Program/simulation tools
ROS/Gazebo/OpenHRP

Robotics Principia

24th January 2019, Sophia-Antipolis, France

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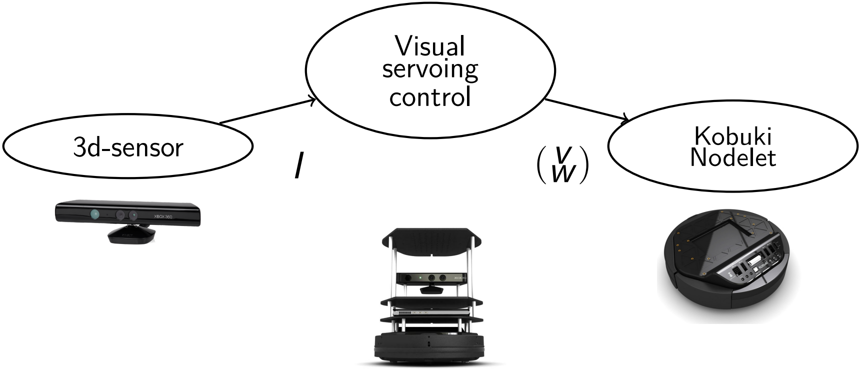
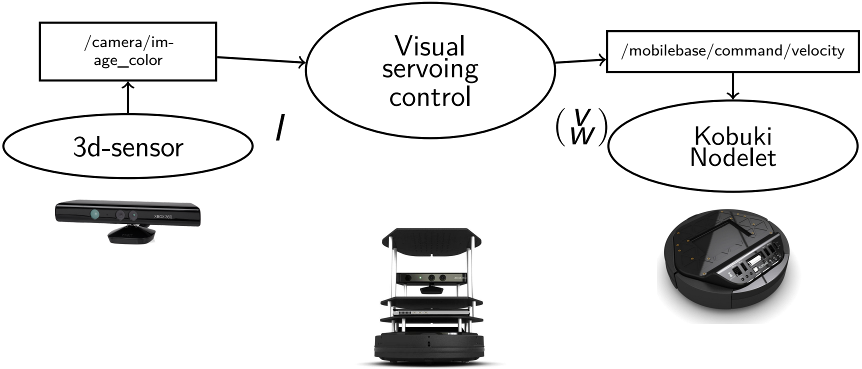
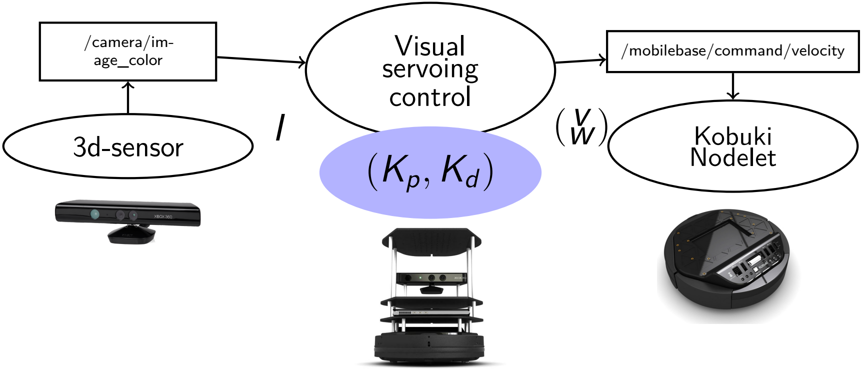
Exemple: Asservissement visuel



