AMRU5 six-legged robot :
Dynamic Simulation and Embedded Control

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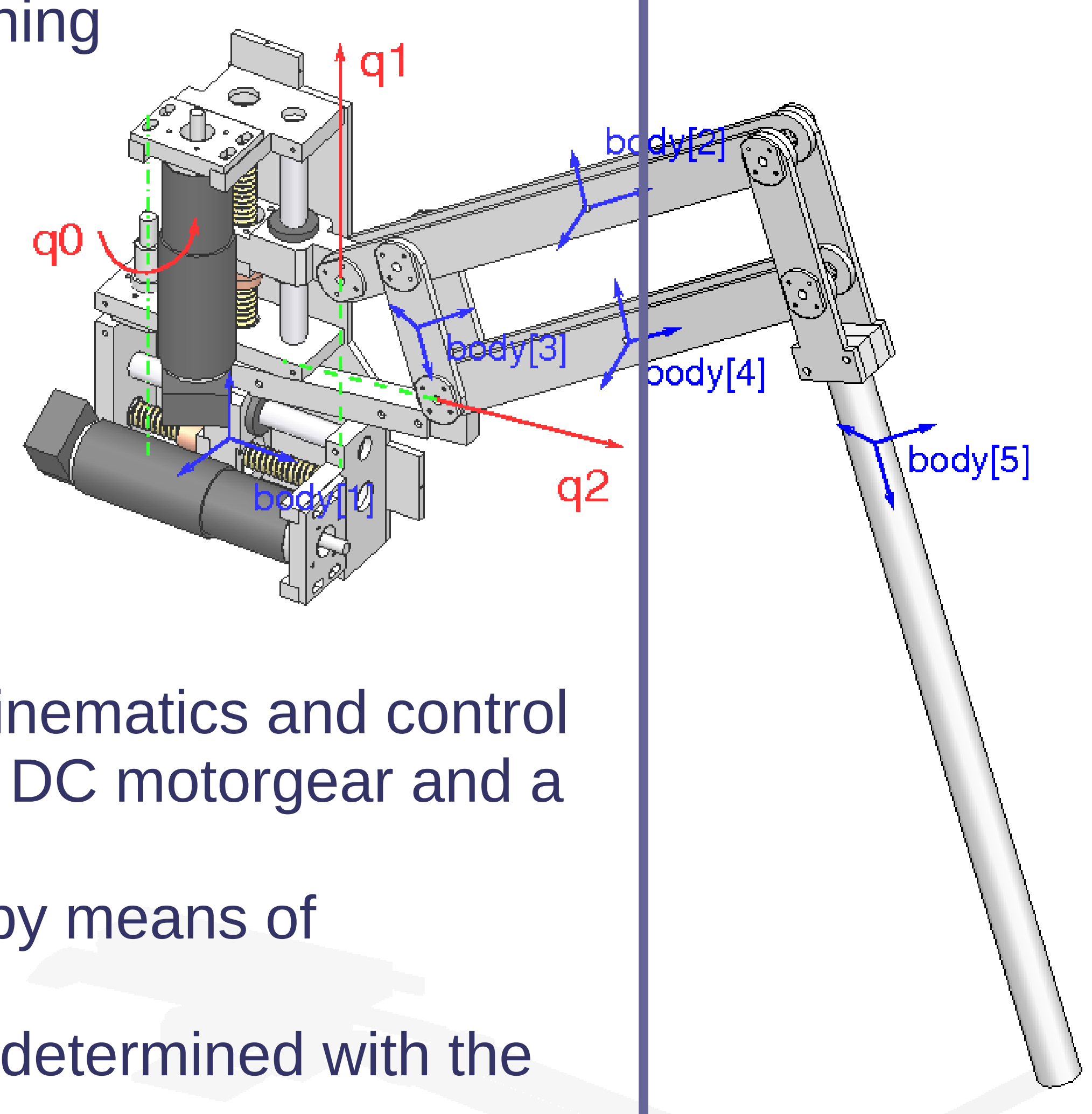
Introduction and previous work

