

- **Whole-body motions:
a pre-cognitive stage for humanoids**

J.P. Laumond



Toulouse .





- Micro and Nano Technologies
- Modeling and Control
- Information technology
- Robotics and AI



- Robotics and AI
 - RIS (Robotics and Interactions)
 - RAP (Robotics, Action, Perception)
 - Gepetto (Anthropomorphic motion)



LAAS

Gepetto, 2008 LAAS-CNRS

Gepetto

« C'era una volta... »



Carlo Lorenzini detto Il Collodi (1826-1890)
Padre di Pinocchio

Gepetto, 2008

LAAS-CNRS

Anthropomorphic Motion

Team



Senior :

- J.P Laumond (DR CNRS)
- F. Lamiroux (CR CNRS)
- P. Souères (CR CNRS)
- M. Taïx (MC UPS)
- F. Kanehiro (AIST, Japan)
- E. Yoshida (AIST, Japan)
- K. Mombaur (Heidelberg U.)

Ingénieurs :

- A. Mallet
- M. Vaisset

Technicien :

- C. Benazeth

PhD :

- W. Suleiman
- J. Himmelstein
- O. Kanoun
- M. Poirier
- A. Nakhaei
- M. Tran
- S. Dalibard
- D. Flavigné
- C. Halgand
- F. Montecillo
- A. Truong
- M. Sreenivasa

Alumni :

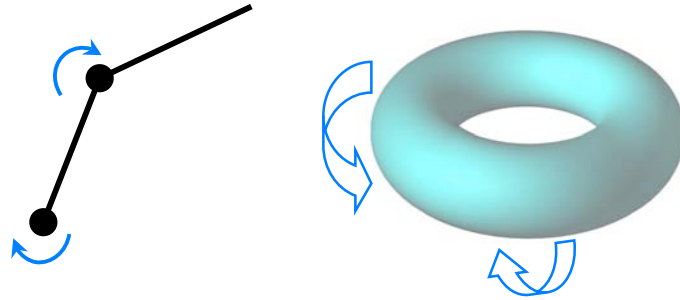
- J. Pettré
- O. Lefebvre
- C. Esteves
- J.M. Pfimlin
- F. Boyer
- G. Arechavaleta

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Anthropomorphic Motion

- Motion : a continuous function from time to space

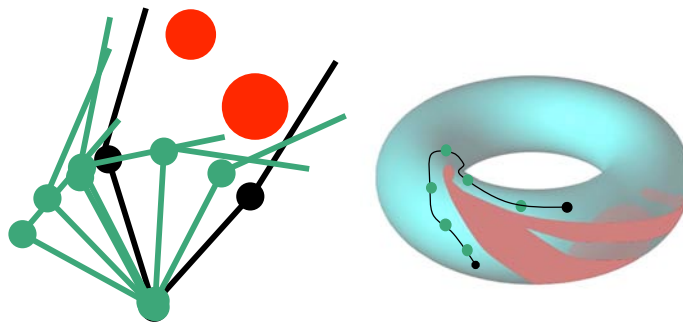


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Anthropomorphic Motion

- Motion : a continuous function from time to space



Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how

- 80's Configuration Space Approach, Decidability, Deterministic Approaches

« Robot Motion Planning » Latombe,
Kluwer Academics Pub., 1991

- 90's Nonholonomy and Probabilistic Approaches

« Robot Motion Planning and Control » Laumond,
Springer Verlag, 1998

<http://www.laas.fr/~jpl> (free of charge)