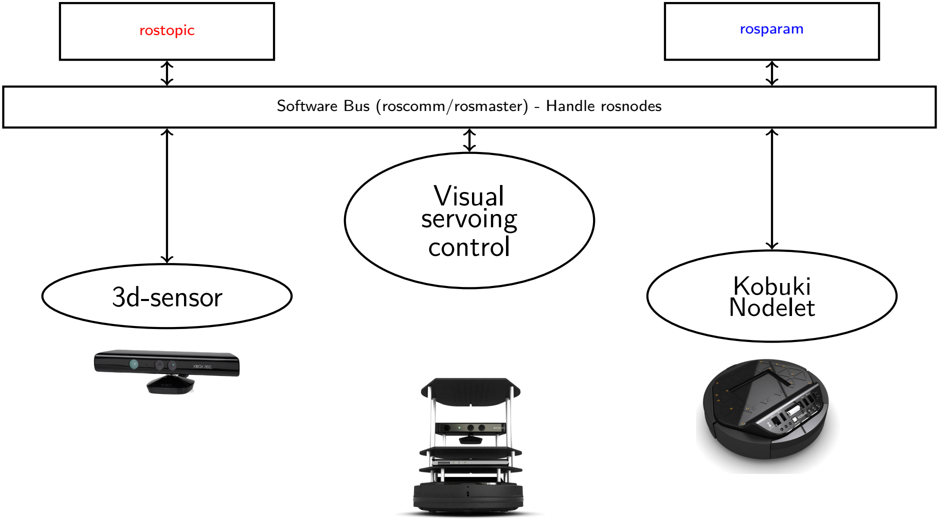
Exemple: Asservissement visuel - Topics



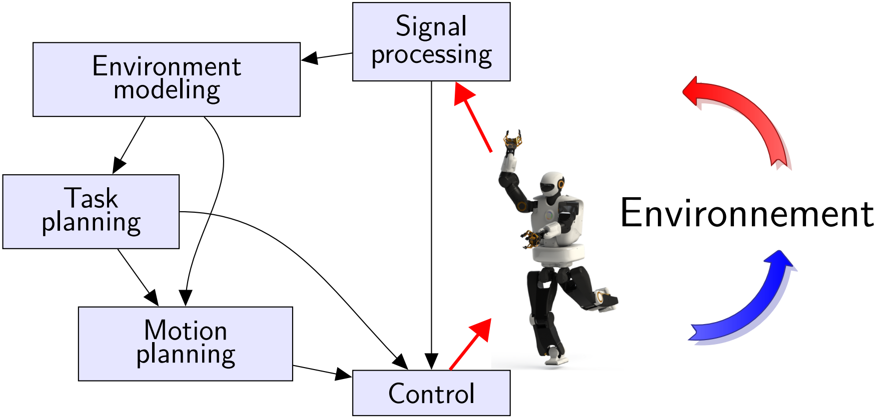
Exemple: Asservissement visuel - Topics - Params



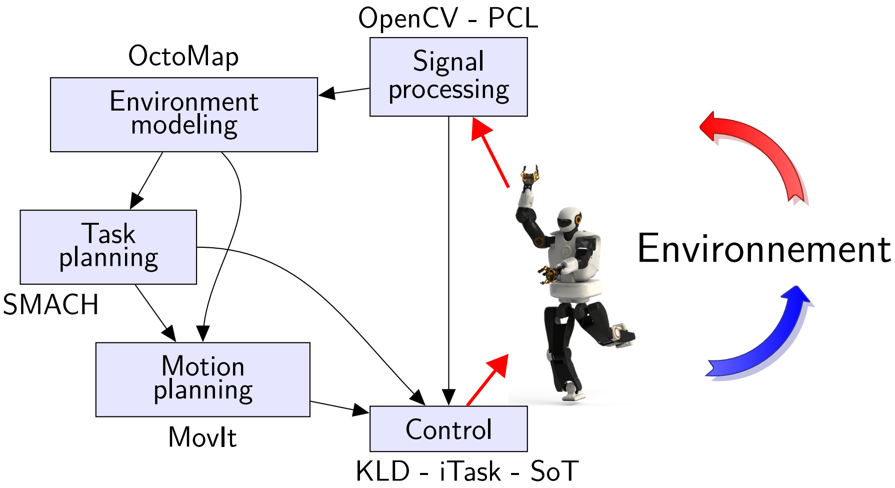
Exemple: Asservissement visuel - Software bus