Context of the research

Six legged robot, initially devoted to demining
Developped @ RMA, Belgium
Application case for :

- Mechatronics integrated system simulation tools
- Implementation of a decentralized control with position and force feedback

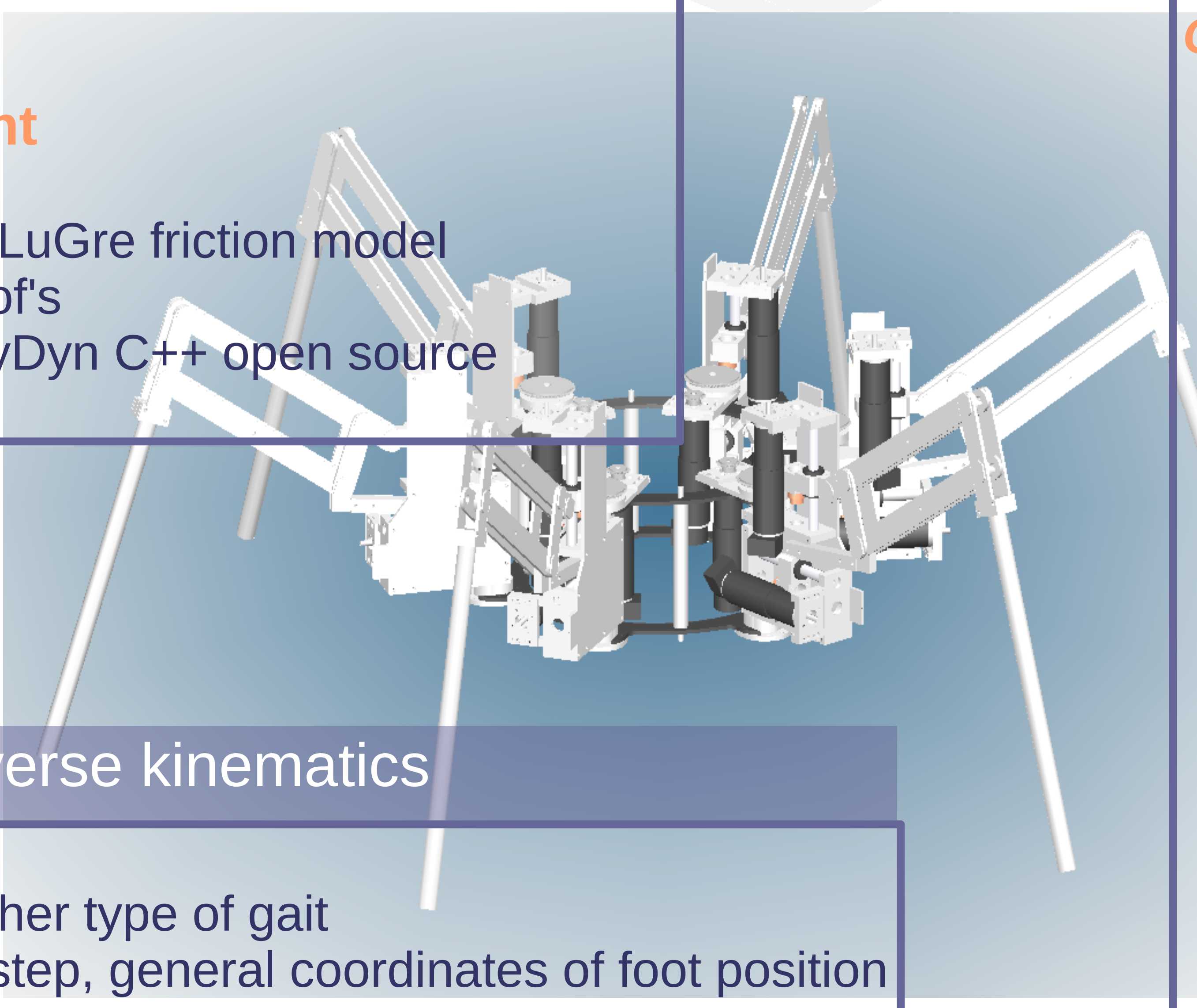


Characteristics

18 electrical actuators
Pantograph leg mechanism = easier for kinematics and control
3 degrees of freedom per leg, driven by a DC motorgear and a screw ball or a simple sprocket chain
Bodies are positionned in a global frame by means of homogeneous transformation matrices
Each center of mass and inertia tensor is determined with the help of CAD tools
Global robot = 49 bodies

