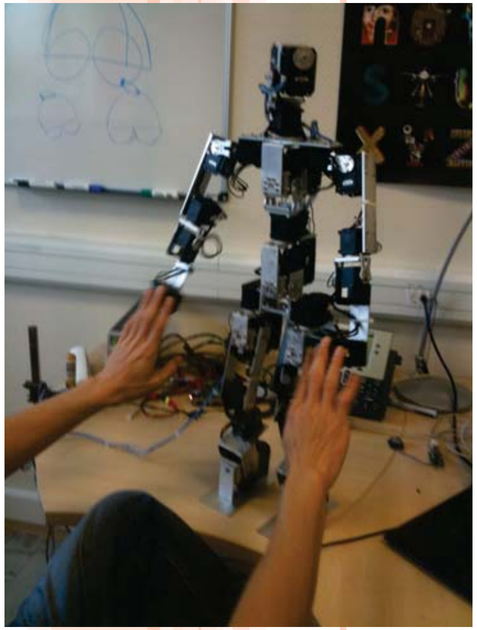

Bordeaux Humanoids

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H. Gimbert [LaBRI – CNRS]
L. Gondry
P.-Y. Oudeyer [INRIA Flowers]

PLAN

- A First Project : Rhoban
  What can we do with low precision mechanic / slow control ?
- Acroban Project
  Compliance and flexibility
  Exploring new mechanical design (articulated spine)
  Balance system
- A new prototype
  dampers for fighting the inelastic shocks ☺

A First Project : Rhoban

What can we do with
low precision mechanic / slow control ?

RHOBAN

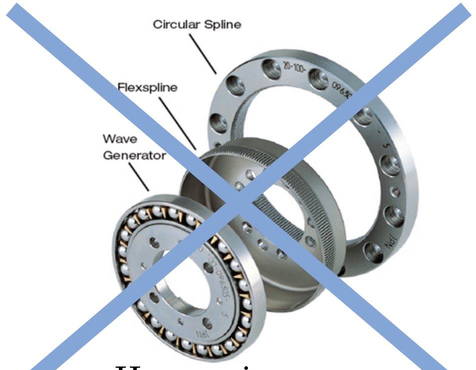
Humanoid robots with limited resources

- Low precision mechanic / mechatronic
- Small embedded computation power
- Complete autonomy

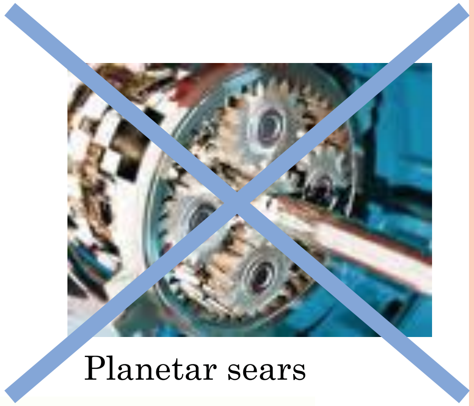
RHOBAN

Low Precision / Torque Mechatronic

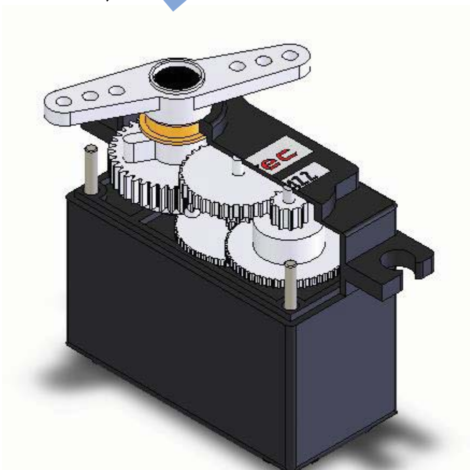
- RC standard servomotors
- Joint position control
- Structural modifications of servomotor to
  - Improve performances (backlash, robustness)
  - Improve mechanical integration



Harmonic gears



Planetar sears



Standard RC Servomotor

RHOBAN

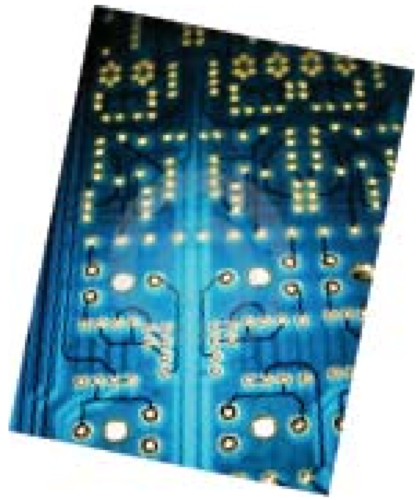
Hand made Mechanics

- Rapid prototyping techniques:

Structure made of resins (epoxy, polyuréthane) et aluminium.

- Elastics, silicone, caoutchoucs

➡ Absorbing shocks and high frequency oscillations.