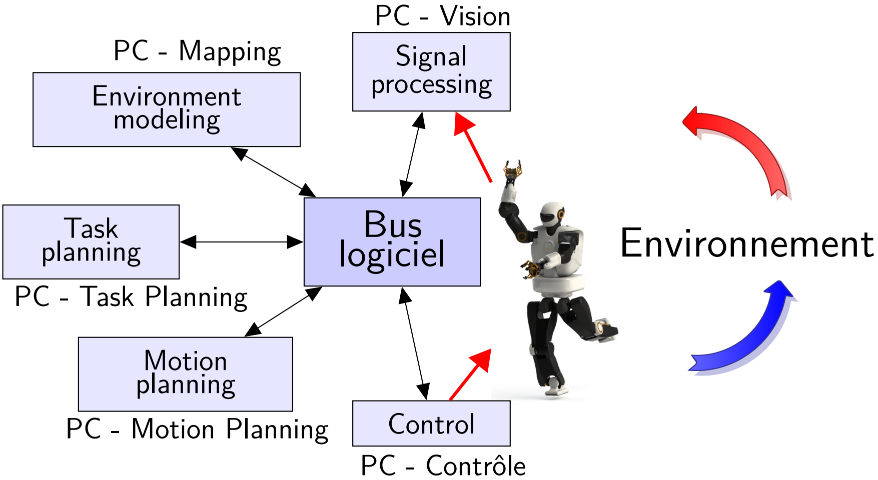
Motivations - Robotics application



Motivations - Robotics application - Tools



Motivations - Robotics application distributed



Motivations

The robotics community must *collaborate* to create robotics systems of the same quality than in the computer science and physics community.
ROS is the tool that allowed to scale-up.

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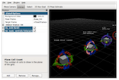

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Plumbery   Tools   Capacities   Ecosystem

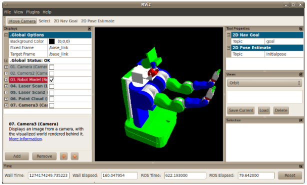
Motivations - Plumbery

Middleware

- Publication/subscription transmission on anonymous messages (Message Passing)
- Record and playback messages
- Requests/answers using remote procedure calls
- Distributed parameter server

Motivations - Tools

rviz	3D graphical interface
rosbag	Record and data visualizing
rxplot	Online viewing quantities
rxgraph	Graph application structure display
rqt	Incremental Graphical User Interface
catkin	Compiling and packages management system



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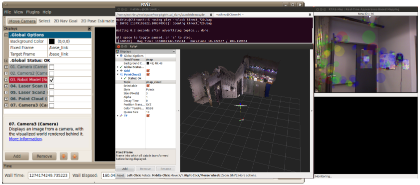

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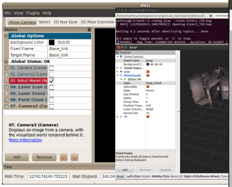

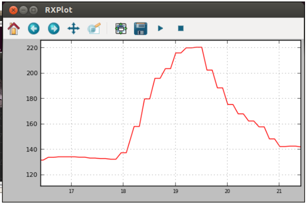

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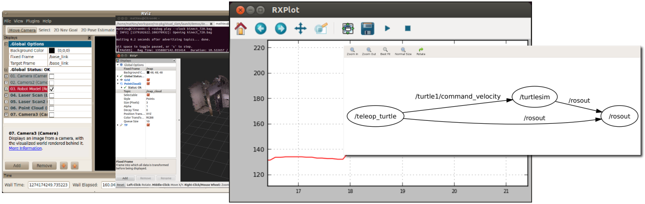

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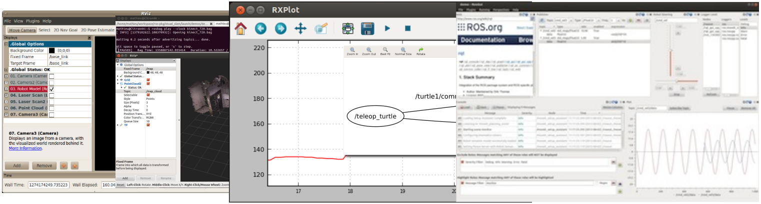


Motivations - Ecosystem

- Messages standardization for the robots
- Model description language (even if imperfect)
- Geometry - Dynamical libraries for robots
- Preemptable remote procedure calls
- Diagnostics
- Pose estimation
- Localization
- Map building
- Navigation

Motivations - Ecosystem

Operating Systems

Robots

Packages

Support : Ubuntu

Experimental :

Ubuntu ARM | OS X (Homebrew) | OS X (MacPorts)

OpenEmbedded/Yocto | Debian | Arch Linux

Windows | Ångström | UDOO

Motivations - Ecosystem

Operating Systems

Robots

Packages

01/05/2014 : 111 Supported robots on http://wiki.ros.org/Robots
25/04/2017 : 27 Supported robots on http://wiki.ros.org/Robots
01/05/2014 : 2048 Supported packages on http://wiki.ros.org/Packages
25/04/2017 : 1400 Supported packages on http://wiki.ros.org/Packages