Dynamic simulation at present

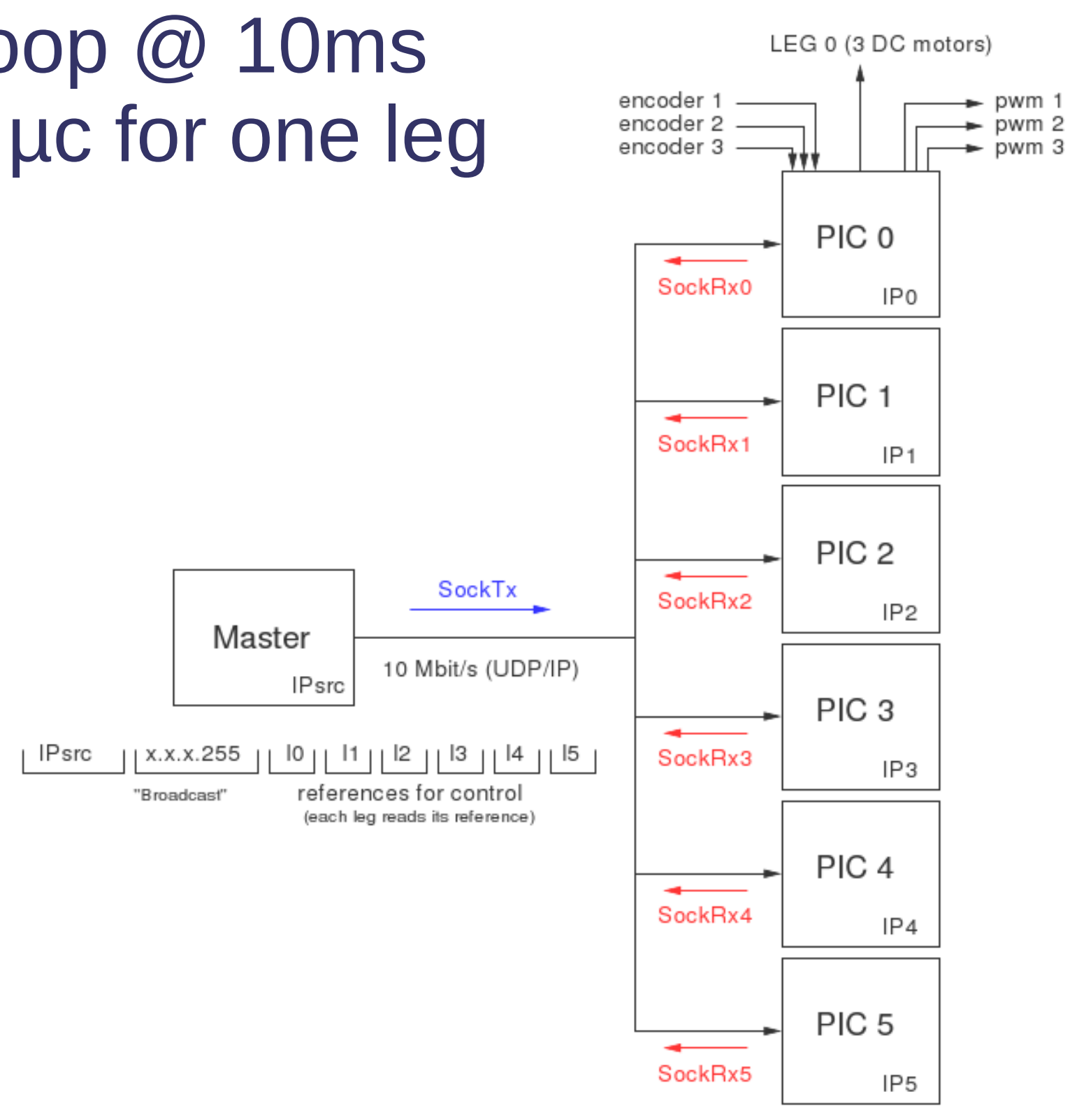
Ground contact forces (k, c, ffrict)
Possibility of taking into account a LuGre friction model
PID position control (only) of the dof's
Multibody simulation with the EasyDyn C++ open source librairy, developed at FPMs