RHOBAN

Embedded System – First Version

Behaviour Management
(State Machine)

Motion Scheduler

Sensor sampling
(can, i2c, …)

Motor control
(série, pwm)

- Real time -
Real time control of motion schedule

Very limited resources !
- 8-bits microcontroler
- *4 ko of RAM*
- no OS
- 16 MHz

…

The Acroban Platform

Compliance and flexibility
Exploring new mechanical structures (articulated torso)
Human interaction

The humanoid robot Acroban

- **Compliance**

  - compliant soft motions – compliant mechanics

  - physical interactions with humans

- **Vertebral column / Articulated Torso**

  - complex motions and stabilizing strategies
  - natural motions

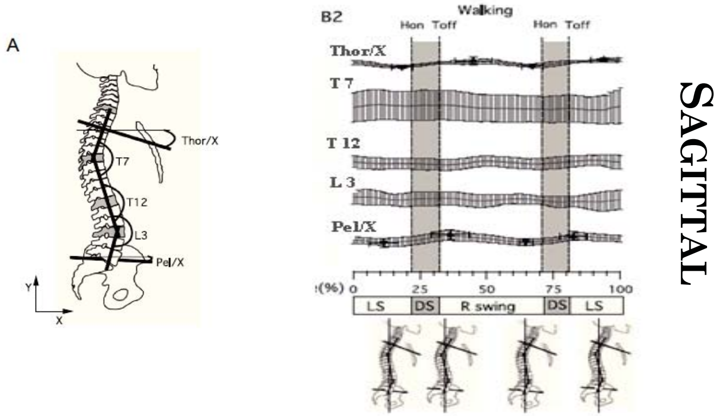
- **Small height**

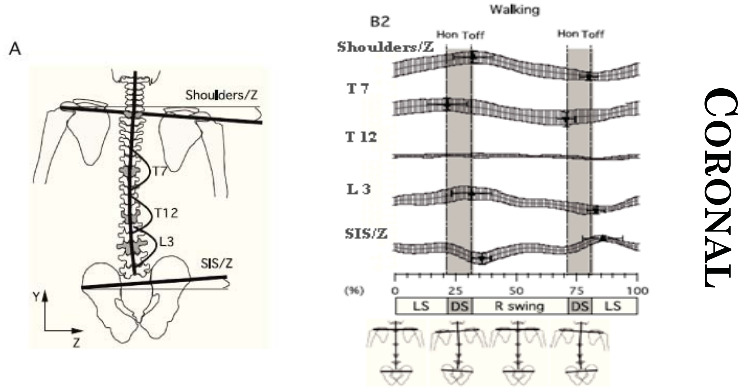
  - light experiment process

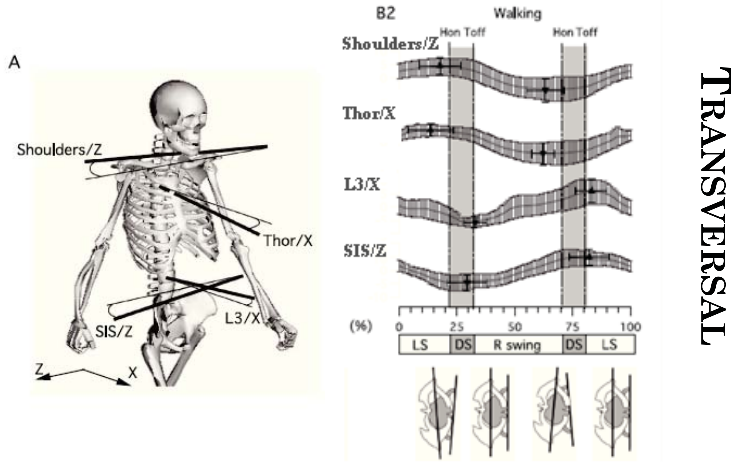
  - design of motions by experiment

BIO-INSPIRED DESIGN OF THE VERTEBRAL COLUMN / ARTICULATED TORSO.

- 5 essential DOF can be emphasized in the human torso.







Mechanical Structure

- Leg : 7 joints
- Torso : 5 joints
- Arm : 5 joints
- Head : 3 joints

- Pelvis
- vertebral column (5 joints)

32 joints

CONTROLED COMPLIANCE

- Control of the maximum torque of joint

Compliance

- Control of the maximum torque of each joint
- The mechanic structure is flexible
  (including springs, elastics, caoutchouc)

- (Semi-passive mechanics)
  Allows physical interactions with humans
- Act as energy reserves (springs and inverse pendulums)
- Turn backlash into P force controller