Choset et al, 2005

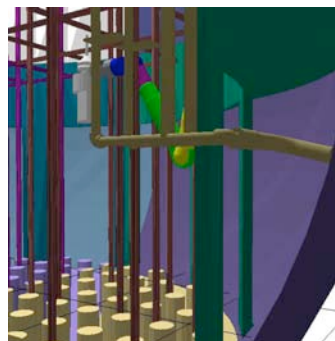
LaValle, 2006

Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



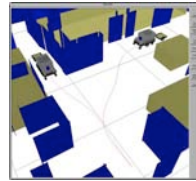
Robot programming

Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



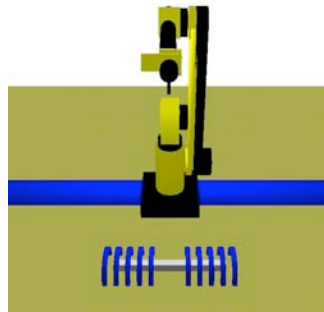
Robot motion autonomy

Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



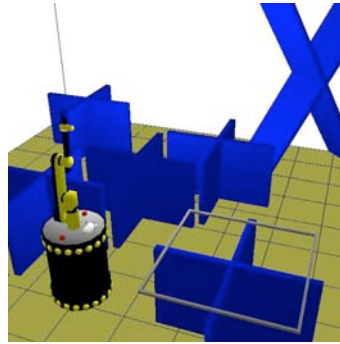
Geometry based manipulation planning

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Anthropomorphic Motion

- Computer aided motion: a know-how



Geometry based manipulation planning



Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



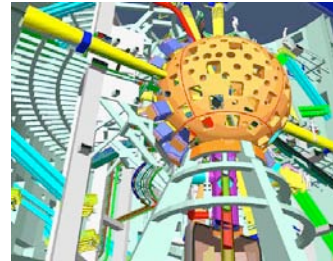
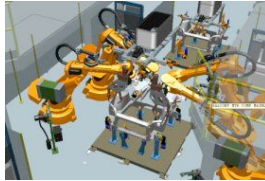
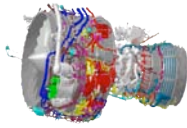
2001 :  created the spin-off company 

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Anthropomorphic Motion

- Computer aided motion: a know-how in PLM applications



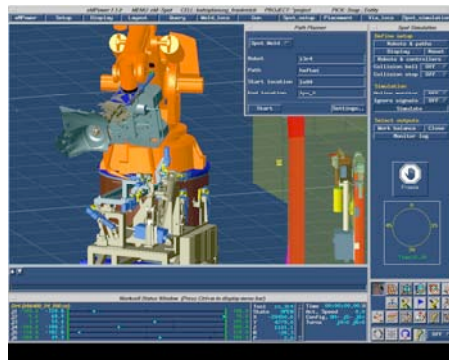
Digital mockup: extract *informations* from *data*

Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



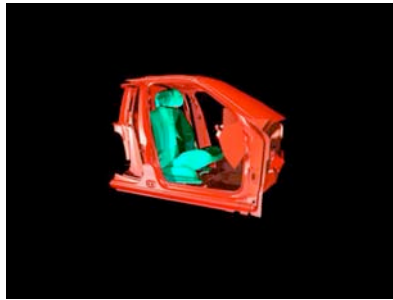
-KINEO-

Gepetto, 2008

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Anthropomorphic Motion

- Computer aided motion: a know-how



KINEO

2 minutes (automated solution) versus several hours (hand made motion)

Gepetto, 2008

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Anthropomorphic Motion

- Digital mannikins



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Anthropomorphic Motion



- Anthropomorphic systems: the complexity challenge
- Three research objects
 - humanoid robots
 - human beings
 - digital actors

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Anthropomorphic Motion



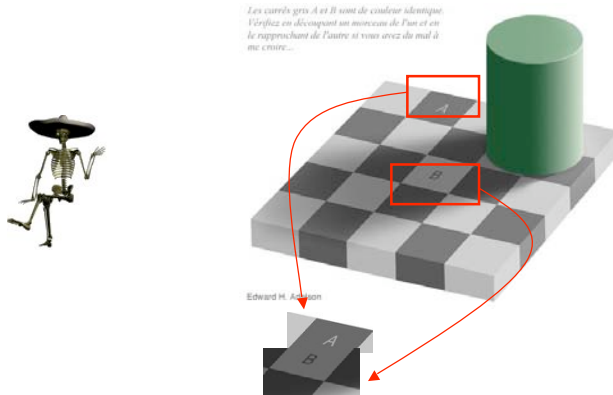
- Anthropomorphic systems: the complexity challenge
- Human body: a system both
 - redundant, and
 - underactuated
- Tools
 - signal processing
 - control
 - combinatorics