Control of AMRU5

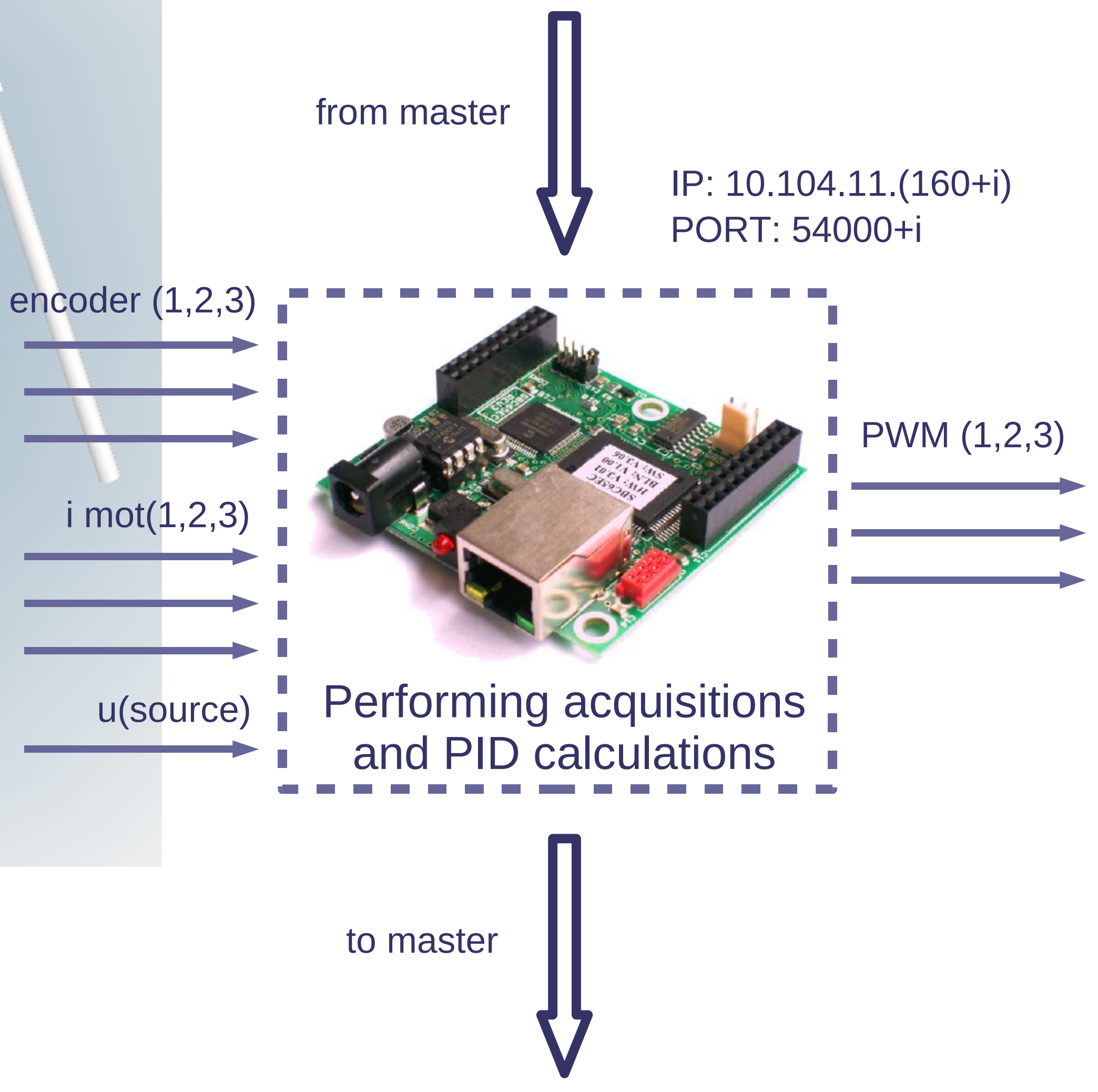
General scheme of the control loop

master : dual core Intel Pentium 4, 3GHz
slaves : SBC65EC (PIC18f6627 µc-based)
Control loop @ 10ms
One PIC µc for one leg