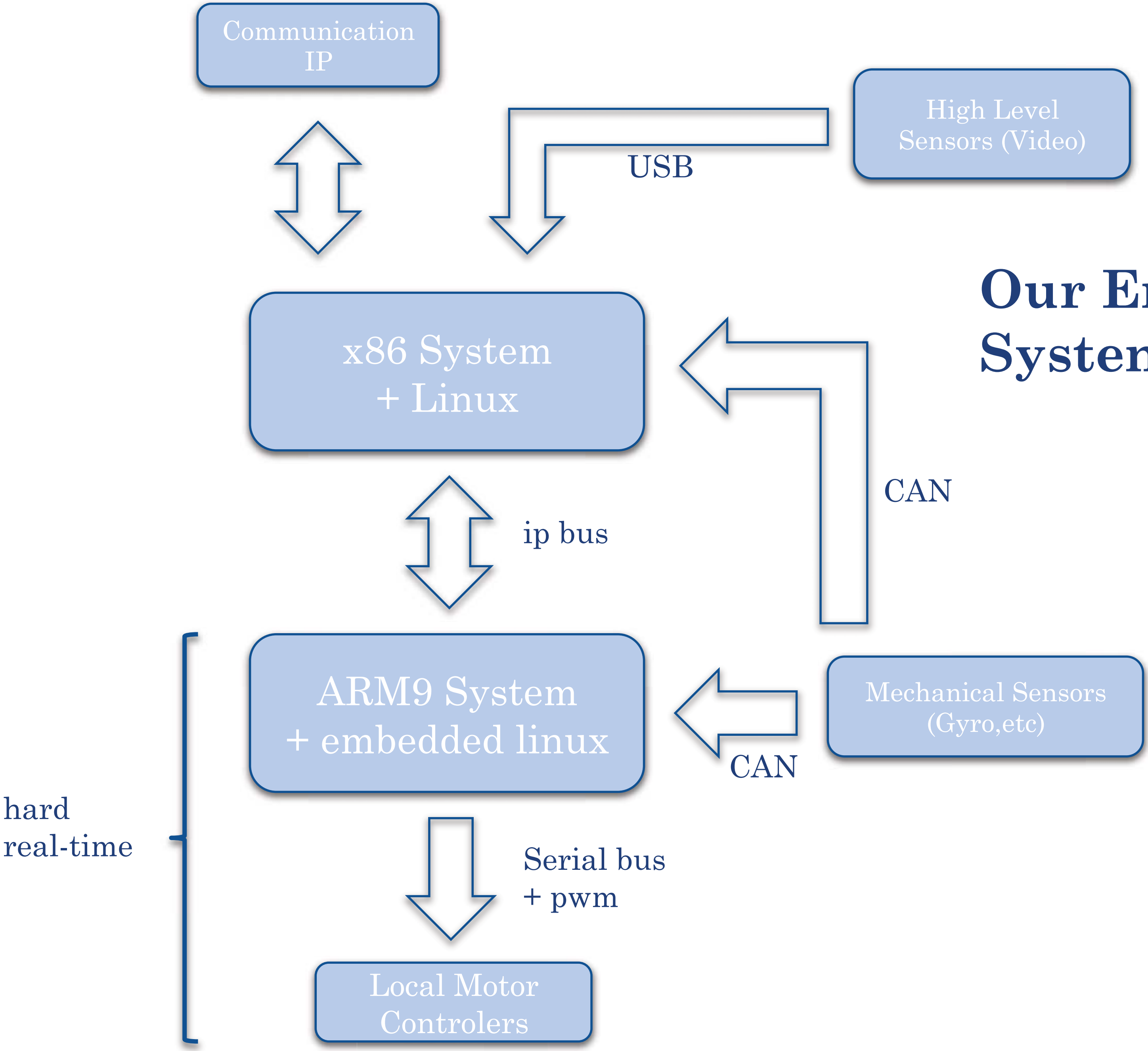
Human / robot interaction

MECHATRONIC

- Servo Dynamixel – RX series / MX series

- Position Control
- Maximum Torque ~ low frequency torque control
- Position feedback
- Torque feedback (low frequency)

Our Embedded System Today



Our embedded system today

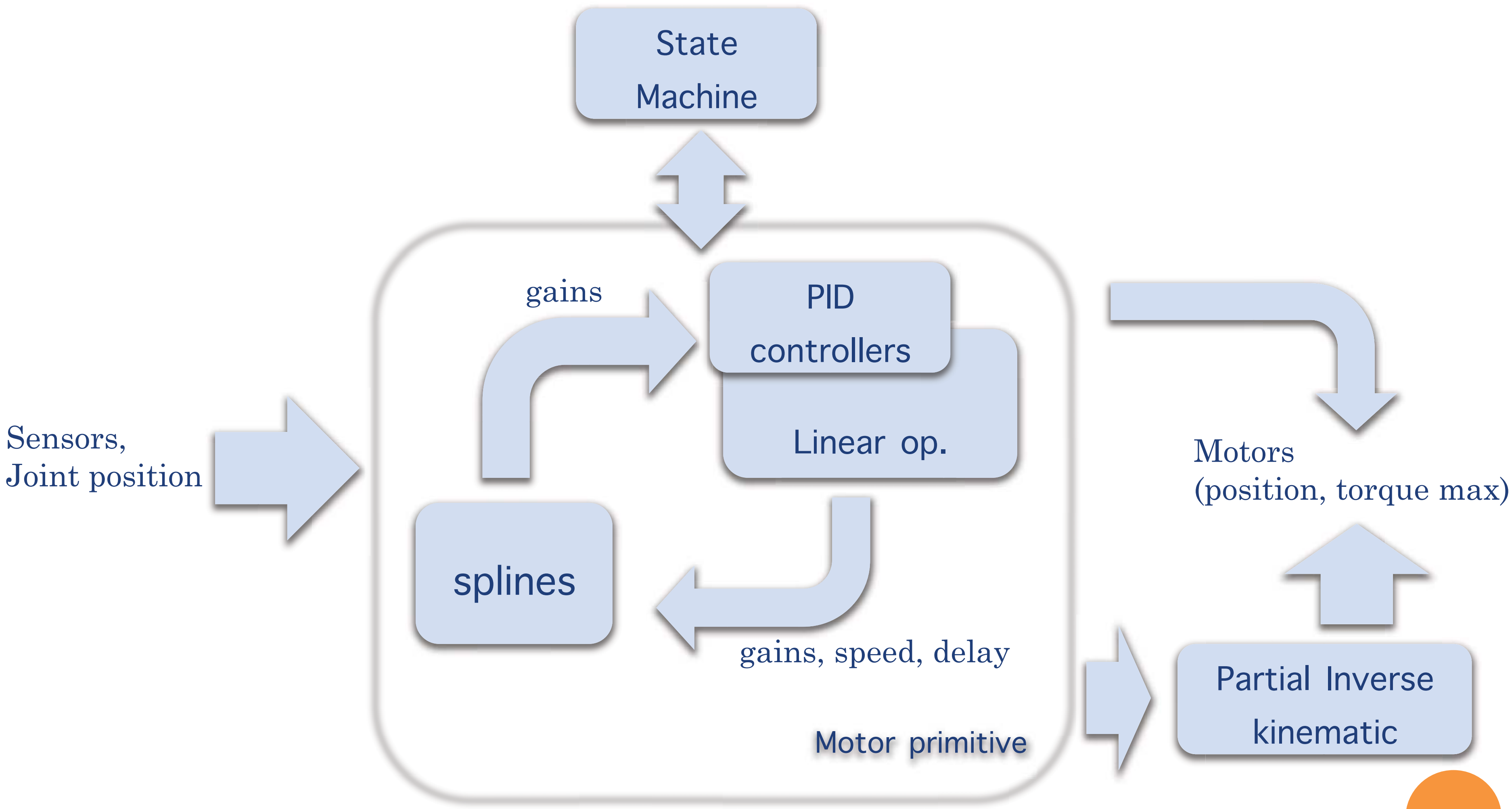
- ARM technology (ARM9 + Linux)
- Sensors:
  - accelerometer
  - gyroscope
  - force/pressure
  - [distance (ultrason, infrared), electronic compas]
- Partial inverse kinematic
- Motor control (pwm, serial)
- Embedded video processing (openCV)
- Wifi / Xbee communication
- Interface with physical simulator (Breve)

