Human motion: Back to Real

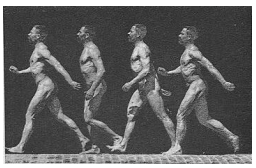
SIGGRAPH2008

Jean-Paul Laumond

Back to real: humanoid *versus* human

- References:

  - E. Yoshida, I. Belousov, C. Esteves and J-P. Laumond. *Humanoid Motion Planning for Dynamic Tasks.* IEEE Int. Conf. on Humanoid Robots, Tsukuba (Japan), 2005.
  - H. Hicheur, Q.C. Pham, G. Arechavaleta, J.P. Laumond, A. Berthoz. *The formation of trajectories during goal-oriented locomotion in humans. I. A stereotyped behaviour.* European J. of Neuroscience, 26 (8), 2007
  - G. Arechavaleta, J.P. Laumond, H. Hicheur A. Berthoz. *An optimal principle governing human walking.* IEEE Transactions on Robotics, 24 (1), 2008.



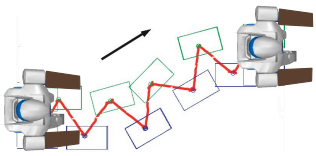
E.J. Marey in *Le Mouvement*, 1894

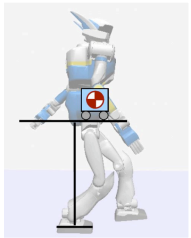
Humanoid Robots: facing dynamics

- HRP-2: 58kg against gravity
- Accounting for second derivatives
- Coupling with force sensors
- ZMP approach

Humanoid Robots: ZMP Approach

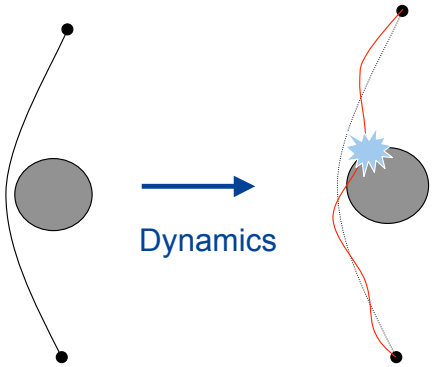
- Dynamic stability: ZMP above the support polygon
- Dynamic pattern generator [Kajita 03]
  - Inverted pendulum
  - Preview control





Humanoid Robots: Motion Planning

- Combine kinematics and dynamics via iterative reshaping:
  - Compute a path
  - Apply dynamic pattern generator
  - Check collision and reshape



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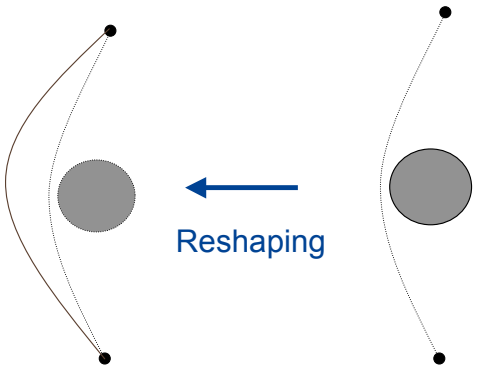

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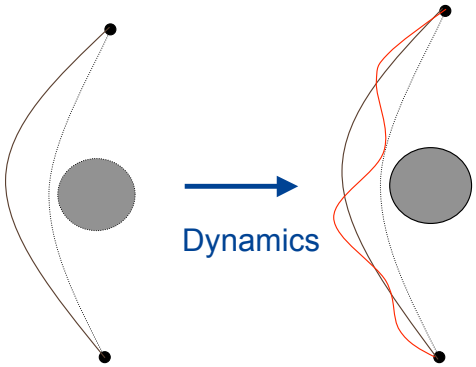

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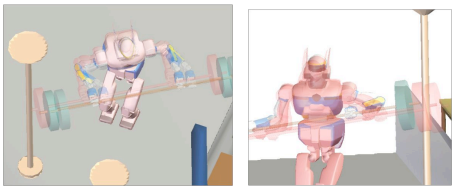

