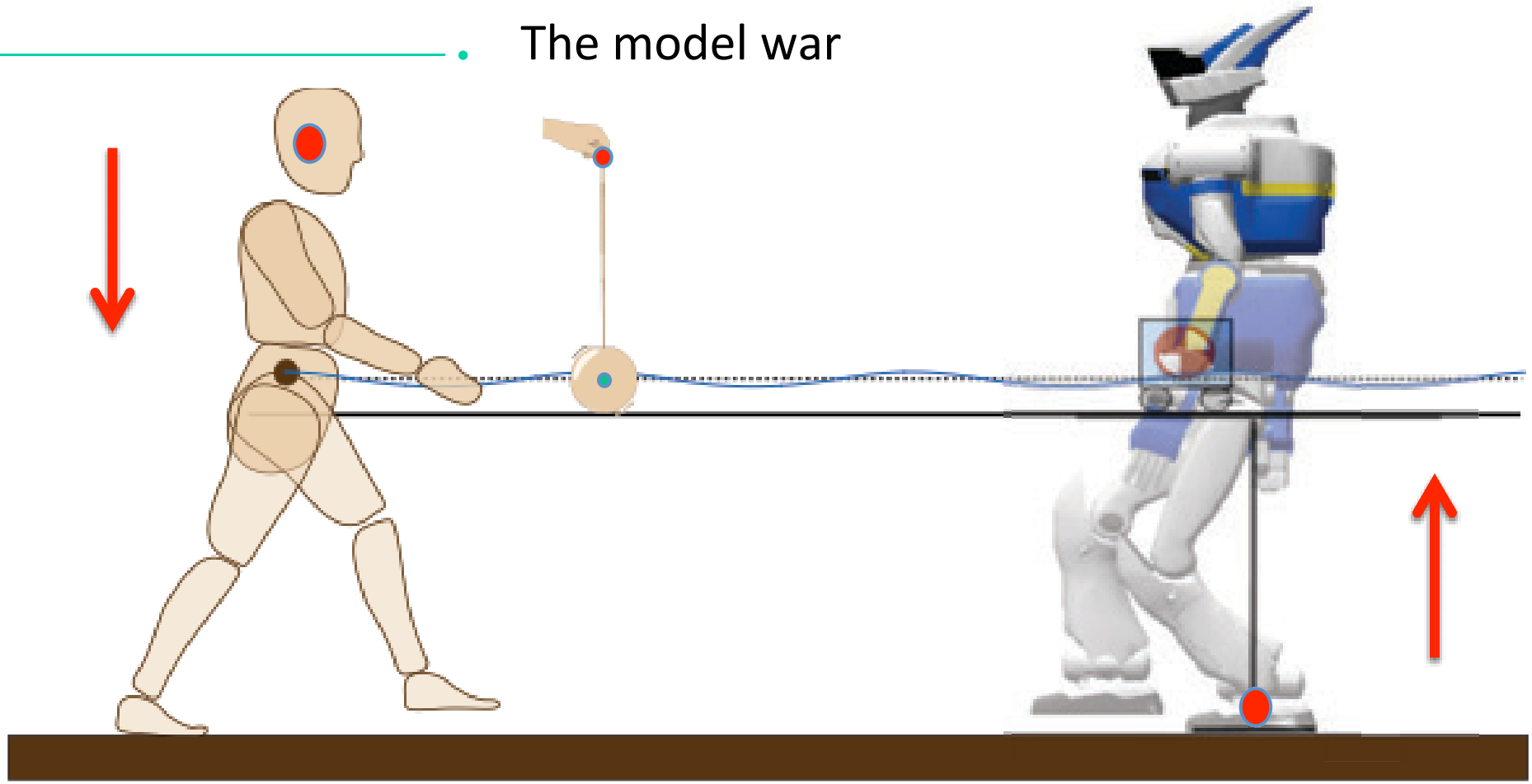


The Yoyo-Man