KEEPING BALANCE

- Compliance + torque sensing
- Inertial sensor
- Arms and spine act as pendulum

=> Stabilization

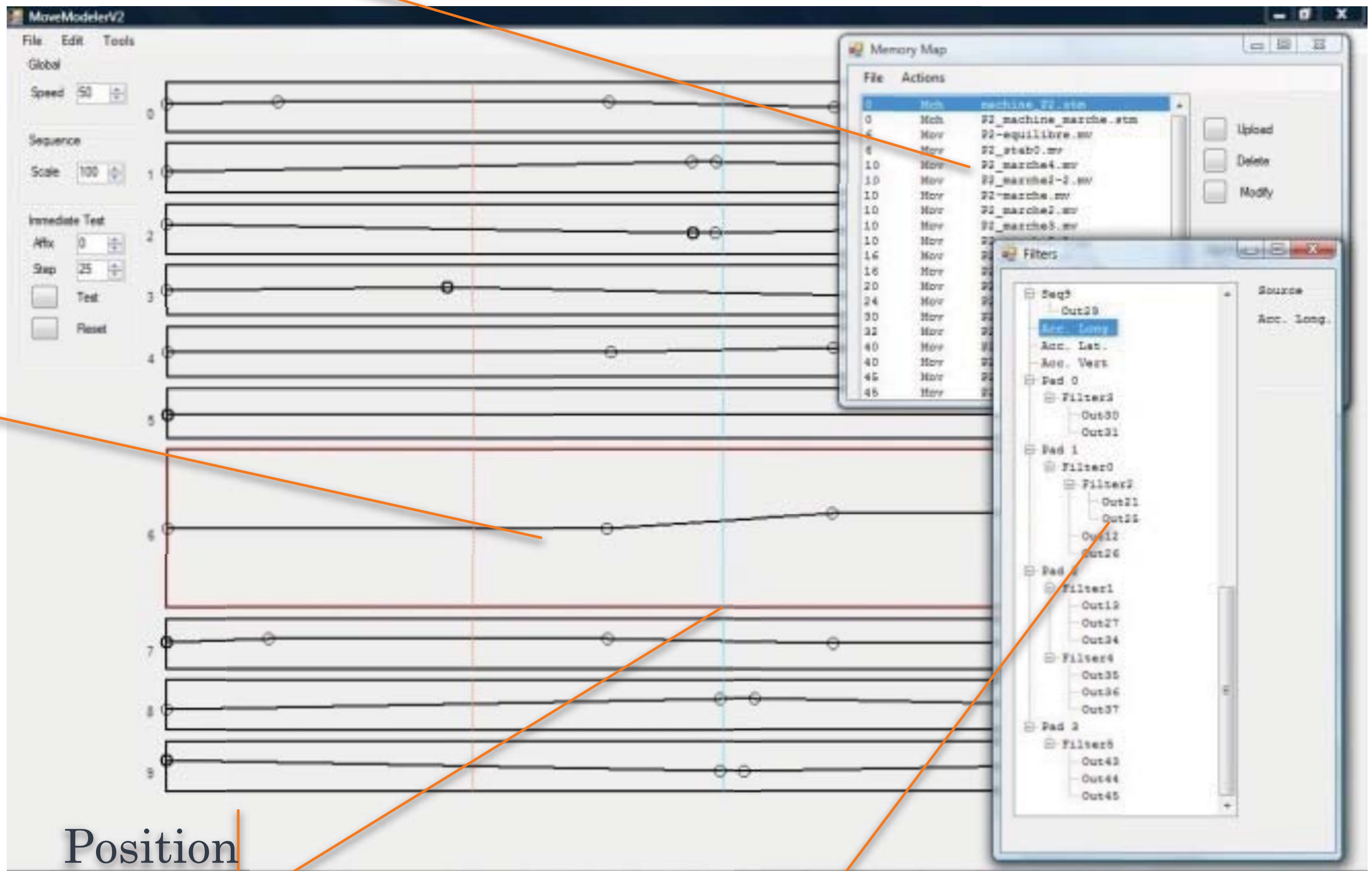
Motor Primitives: Bloc schemes



MOTOR PRIMITIVE DESIGN (OLD VERSION)

Move Store Management

Spline design



Position Test

Block Organisation

Motor Primitives: Bloc schemes

Entries

Sensors
- Accelerometers
- gyros

Joint error (regarding position target)

Joint pressure

Analogic interfaces
- joypad
- future Iphone, Wiimote, etc

Splines
- piecewise linear curves defined point by point by the user
- predefined curves (ex. trigonometric periodic functions)

