INF3480 - Introduction to Robot Operating System

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This is an overview lecture, but do expect exam question on ROS topic also. Please pay more attention to the slides marked with “Study Material” such as below.
Let’s Design a Robot
What a mess!
How can we deal with it?
ROS is an open-source, meta-operating system
What’s so special about ROS?

- Reusable robotics components!
- 120+ Robotic platforms officially support ROS (+25 from this time last year) [http://wiki.ros.org/Robots](http://wiki.ros.org/Robots)
- Modular design
- Hundreds of ready to use algorithms
- Efficient, so it can be used for actual products, not just prototyping
- Runs on Ubuntu, also ARM Processors
  - Experimental versions for OS X, Android, Arch Linux, Debian, OpenEmbedded/Yocto
- Parallelisation and networking made easy, can use multiple machines simultaneously
**Current Robotics Job Ads**

A relevant degree is required, for instance in Computer Science or Engineering. A background in Robotics/Computer Vision is desirable, while knowledge of the Robot Operating System (ROS), the Point Cloud Library (PCL), or the Open Source Computer Vision Library (OpenCV) is a big plus.

Goal of this PhD is to study, design and build novel industry-level software based on ROS or ROS-Industry which is modular, reconfigurable, adaptive, easy to use to integrate and control various robotic systems.

**Job Requirements**
- Experience with software development and integration preferably in a Linux environment
- Proficient in C, C++, Python and Matlab
- Those with past experience using ROS will be preferred

The candidate must be a proficient user of C/C++ and ROS and any relevant computer vision library (e.g., ViSP, OpenCV, PCL). Scientific curiosity, large autonomy and ability to work independently are also expected.

**Required Qualifications**
- A university degree (Master or Diplom-Ingenieur)
- Proven programming skills in Matlab, C / C ++, ROS
- Good knowledge of cooperative software development with GIT or SVN

Required Skills
- MSc in Engineering / Computer Science or equivalent.
- Experience with Robotics
- Knowledge about ROS (Robot Operating System) and CV.
- Advanced experience with C++ and soft real-time programming.
- Team spirit and ability to work independently.
- Excellent communication skills, flexibility and creativity.
Let’s see how it works!

“Plumbing”
Nodes

http://wiki.ros.org/ROS/Tutorials/UnderstandingNodes

Nodes are processes that perform computation, “executables”. Each node performs a specific processing part, usually a part of the algorithm.

Study Material - highly recommend to check the URL
Topics

http://wiki.ros.org/ROS/Tutorials/UnderstandingTopics

Topics are streams of data with publish / subscribe semantics. They are uniquely identifiable by its name. Nodes can publish and subscribe to topic in order to transfer data.

Study Material - highly recommend to check the URL
Services

http://wiki.ros.org/ROS/Tutorials/UnderstandingServicesParams

Request / reply is done via services, which are defined by a pair of message structures: one for the request and one for the reply.

Study Material - highly recommend to check the URL
A message is simply a data structure, comprising typed fields. Language agnostic data representation. C++ can talk to Python. Messages are sent on defined topics.

File: pos.msg
string robotName
uint32 posX
uint32 posY
uint32 goalX
uint32 goalY

Mapping

Motion Planner
The ROS Master provides name registration and lookup to nodes. Without the Master, nodes would not be able to find each other, exchange messages, or invoke services.
Example System - Mobile Robot

Green - Sensors
Blue - Planning algorithms
Red - Hardware integration
“Tools”
System Visualisation: rqt_graph
Live Plotting: rqt_plot
Logging and Visualization Sensor Data: rosbag and rqt_bag
3D Visualisation: RVIZ
“Capabilities”
“Ecosystem”
ROS Statistics
July 2015 - July 2016

Total unique ROS Downloads (.deb files):
- 113,345 (143% Increase)

Total downloads of ROS .deb files:
- 8,441,279 (158% increase)

Total number of papers citing ROS:
- 2,683 (46% increase)
Worldwide User Base
Number of Robots Supporting ROS

Robots listed on wiki.ros.org/Robots
Technical Capabilities

- Motion Planning
  - Fast and good quality paths
  - Kinematic Constraints
- Fast and flexible collision checking
- Integrated Kinematics
- Integrated Perception for Environment Representation
- Standardised Interfaces to Controllers
- Execution and Monitoring
- Kinematic Analysis
- Simulated Robots
Motion Planning

MoveIt! includes a variety of motion planners:

- Sampling-based motion planners (implementations from [OMPL])
- Search-based motion planners (implementations from SBPL)
- Optimization-based motion planners (CHOMP)
You can specify the following kinematic constraints:

- **Position constraints** – restrict the position of a link to lie within a region of space
- **Orientation constraints** – restrict the orientation of a link to lie within specified roll, pitch or yaw limits
- **Visibility constraints** – restrict a point on a link to lie within the visibility cone for a particular sensor
- **Joint constraints** – restrict a joint to lie between two values
- **User-specified constraints** – you can also specify your own constraints with a user-defined callback.
Collision Detection

Flexible Collision Library (FCL) is used.

Types of objects supported:
- Meshes
- Primitive shapes (boxes, cylinders, cones)
- Octomap

40,000 to 80,000 collision checks per second!
MoveIt - Robot Setup Assistant
MoveIt Capabilities

Computation of motion plans
How to use it?

To simulate and play around with Universal Robot UR5

1) Have ROS installed (current version: Indigo)
2) Install MoveIt for UR5:
   ○ “sudo apt-get install ros-indigo-ur5-moveit-config”
3) Launch UR5 RViz simulator:
   ○ “roslaunch ur5_moveit_config demo.launch”

That’s it!

How to use it?
Future?

ROS 2
coming soon...
Actual Projects:

People detection for HMC

Joint Human Detection From Static and Mobile Cameras
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6894232&tag=1
Autonomous Hot Metal Carrier (HMC)
Workspace

30 meters

(B block) Camera A

Camera B
(U-block)
Detection Process
Automatic Calibration of a Robot Manipulator and Multi 3D Camera System

And the end-effector to the checkerboard center offset is estimated.
Robot-Based Electric Vehicle Charging Station

Work in progress...
Summary

- ROS is a meta-operating system for robotics
- Provides basic (and many!) algorithms for robotics
- Modular approach allows easy adaptation to hardware changes and both hw and sw updates
- Effective visualisation and simulation tools
- World-wide spread in research and commercial use
- BSD license - open source, free to use!
- Over 120 robot platforms support ROS, and growing!
- Easy to start
- Linux based, best works on Ubuntu
- Easy to parallelise, nodes based approach communicate over TCP and can be synchronised using timestamps for messages
Useful URLs

- [http://www.ros.org/](http://www.ros.org/) - ROS homepage
- [http://www.ros.org/is-ros-for-me/](http://www.ros.org/is-ros-for-me/) - Is ROS for me?
- [http://wiki.ros.org/ROS/Installation/TwoLineInstall](http://wiki.ros.org/ROS/Installation/TwoLineInstall)
- [http://moveit.ros.org/](http://moveit.ros.org/) - MoveIt
- [http://wiki.ros.org/rviz](http://wiki.ros.org/rviz) - RViz
- [http://opencv.org/](http://opencv.org/) - OpenCV
- [http://pointclouds.org/](http://pointclouds.org/) - Point Cloud Library
Thank You!

Any Questions?