ROS: short history

2008	ROS started with Willow Garage
2010 - Jan	ROS 1.0
2010 - Mar	Box Turtle
2010 - Aug	C Turtle
2011 - Mar	Diamondback
2011 - Aug	Electric Emys
2012 - Mar	Fuerte Turtle
2012 - Dec	Groovy Galapagos
2013 - Feb	Open Source Robotics Fundation continues ROS
2013 - Aug	Willow Garage became Suitable Technologies
2013 - Aug	PR-2 Support is handled by Clearpath Robotics
2013 - Aug	Hydro Medusa
2014 - Jul	Indigo Igloo (EOL - Apr 2019)
2015 - May	Jade Turtle (EOL - May 2017)
2016 - May	Kinetic Kame (EOL - May 2021)
2017 - May	Lunar Loggerhead (EOL - May 2019)
2018 - May	Melodic Morenia (EOL - May 2023)

ROS: Release normalization

- Lunar Loggerheard (May 2017- May 2019)
  - Ubuntu Xenial (16.04), Yakkety (16.10)
  - Ubuntu Zesty (17.04 LTS)
  - C++11, Boost 1.62, Lisp SBCL 1.2.4, Python 2.7 (tests against Python 3.5 recommended) CMake 3.7.2
  - Ogre3D 1.9.x, Gazebo 7.5, PCL 1.8.0, OpenCV 3.x, Qt 5.7.1, PyQt5 5.7
- Melodic Morenia (May 2016 - May 2023)
  - Ubuntu Artful (17.10)
  - Ubuntu Bionic (18.04 LTS)
  - C++14, Boost 1.55, Lisp SBCL 1.3.14, Python 2.7 (tests against Python 3.5 recommended), CMake 3.10.2
  - Ogre3D 1.9.x, Gazebo 9, PCL 1.8.1, OpenCV 3.2, Qt 5.9.5, PyQt5 5.10.1
- Lien vers la ROS Enhancement Proposal (REPs) : `http://www.ros.org/reps/rep-0003.html`

Online exercices

What is a simulator ?

[Ivaldi,ICHR,2014]

System simulators

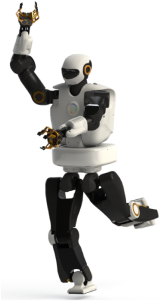
- Simulate sensors, actuators, environment
- Smoothly going from simulation to real robot
- Accurate representation of reality
- Stability

Control simulator

- Real-time
- Catch the robot main dynamics
- To be integrate inside the control loop

What is a simulator ?

[Ivaldi,ICHR,2014]



System simulators

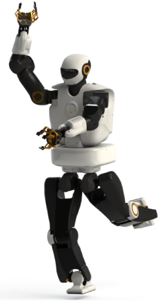
- Gazebo
- Stage
- Morse
- OpenHRP

Control simulator

- MuJoCo
- RBDL
- Pinocchio
- Robotran

What is a simulator ?

[Ivaldi,ICHR,2014]



System simulators

- Gazebo
- Stage
- Morse
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Dynamics Engine: ODE

Control simulator

- MuJoCo
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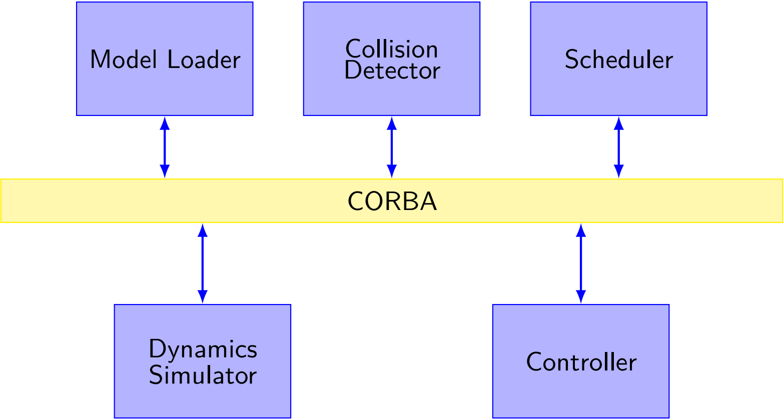
Problem 1: Reality

- Impact
- OpenHRP 2.x: 800 N
- Real robot: 1300 N
- Giving up speed
- Compliant material
- Dynamics
- Vision