Gepetto, 2008

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Anthropomorphic Motion

- Imitation: the power of illusion

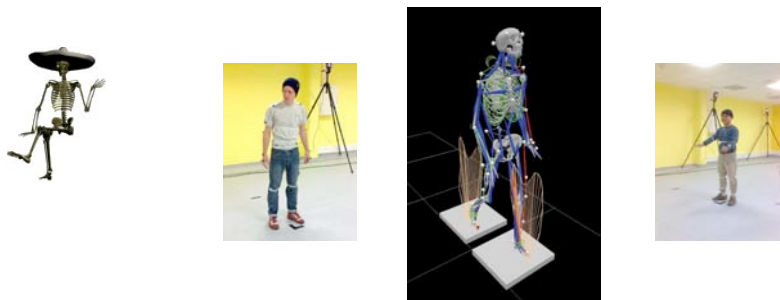


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Anthropomorphic Motion

- Digital actors
 - Motion capture

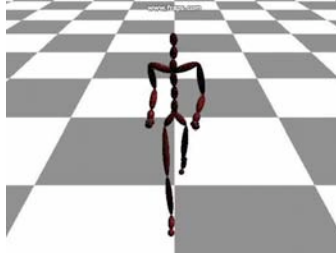


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Anthropomorphic Motion

- Digital actors
- Motion capture based locomotion control

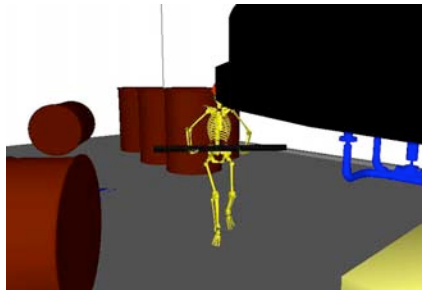
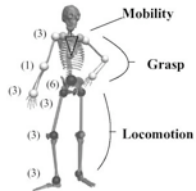


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Anthropomorphic Motion

- Digital actors
- Motion planning by functional decomposition

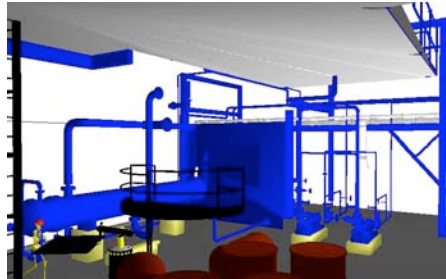


Gepetto, 2008

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Anthropomorphic Motion

- Digital actors
- Motion planning by functional decomposition

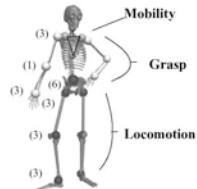


Gepetto, 2008

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Anthropomorphic Motion

- Digital actors
- Motion planning by functional decomposition



Gepetto, 2008

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Anthropomorphic Motion

- Digital actors: the power of illusion



Collaboration with computer graphics: EPFL

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Anthropomorphic Motion

- Imitation is not understanding

- Understanding requires to:



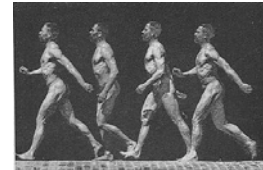
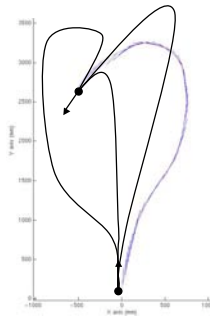
- stating the research objectives
(robotics *versus* neurosciences)
- pluridisciplinary research
(keep your know-how)

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Anthropomorphic Motion

- To understand the shape of the intentional locomotion trajectories



Etienne-Jules Marey in *Le mouvement*, 1894

Collaboration with neuroscientists: LPPA (Paris)