On-board controller for a leg

udp socket, sending broadcast packet (x.x.x.255) with qref from master



udp socket with q, i, u of the leg

Moving AMRU5 : inverse kinematics

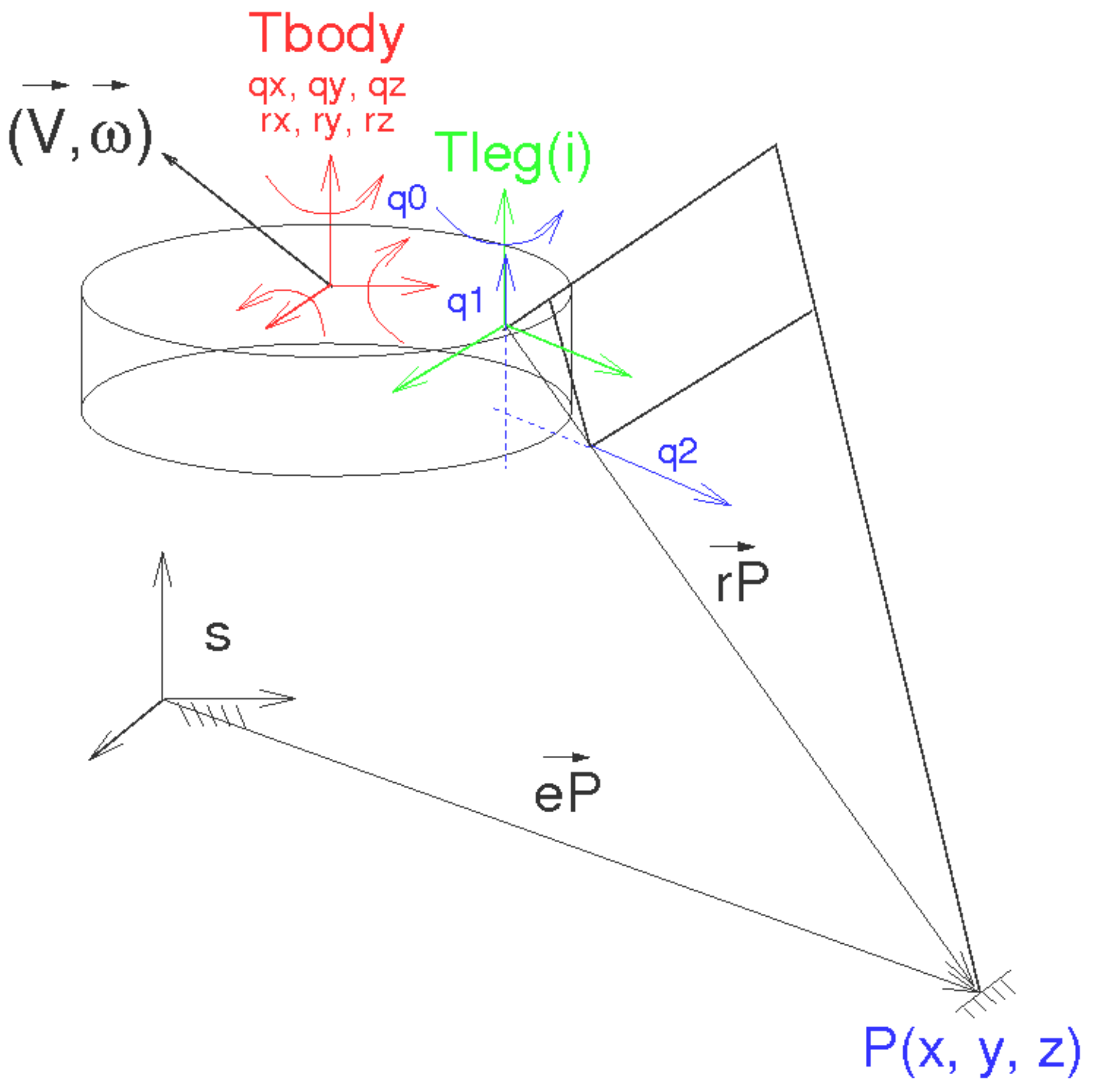
Assumptions are :

