Practical Course Robotics

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2 Setting up your work environment

Prelimiminaries

- You need a gitlab account; access to `mlr_students`
- Connect to the local mlr-robolab WIFI

Install from a fresh Ubuntu

- install fresh Ubuntu 14.04.4 LTS
- google 'ros install indigo'; copy&paste steps; install package `ros-indigo-desktop`
- install packages:

  `sudo apt-get install synaptic git qtcreator`

  `sudo apt-get install ros-indigo-ar-track-alvar-msgs ros-indigo-baxter-core-msgs`
- create ssh key:

```
cd
ssh-keygen
cat .ssh/id_rsa.pub
```

- enter ssh key in gitlab: gitlab start page; profile settings; ssh keys; copy&paste the key (without linebreaks!!!); 'Add key'
- in gitlab go to the project page; see the ssh URL ending with ...git
- checkout our code

```
cd
mkdir git
cd git
git clone <SSH-GIT-URL>
```

- Install the code dependency ubuntu packages:

```
cd ~/git/mlr/install
./INSTALL_ALL_UBUNTU_PACKAGES.sh
```

Trouble shooting: read the README.md in /git/mlr

- configure code and test make:

```
cd ~/git/mlr/share/
git checkout baxter
cp gofMake/config.mk.default gofMake/config.mk
bin/createMakefileLinks.sh
cd src/Ors
make
```

- goto project page and test make

```
cd ~/git/mlr/share/teaching/RoboticsPractical/01-...
make
```

Test starting to run `./x.exe`

Make the baxter move

- setup the WIFI connection to the baxters ros server

  `source ~/git/mlr/share/bin/baxterwifisetup`

- In a project folder, try to run `./x.exe -useRos 1`

Get comfortable

- put all extra documentation useful for others in text files in ./doc
- Use qtcreater. You need to be able to:
  - Create a new 'project' that uses the makefile: 'New Project' -¿ 'Import Existing Project' -¿ select the project path (with the makefile)
  - Enable and use auto completion and code browsing: add include paths to PROJECT-NAME.includes, especially `../../../src`. Test it with 'right mouse' on symbols
  - Know how to use the debugger
  - Create a symbolic link `.gdbinit -> git/mlr/tools/qt_mlr_types.py` That will enable pretty printing of mlr data structures in the debugger
  - Optionally, import our coding style: Options -¿ C++ -¿ Import... `git/mlr/tools/qt_coding_style.xml`
- create own folder `groupX`, maybe own branch

3 Plan

3.1 Milestone 1: Pick-and-place

Target: The robot perceives objects on the table (= segment, localize). The robot grasps them and puts them into a bin.

3.1.1 Lecture: Basic Motion revisited

- Task spaces, general problem:
  - A task space is defined by a task map $\phi : q \mapsto y$
  - In each task space we have a desired behavior (*linear acceleration laws*, 2nd order differential equation) $\ddot y^* = \dots$. This is usually a PD behavior, optionally with max velocity and acceleration.
  - The desired task behaviors are 'projected down' to q-space using the operational space control objective. That defines a desired $\ddot q^*$.
- There is three ways to send this to the robot
  - directly, using the dynamics equation $u = M\ddot q + F$. But it is computationally not feasible/desirable to have ALL of the above computations in a 1kHz real-time loop
  - A 1st-order Taylor approximation of $\ddot q^* \doteq -K_p q - K_d \dot q + q_0$. (We try this).
    Both of the above are very hard if the dynamics model is inprecise! Later we will test these, with a well learned model from data.
  - Forward simulate $\ddot q^*$ (just integrating the differential equation). That defines a $q^{\text{ref}}(t)$. Send this to the existing position controller of the robot.
- Discuss (practial is later): impedance, stiffness
- How is this reflected in the code?
  - ϕ: `TaskMap`
  - $\ddot y^* = \dots$: `CtrlTask`
  - Computing $\ddot q^*$: `TaskController`
  - Sending it to the robot and threading the computation: `TaskControllerModule::step`

3.1.2 Subproblem: Basic Motion

Learn how to use our code to generate targets in various task spaces. Learn how create `CtrlTask`s directly in C++. Optionally, have a look at the much more abstract RAP interface.

Concretely:

- What are task spaces? Read the `share/doc/taskSpaces.pdf`!
- Make the robot do funny things, like point the hands at each other, etc.
- Think of positioning and orienting the gripper to grasp a box. Define the grasp center, and grasp orientation.

3.1.3 Subproblem: Segmenting & tracking objects

Understand how the `tabletop` ROS packages can extract planes (the table) and point cloud clusters on top of the plane. Learn how the objects are imported in our system.

3.1.4 Lecture: Basic perception

- The pain of computer vision...
- Keep it simple: point clouds, planes, clusters, markers
- Practical packages

3.1.5 Subproblem: Pick & Place

Realize the whole pick-and-place scenario. Core issues are

- Designing the motion tasks
- Sequening, ideally failure detection & reaction

3.2 Milestone 2: System Identification, Machine Learning & Compliant Optimal Control

Target: The robot is controlled on the lowest level, sending direct 'torques' (or alike). Using system identification (ML) we learnt a perfect model of both, the dynamics and the observations. Using Bayesian filtering we can perfectly track the state—giving nice and smooth velocity estimates. The robot 'intelligently' explores its state-space to collect data for the previous tasks.

3.2.1 Lecture: Dynamics Basics; and motivation

- Dynamics & optimal control revisited
- Compliance, impedance control, manipulation & teleoperation
- (Do we have F/T sensors?)
- caveats of real robots: 'non-Markovian', sticktion, time lag, gear clearance

3.2.2 Subproblem: Collect data, formulate model, ML

Think about motion patterns to collect data. Formulate models for the robot dynamics as well as observation model. Apply ML.

3.2.3 Subproblem: Use the model for (extended/unscented) Kalman filtering of the state

3.2.4 Subproblem: Use the model to translate desired q-accelerations directly to torques

3.3 Define your own project!