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Anthropomorphic Motion

- First statement: position and direction are coupled

The natural way for walking is to put one foot *in front of* the other and to repeat this action



in front of means that the direction of the motion is given by the direction of the body

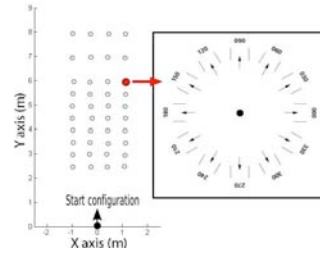
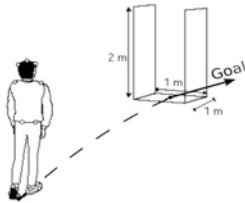
$$\dot{y} \cos \theta - \dot{x} \sin \theta = 0$$

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Anthropomorphic Motion

- Protocol and apparatus: intentional goals defined **both** in position and orientation

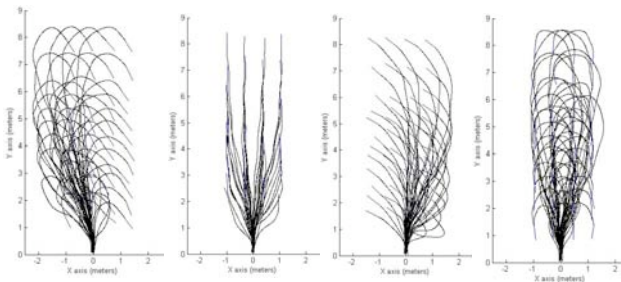


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Anthropomorphic Motion

- Trajectories



The trees of the human locomotion
Data basis: 14km, 6 subjects

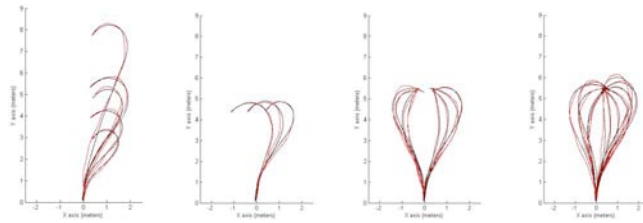
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Anthropomorphic Motion

- “Theorem”: Locomotor trajectories optimize the derivative of the curvature

“Proof”: Integration: 90% of 1430 trajectories with error less than 10cm (torso frame)