Tripod gait, with probable evolution to other type of gait
No slip at ground interface : during one step, general coordinates of foot position remain constant (eP = constant)
Rigid soil

Motion of the robot : the user gives position and orientation of the main body, modifying the homogeneous transformation matrix Tbody:

Position of the end of the leg is then :

$$\begin{aligned}\vec{e}_p &= T_{leg} \star \vec{r}_p \\ \vec{r}_p &= T_{leg}^{-1} \star \vec{e}_p \\ \vec{r}_p &= (T_{body} \star T_{body/leg})^{-1} \star \vec{e}_p\end{aligned}$$



Once the new rP is know :

Newton-Raphson algorithm is applied to solve inverse kinematics by leg :

$$\vec{q}^{(i)} = \vec{q}^{(i-1)} - [J]^{-1}(\vec{f}(\vec{q}^{(i-1)}) - \vec{r}_P)$$

New references of dof's are then sent to the PID controller

Measure for force feedback

Principle

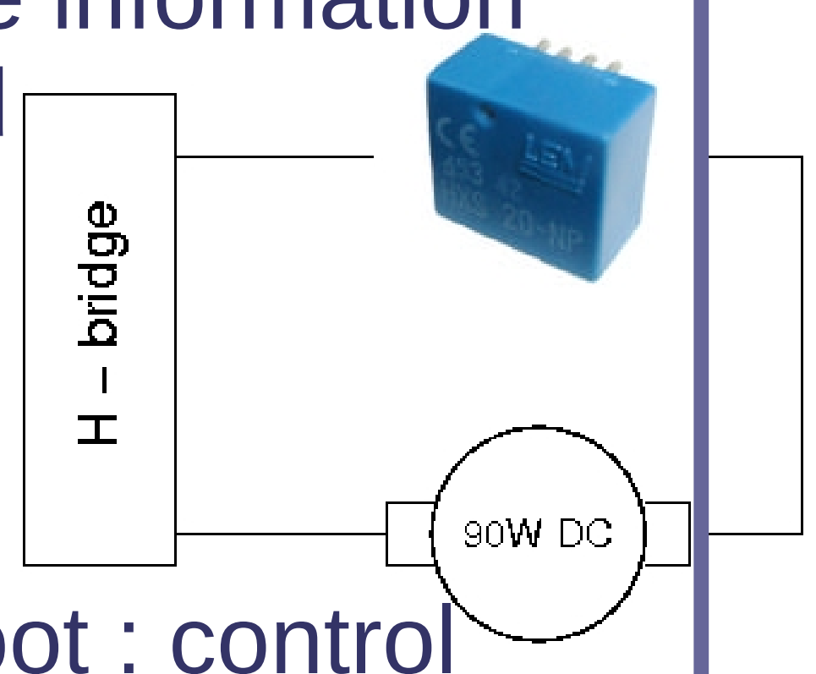
No classical sensing at the end of the leg
Measure of the current inside the motors

Drawback

- needs a motion to have the force information
- precise friction model is required

Advantage

- reaction is possible for any location of the perturbation on the leg
- no special sensors needed at foot : control more robust because risks of damage at foot are reduced



FURTHER RESEARCHES :

- Generate gait pattern combinated with inverse kinematics calculations to have a complete autonomous robot
- Determine a precise LuGre friction law for the joints, and complete the simulation model
- Implement a force control, thanks to the current measured inside the motor, to have a smooth gait, to fix some consumption objectives, or to walk on unstructured area