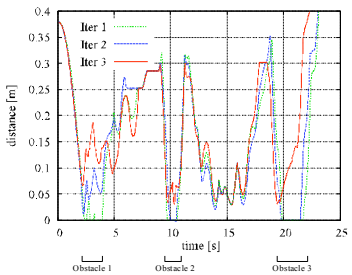

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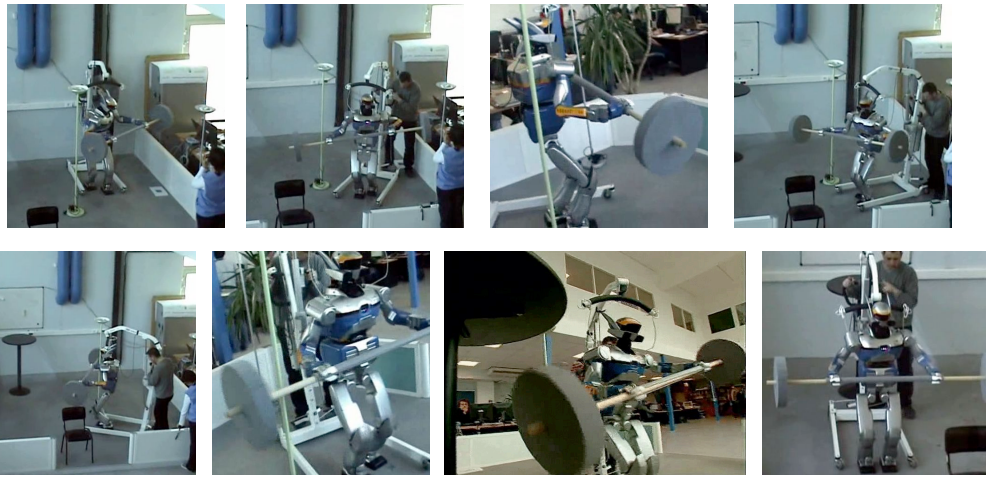
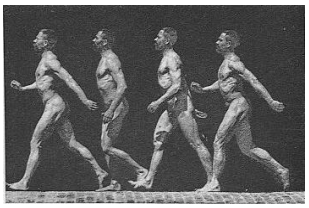


Human Locomotion: a NeuroRobotics Perspective

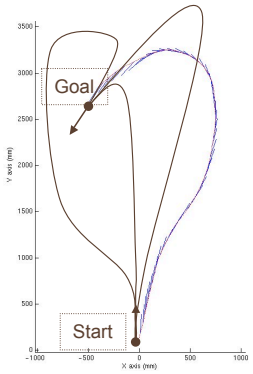
- An old still open problem
- To find motion invariants



Etienne-Jules Marey in Le mouvement, 1894

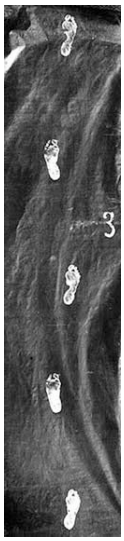
Human Locomotion: a NeuroRobotics Perspective

- Problem statement:
  - Why that path?



Human Locomotion: Approach

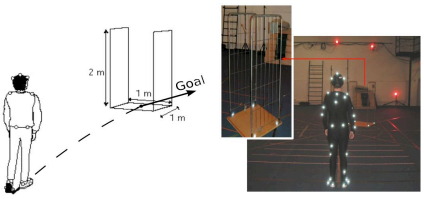
- Body position and direction are coupled
- Not integrable coupling: natural human locomotion is nonholonomic