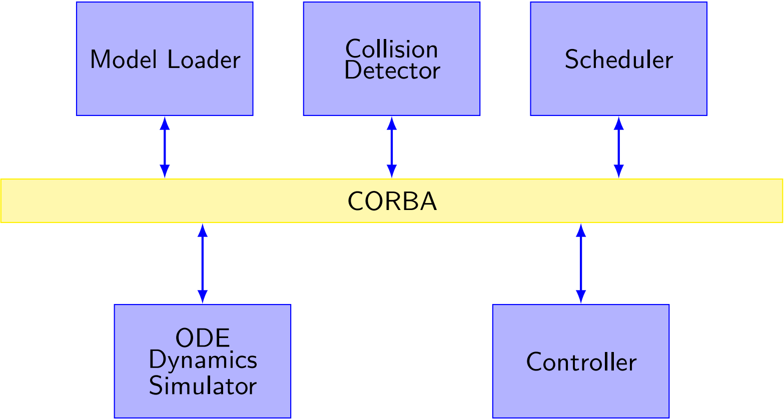
Problem 2: Software flexibility

- From simulation to real robot
- Being able to change parts of the simulator
- Strong middleware
- Sensor simulation

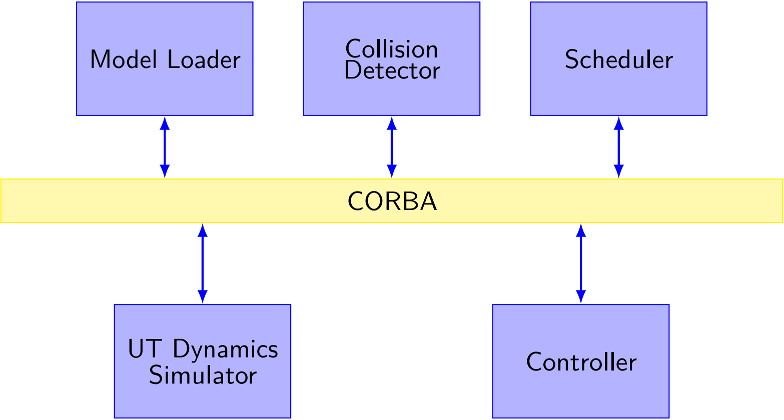
OpenHRP architecture



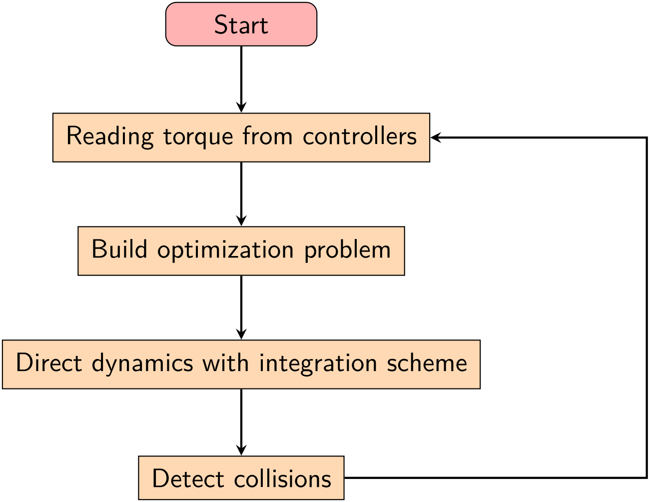
OpenHRP architecture



OpenHRP architecture



Global sequence - scheduler

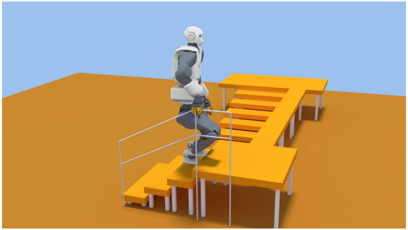


OpenHRP AIST Dynamics Simulator

- Uses a mixture of *generalized* and *maximal* coordinates formulation
- The *generalized* coordinates are used to compute the robot state.
- This assumes a perfect rigid body dynamics (true for a high PID control)
- The *maximal* coordinates are used to compute the rest of the world state.
- Specific compliant joint are introduced in the direct dynamics of the robot.