Motor Primitives: Bloc schemes

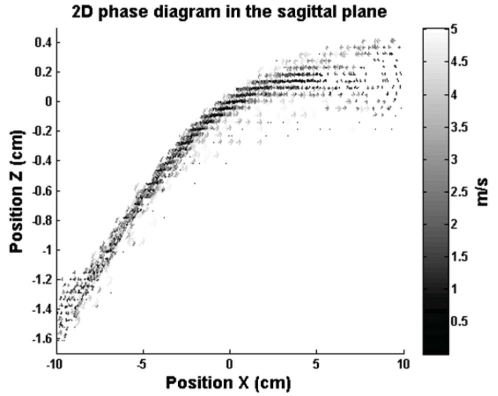
Outputs

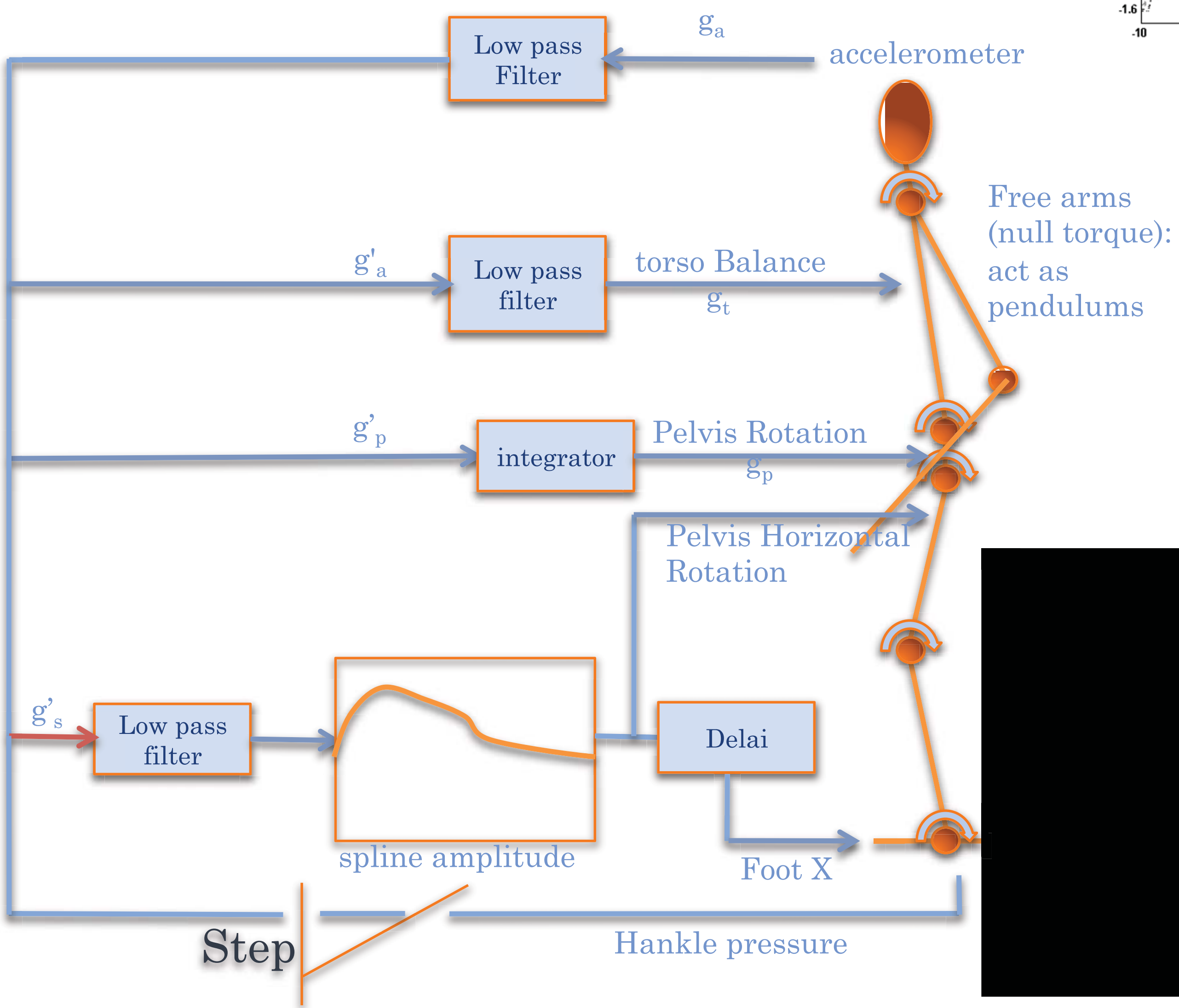
- Join angles
- Join maximal torque
- Partial task space position (cartesian position of feet)
- Simple combined actions (pelvis rotations, torso moves, etc)

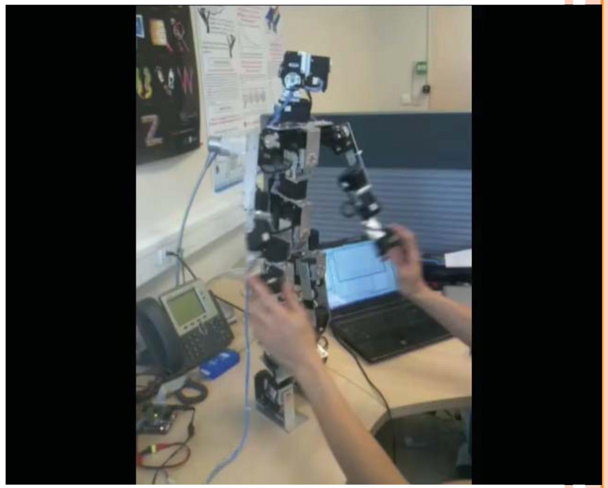
- Motor primitive parameters
    - gains of output
    - gains of splines
    - gains of controllers
    - speed and delay of splines