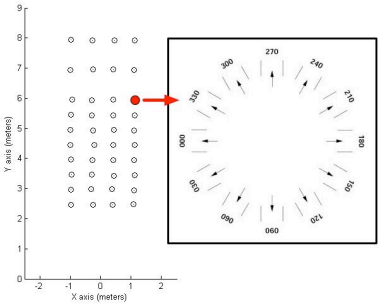


$$\tan\theta = \frac{\dot{y}}{\dot{x}}$$

Human Locomotion: Protocol

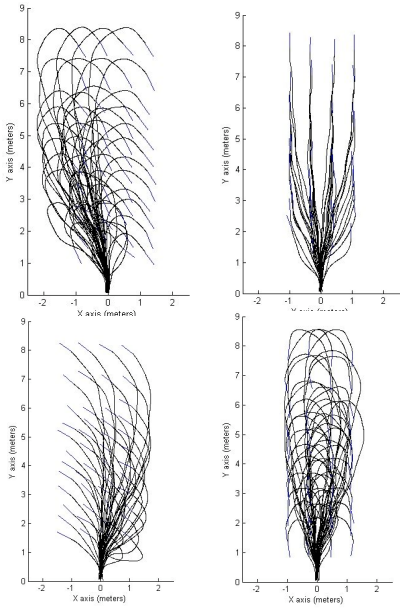
- Build the (x,y,θ)-space





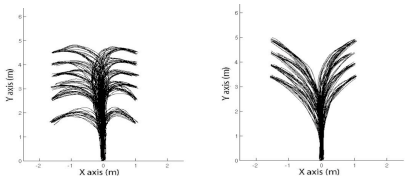
Human Locomotion: Protocol

- Build the (x,y,θ)-space
- 1430 trajectories (14km)
- 7 subjects



Human Locomotion: Methodology

- Stereotyped behaviors
- Nonholonomic behavior
- Geometry from optimal control



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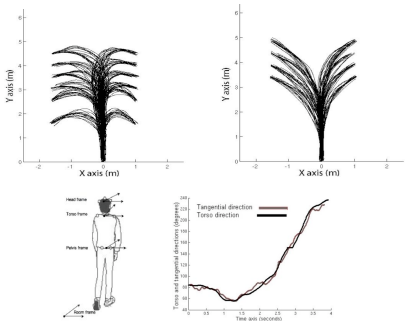

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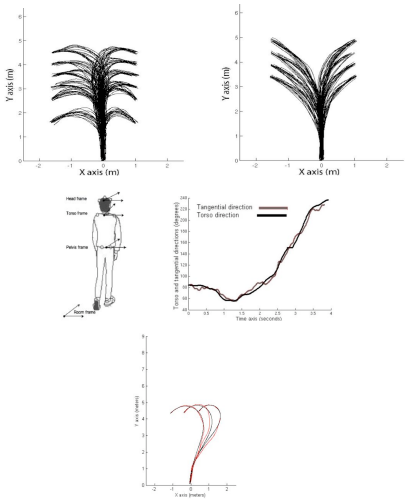
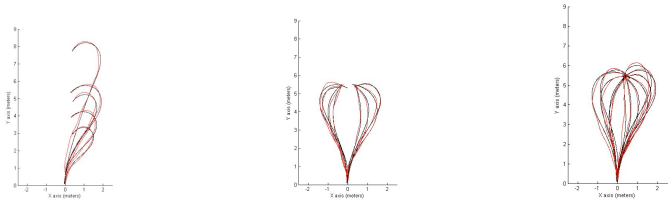
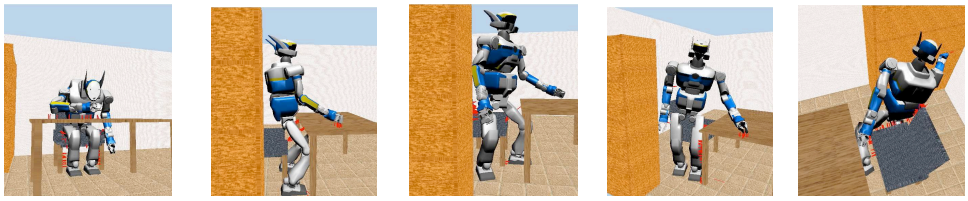


Human Locomotion

- “Theorem”: Locomotor trajectories optimize the derivate of the curvature.
- “Demonstration”: 90% of 1430 trajectories with error less than 10cm



Human Motion: Perspectives

- What are the invariant parameters of a given motion?
- What is an “action”?