Task-Space Inverse Dynamics: Implementation (Joint Space)

Optimization-based Control of Legged Robots

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Introduction

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TSID (currently) relies on:

- Eigen for linear algebra
- Pinocchio for multi-body dynamics computations
- Eiquadprog for solving Quadratic Programs

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Main features: Pros & Cons

CONS

- Some missing features
  - Hierarchy
  - Bilateral contacts
  - Line contacts
  - ...

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PROS

- Efficient (<0.6 ms for humanoid)
- Tested on humanoids & quadrupeds
- Open source
- Modular design
  - $\rightarrow$ easy to extend
- Python bindings
- Easy to install (Debian packages)
- Not many alternatives (AFAIK)
  - $\rightarrow$ ORCA

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Some numbers:

In 6 years:

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Key Concepts

Task

- JointPosture
- JointVelLimits
- JointTorqueLimits

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HQP Solver

- solves HQP (LSP)

Details

Robot Wrapper

Interface for computing robot-related quantities:

```
RobotWrapper(string filename, vector<string> package_dirs,
             JointModelVariant rootJoint);

int nq(); // size of configuration vector q
int nv(); // size of velocity vector v

Model & model(); // reference to robot model (Pinocchio)

// Compute all quantities and store them into data
void computeAllTerms(Data &data, Vector q, Vector v);

Matrix mass(Data data);
Vector nonLinearEffects(Data data);
```

InverseDynamicsFormulationBase

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HqpData defined as:

```
#typedef vector<pair<double, ConstraintBase>> ConstraintLevel
#typedef vector<ConstraintLevel> HqpData
```

HQP Solvers

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void resize(int nVar, int nEq, int nIn);
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`HqpOutput` is defined as:

```
class HqpOutput
{
    QpStatusFlag flag;
    Vector x, lambda;
}
```

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Results on HRP-2's computer (very old):

```
60 variables, 18 equalities, 40 inequalities
*** PROFILING RESULTS [ms]     (min - avg - max ) ***
Eiquadprog ..................... 0.651 0.704 0.870
Eiquadprog Fast ................ 0.563 0.605 0.810
Eiquadprog Real Time ........... 0.543 0.592 0.712

active inequalities .... 16.0 19.8 26.0
```

Exercises

Exercise 0

Open Terminal, navigate to the orc folder and execute:

```
cd reactive_control/tsid
python ex_0_ur5_joint_space_control.py
```