Example of balance strategy

The alchemy method / Expert knowledge (…)

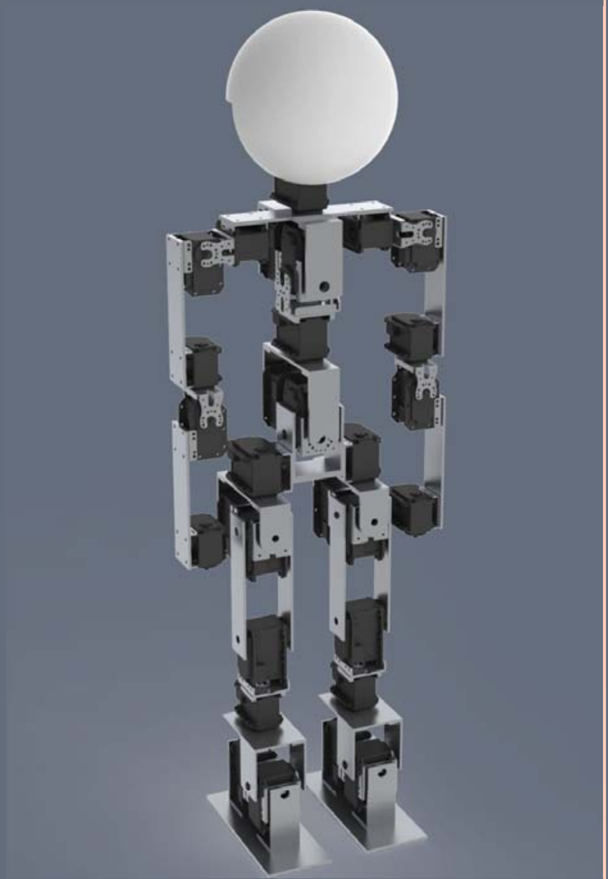






A NEW PLATFORM

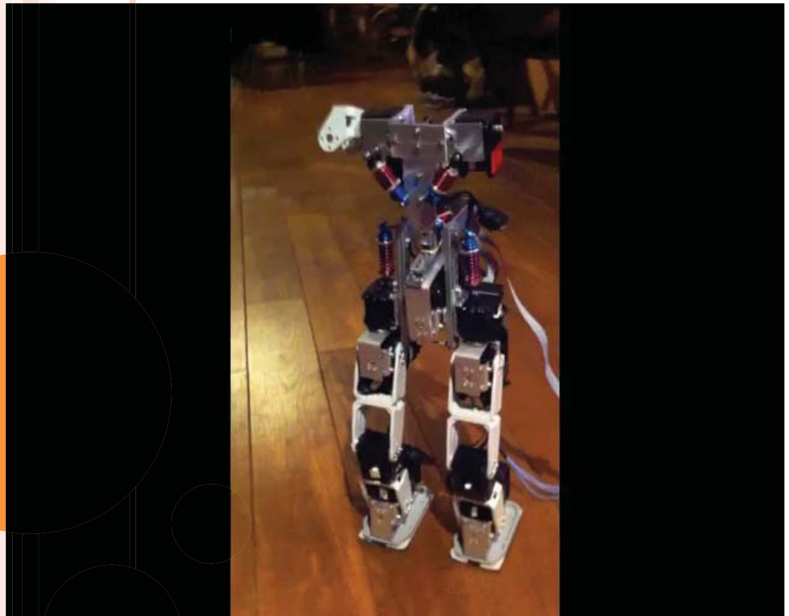
For fighting inelastic shocks ☺



New Prototype : structural Compliance

Vertical dampers on linear joints on hips and in the torso

- Mechanical Compliance : **Dampers** !
- Dampers fight against *inelastic shocks*
- The robot becomes *semi-passive / under-actuated*
- *Dampers length* become a judiscious information