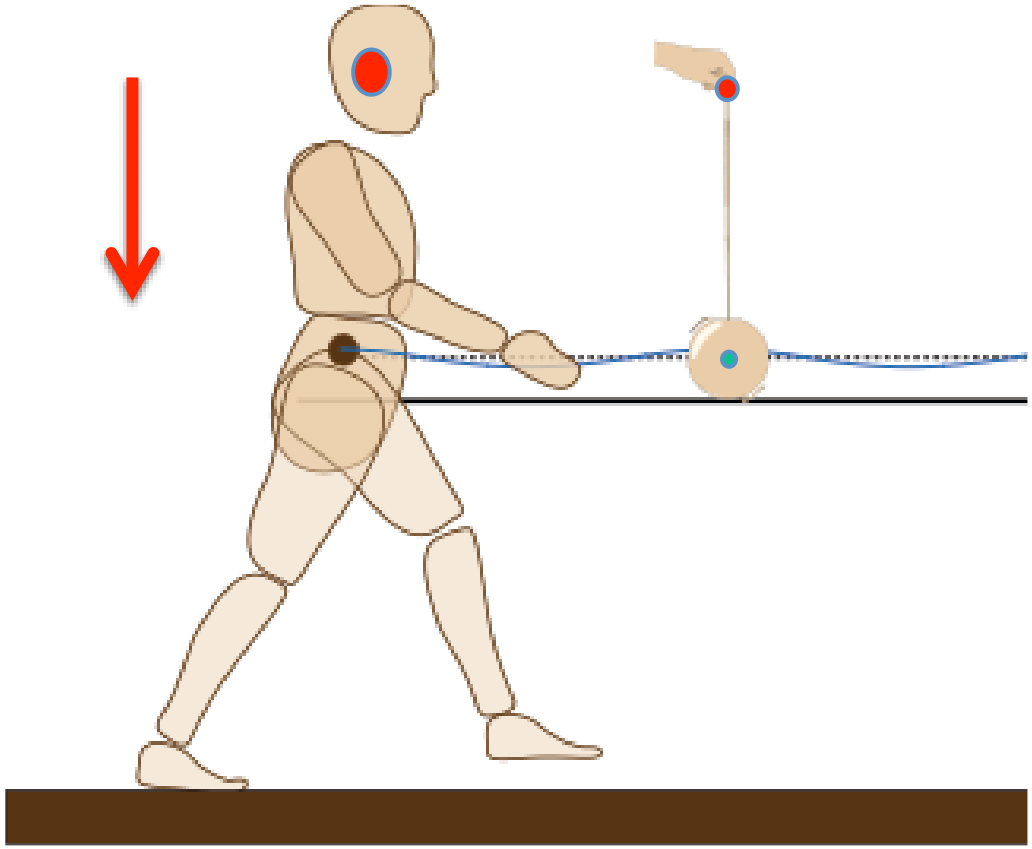
Humans roll!

