The stack of tasks

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The stack of tasks

Outline

Introduction

A few words about the theory

Software

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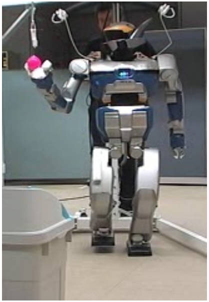
Sensor-based closed loop control of a redundant robot



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The stack of tasks provides a control framework for real-time redundant manipulator control

- implementation of a data-flow,
- control of the graph by python scripting,
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Configuration space

- Robot: set of rigid-bodies linked by joints $\mathcal{B}_0, \cdots \mathcal{B}_m$.
- Configuration: position in space of each body.

$$\mathbf{q} = (\mathbf{q}_{waist}, \theta_1, \cdots \theta_{n-6}) \in SE(3) \times \mathbb{R}^{n-6}$$
$$\mathbf{q}_{waist} = (x, y, z, roll, pitch, yaw)$$

- Position of $\mathcal{B}_i$ depends on $\mathbf{q}$:

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Velocity

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$$\begin{array}{rcl} \dot{\mathbf{q}} & = & (\dot{x}, \dot{y}, \dot{z}, \omega_x, \omega_y, \omega_z, \dot{\theta}_1, \cdots \dot{\theta}_{n-6}) \\ \omega & \in & \mathbb{R}^3 \end{array}$$

- Velocity of $\mathcal{B}_i$

$$\begin{pmatrix} \mathbf{v}_{\mathcal{B}_i} \\ \omega_{\mathcal{B}_i} \end{pmatrix} (\mathbf{q}, \dot{\mathbf{q}}) = J_{\mathcal{B}_i}(\mathbf{q}).\dot{\mathbf{q}} \in \mathbb{R}^6$$

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- Definition: function of the
  - robot configuration,
  - time and
  - possibly external parameters

  that should converge to 0:

$$T \in C^{\infty}(\mathcal{C} \times \mathbb{R}, \mathbb{R}^{m})$$

- Examples
  - trajectory tracking of an end-effector $\mathcal{B}_{left-hand}$
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Given

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Jacobian:

- we denote
  - $J = \frac{\partial T}{\partial \mathbf{q}}$
- then
  - $\dot{T} = J(\mathbf{q}, t)\dot{\mathbf{q}} + \frac{\partial T}{\partial t}(\mathbf{q}, t)$

We try to enforce

- $\dot{T} = -\lambda T \quad \Rightarrow \quad T(t) = e^{-\lambda t} T(0) \rightarrow 0$
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Resolution of the constraint:

$$\dot{T} = J\dot{\mathbf{q}} \quad + \quad \frac{\partial T}{\partial t} = -\lambda T \tag{1}$$

$$J\dot{\mathbf{q}} \quad = \quad -\lambda T - \frac{\partial T}{\partial t} \tag{2}$$

$$\dot{\mathbf{q}} \quad \triangleq \quad -J^{+}(\lambda T + \frac{\partial T}{\partial t}) \tag{3}$$

Where J^{+} is the (Moore Penrose) pseudo-inverse of J.

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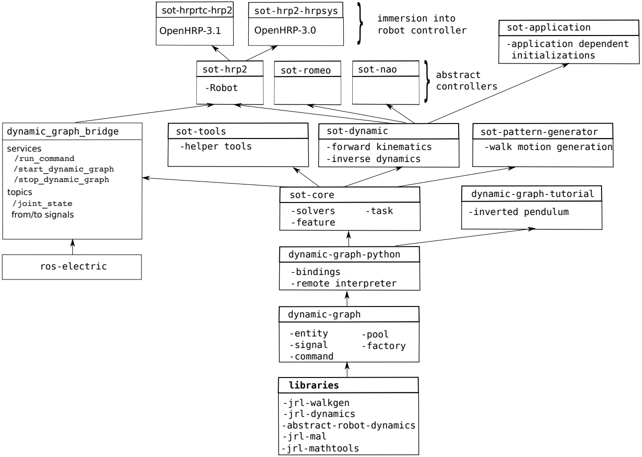

Main features

- Entity
  - Signal: synchronous interface
  - Command: asynchronous interface
- Factory
  - builds a new entity of requested type,
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- Pool
  - stores all instances of entities,
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Synchronous interface storing a given data type

- output signals:
  - recomputed by a callback function
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Command

Asynchronous interface

- typed input
- trigger an action,
- returns a typed result

Main features

Python bindings

- module `dynamic_graph` linked to C++ compiled code
  - class Entity
    - each C++ entity class declared in the factory generates a python class of the same name,
    - signals are instance members,
    - commands are bound to instance methods
  - class Signal
    - value setter and getter

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Main features

Hierarchical task solver

- computes robot joint velocity

Extensions

- `sot-dynamic`: forward kinematics
  - position and Jacobian of end effectors (wrists, ankles),
  - position of center of mass
- `sot-pattern-generator`: walk motion for legged robots,
- `sot-dyninv`: inverse dynamics based control.

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