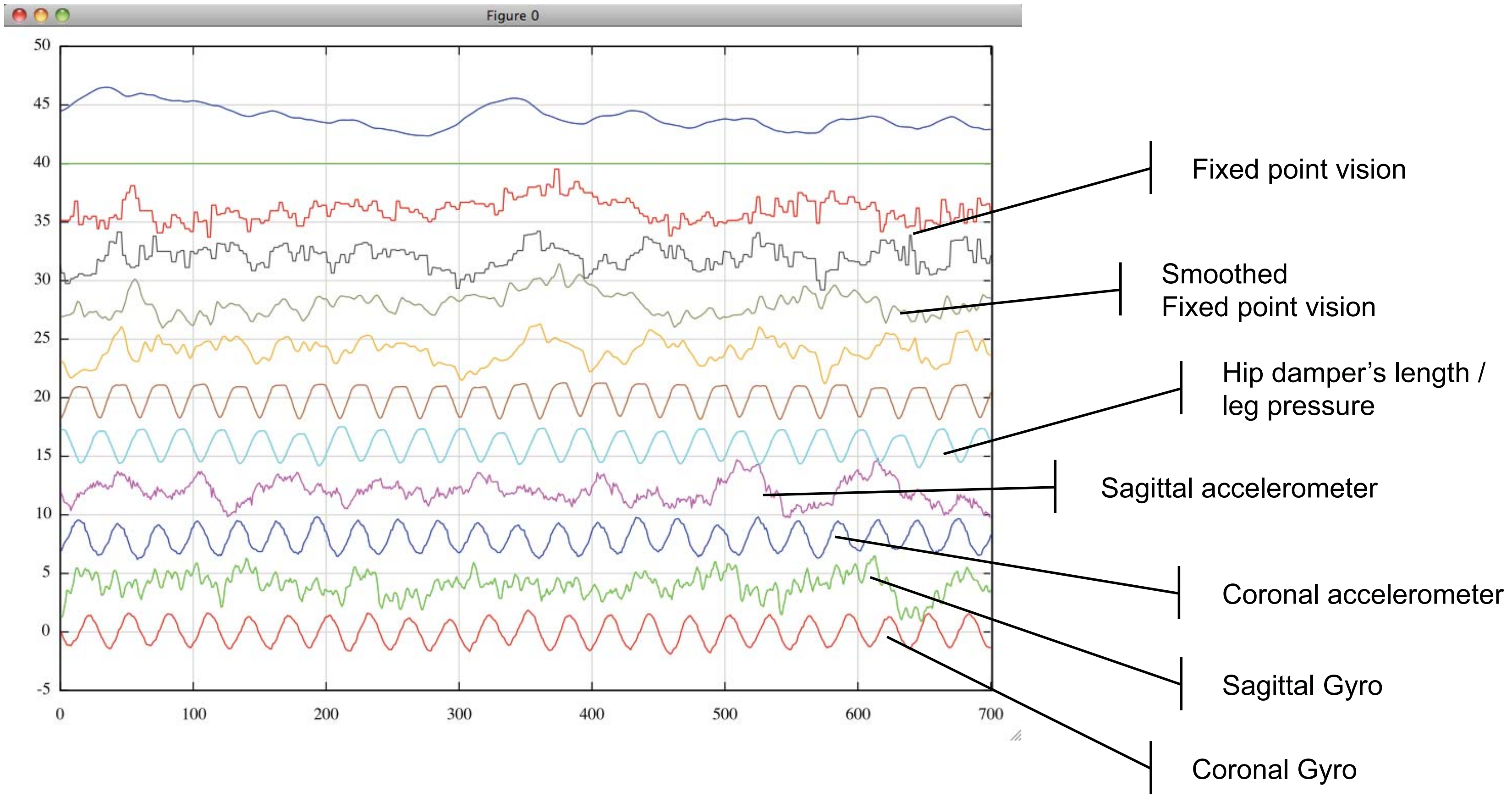
Would you think about designing a car without dampers ?...

Dampers in the Hip
(vertical linear joint)