ODE: The problem

Definitions [Hsu,Simpar,2014]



i-th body - position, quaternion	x, q
velocity	$\dot{\nu}_i = [\dot{x}^T, \omega^T]^T \in \mathbb{R}^{dim(i)}$
force	$F_i \in \mathbb{R}^{dim(i)}$
acceleration	$\dot{\nu}_i$
then	$M_i \dot{\nu}_i = F_i$
	$M\dot{\nu} = F$

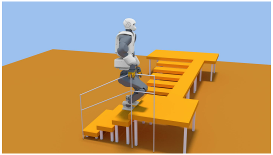
$$M_i \dot{\nu}_i = \begin{bmatrix} m_i \delta & 0 \\ 0 & I_i \end{bmatrix} \begin{bmatrix} \ddot{x}_i \\ \dot{\omega}_i \end{bmatrix} = \begin{bmatrix} f \\ \tau - \omega \times I\omega \end{bmatrix} = F_i$$

ODE: The problem

[Hsu,Simpar,2014]

i-th constraint $h_e(x,q) = 0,\ h_i(x,q) \geq 0,$

Let us linearize constraints



ODE: The problem

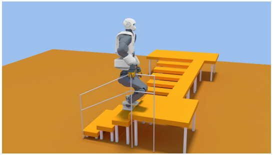
[Hsu,Simpar,2014]

i-th constraint $h_e(x,q) = 0,\ h_i(x,q) \geq 0,$

speed $J_{i1}\nu_1 + \cdots + J_{ik}\nu_k + \cdots + J_{in}\nu_n + c_i = 0$

all together $J\dot{\nu} + c = 0$ (1)

$M\dot{\nu} = F^c + F$



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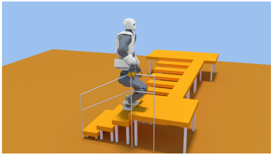
all together	$J\dot{\nu} + c = 0$ (1)
	$M\dot{\nu} = F^c + F$
with	$F^c = J^T\lambda$
then	$M\dot{\nu} = J^T\lambda + F$



ODE: The problem

[Hsu,Simpar,2014]

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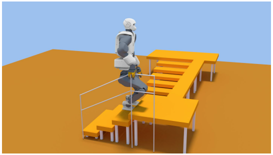
all together	$J\dot{\nu} + c = 0$ (1)
	$M\dot{\nu} = F^c + F$
with	$F^c = J^T\lambda$
then	$M\dot{\nu} = J^T\lambda + F$
then with (1)	$J(M^{-1}J^T\lambda + M^{-1}F) + c = 0$
then	$A\lambda = b$
with	$A = JM^{-1}J^T$ et $b = -(JM^{-1}F^{ext} + c)$



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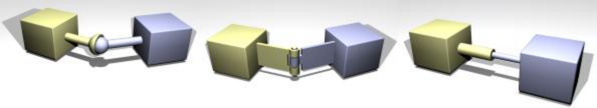
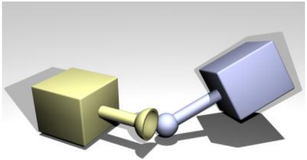


Joints when everythings goes well

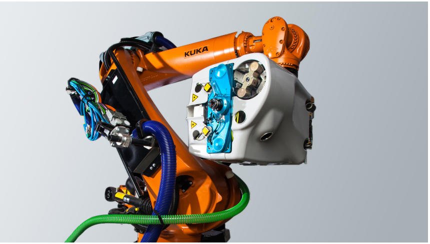


Error Reduction Parameter

Tutorials

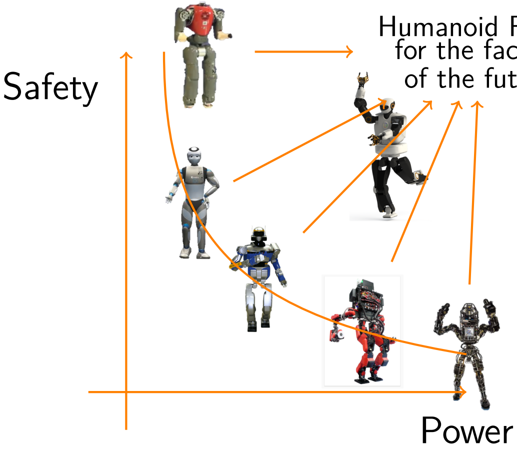
Online Exercices

The problem



Costly, heavy,
not user friendly

The problem - The vision



125 millions of holes drilled by year

75 % are done *manually*