The model war



Downwards approach *versus* Upwards approach

The model war

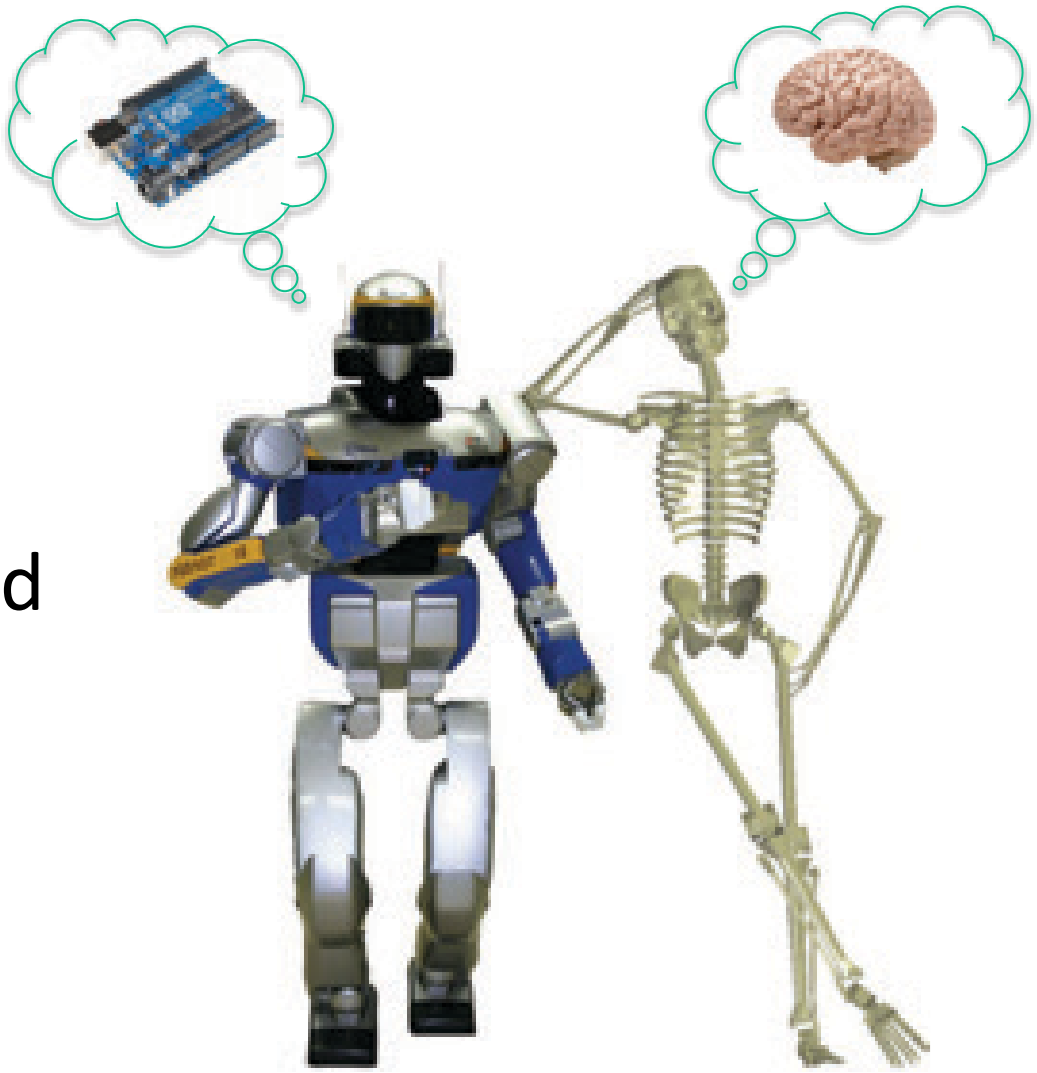


Downwards approach

Open PostDoc Position in Robot Design and Mechatronics

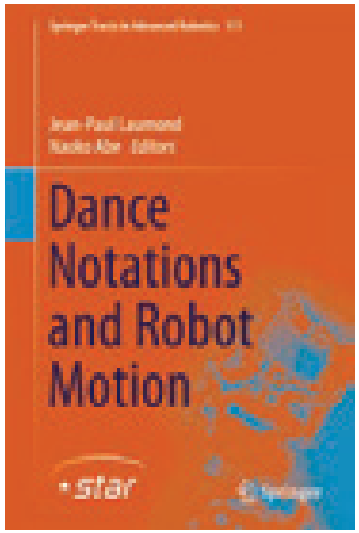
Synergies between:

- robotics,
- biomechanics and
- neurosciences

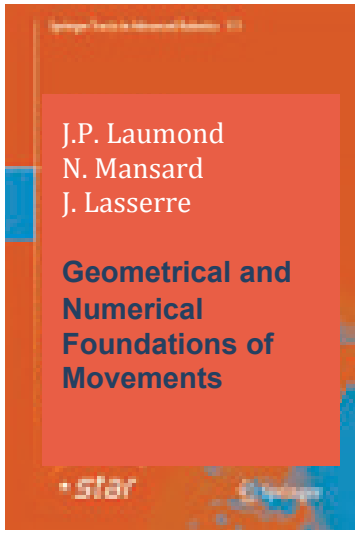


The anthropomorphic action factory

2014 : Workshop on Dance Notations and Robot Motion

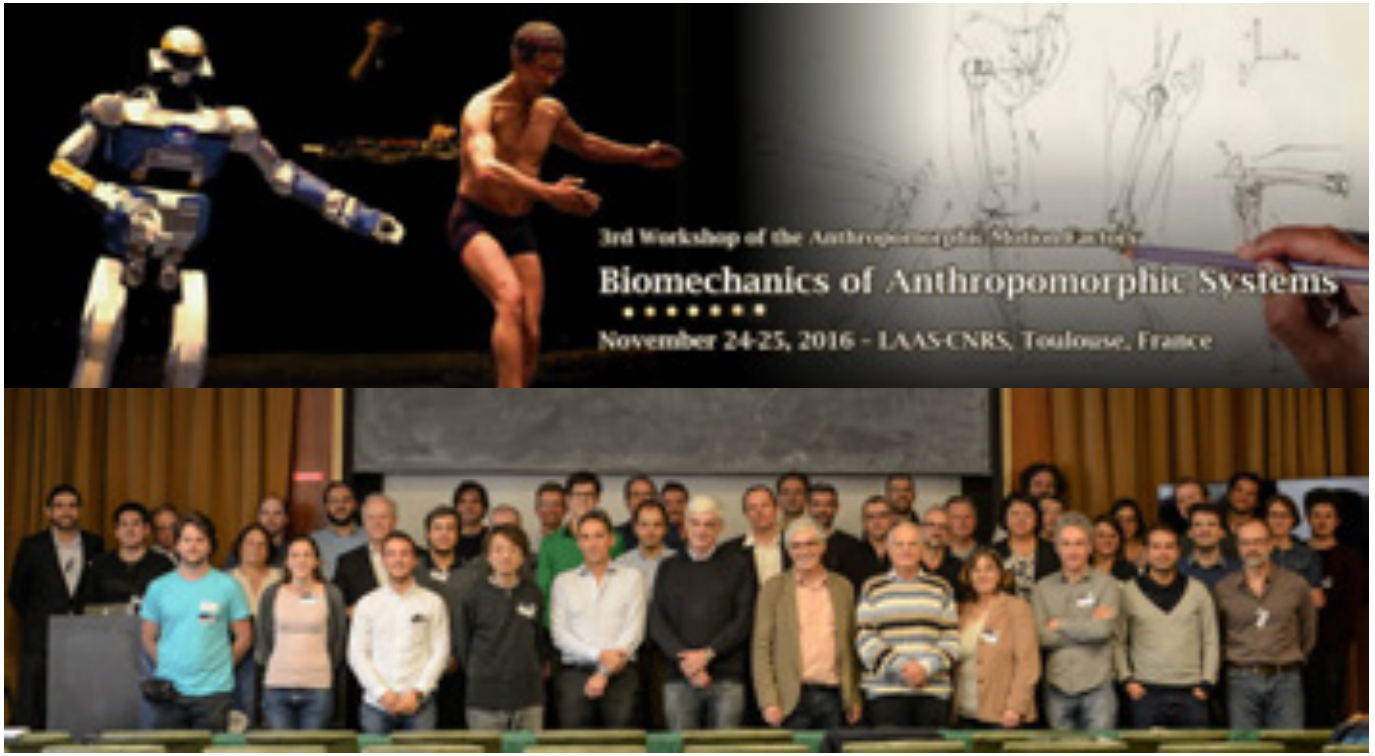


STAR Series 111
Springer, 2016



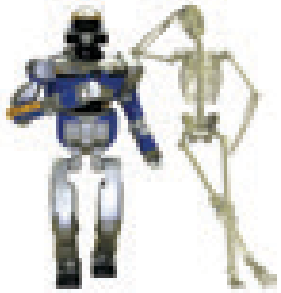
STAR Series
Springer, 2017

2015 : Workshop on Geometric and Numerical Foundations of Movements



2016 : Workshop on Biomechanics of Anthropomorphic Systems

- Thank you!



March 2016