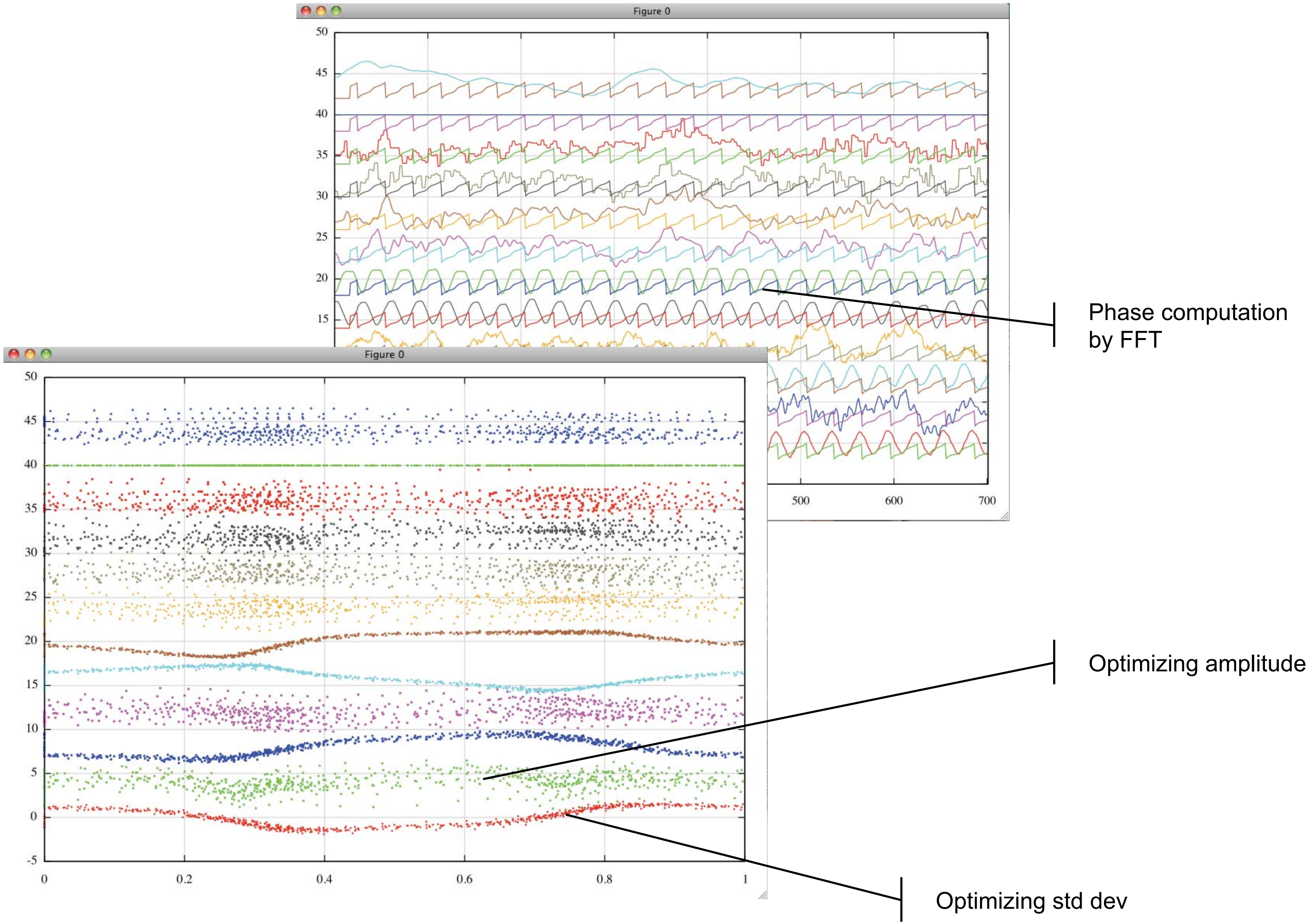
Approach

- CPG + optimization / learning
- ((Semi)-passive) dynamics

CPG + Optimization / Learning



EXTRACTING PHASE



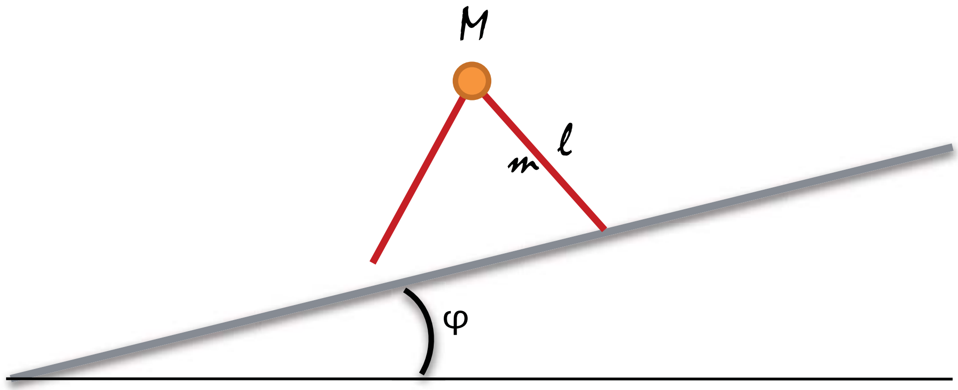
Passive Dynamics : Compas Passive Walker (the simplest one…)

Ultimate simplification of the gait

Find (by simulation)

- static parameters (leg length/mass, etc)
- initial conditions of the step

to reach a stable gait.



Compas Passive Walker
A dynamic system

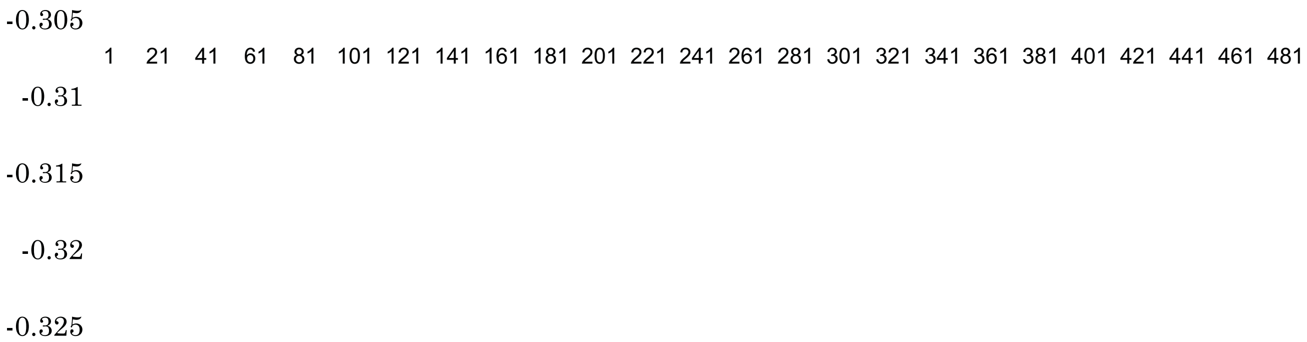
Step by step

$$\phi_{n+1} = F(\phi_n)$$

Computes the trajectory between steps

Φ_n is the state at stepping

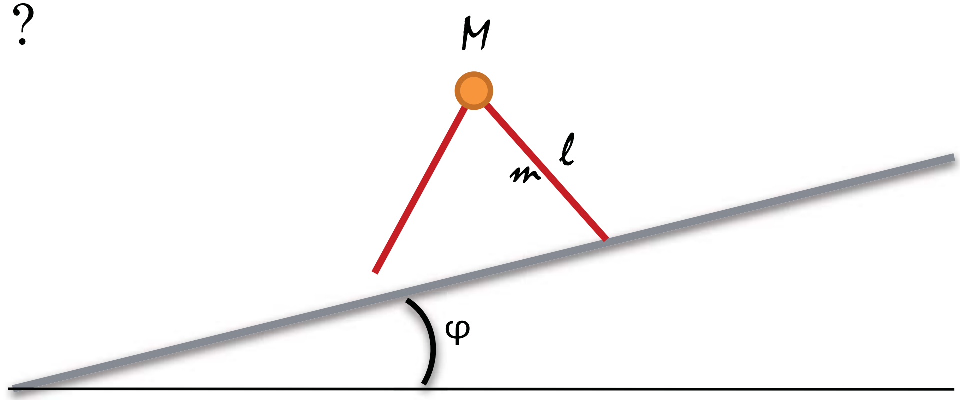
Legs Angle at Stepping



Compas Passive Walker
(THE SIMPLEST ONE BUT NOT SO SIMPLE!)

- Looking for |eigenvalues| < 1 of the jacobian of F
- The example seems to show:
  - Stable but non periodic trajectories
  - Attractive trajectories

- Periodic trajectories ?
- Adding knees / feet ?
- Adding dampers ?



Thank you for attention !