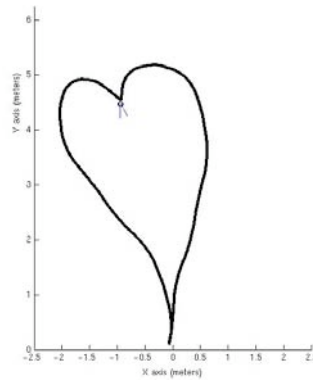
IEEE T-RO, Feb. 2008

Gepetto, 2008

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Anthropomorphic Motion

- **Decision** process may be explained by optimal control



IEEE T-RO, Feb. 2008

Gepetto, 2008

LAAS-CNRS

Humanoid Robotics

- The power of second derivative



Gepetto, 2008

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Humanoid Robotics

- Humanoid motion in the real world: facing dynamics

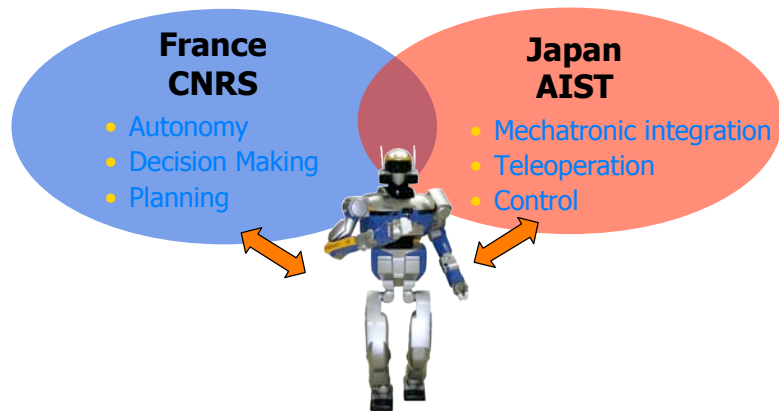


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Humanoid Robotics

- JRL: an international laboratory



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Humanoid Robotics

- AIST-CNRS JRL: (part of the) team

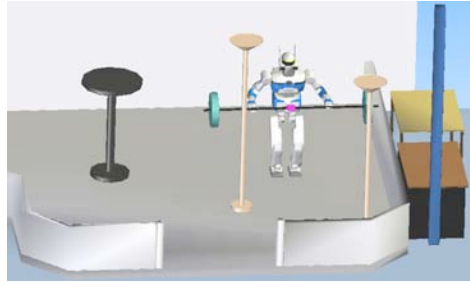


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Anthropomorphic Motion

- Humanoid robotics: the challenge of dynamics



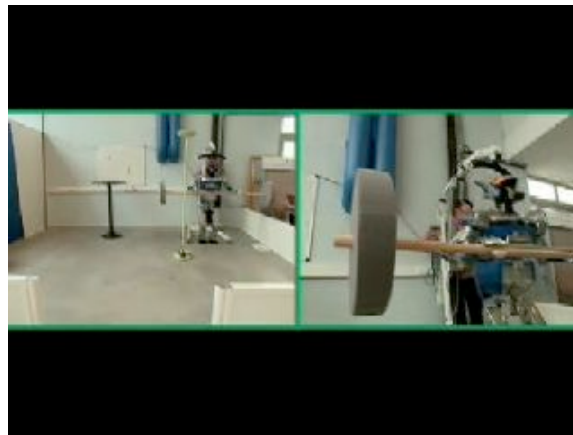
KineoWorks KPP based algorithms

Gepetto, 2008

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Anthropomorphic Motion

- Whole body motion



KineoWorks KPP based algorithms + Kajita's ZMP based control

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Anthropomorphic Motion

- « Give him the Purple Ball »



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Anthropomorphic Motion

- « Give him the Purple Ball »: analysis



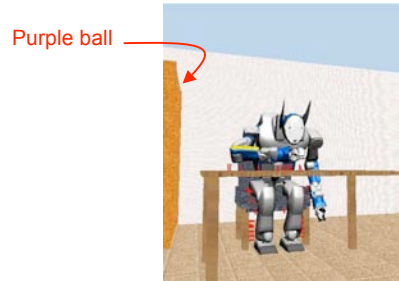
- A same « symbolic » order:
various levels of intelligent behaviors
 - Functional decomposition may fail
 - Should « grasping » generate « locomotion »?
 - If yes: what is locomotion?

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Anthropomorphic Motion

- « Give him the Purple Ball »: analysis
- Is locomotion needed?

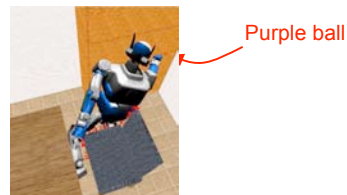


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Anthropomorphic Motion

- « Give him the Purple Ball »: analysis
- Does HRP-2 « walk »?



AIST-CNRS JRL: F. Kanehiro, F. Lamiroux,
E. Yoshida, J.P. Laumond, 2008

Gepetto, 2008

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Anthropomorphic Motion

- As a conclusion



- What are the invariant parameters of a given action?

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Anthropomorphic Motion

- As a conclusion



- What are the invariant parameters of a given action?

- What is an « embodied » action?

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Anthropomorphic Motion

- As a conclusion



- What are the invariant parameters of a given action?
- What is an « embodied » action?
- At which level do we introduce « symbols »?

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Anthropomorphic Motion

- As a conclusion



- What are the invariant parameters of a given action?
- What is an « embodied » action?
- At which level do we introduce « symbols »?

- *not too early!*

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