MATLAB® & SIMULINK®
Tech Forum & EXPO

16th MATLAB & SIMULINK技術高峰會

服務型/移動型機器人演算法開發、測試與實現

Jerry Tung
Sarah Hung

Accelerating innovation
with MATLAB & Simulink

TeraSoft
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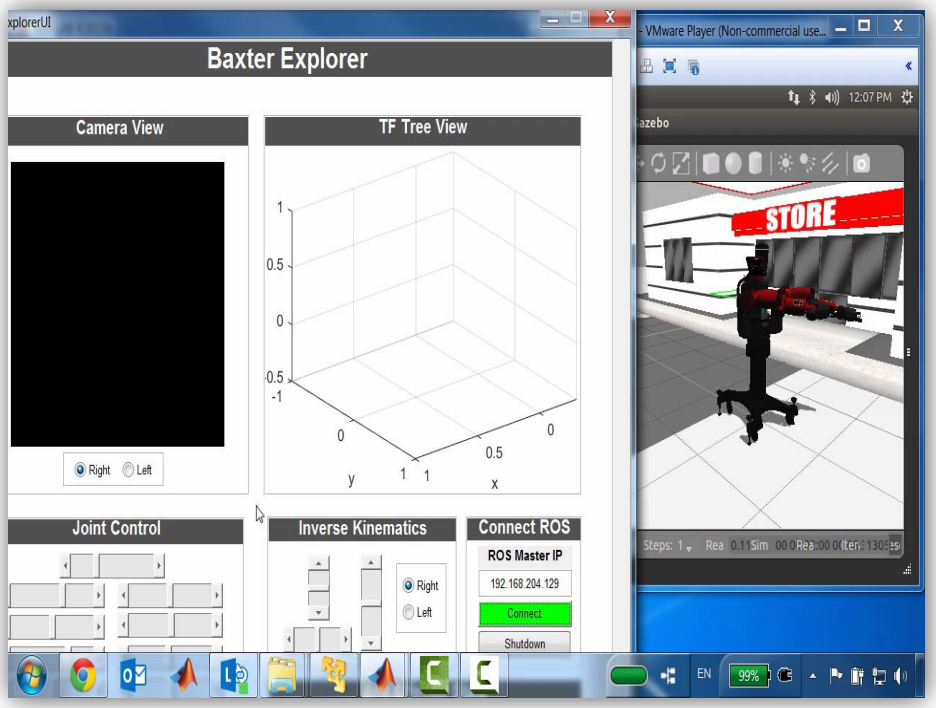
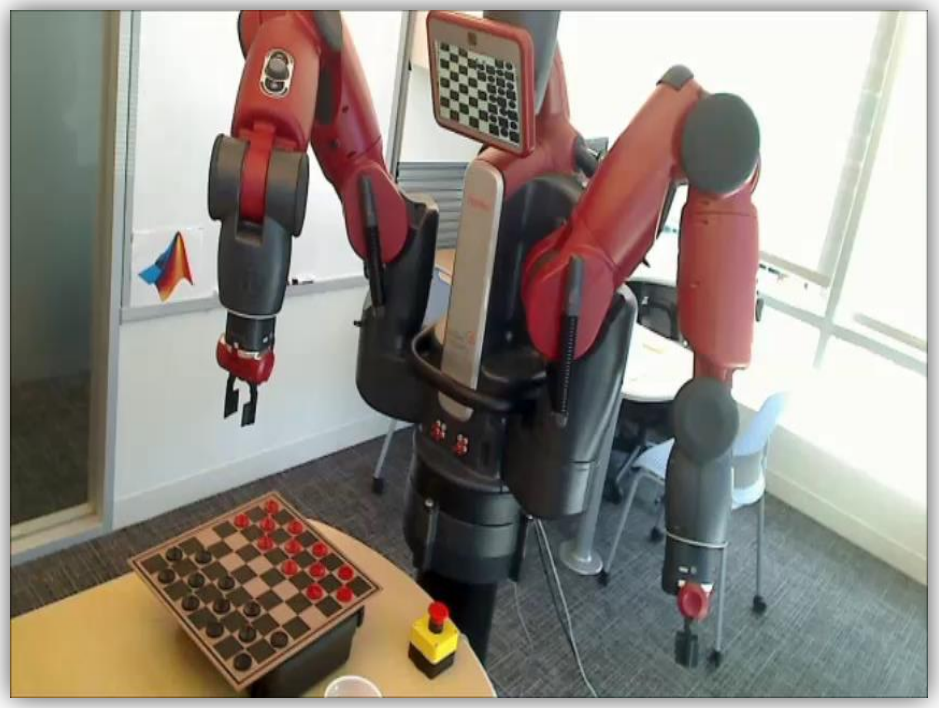
Accelerating the pace of engineering and science

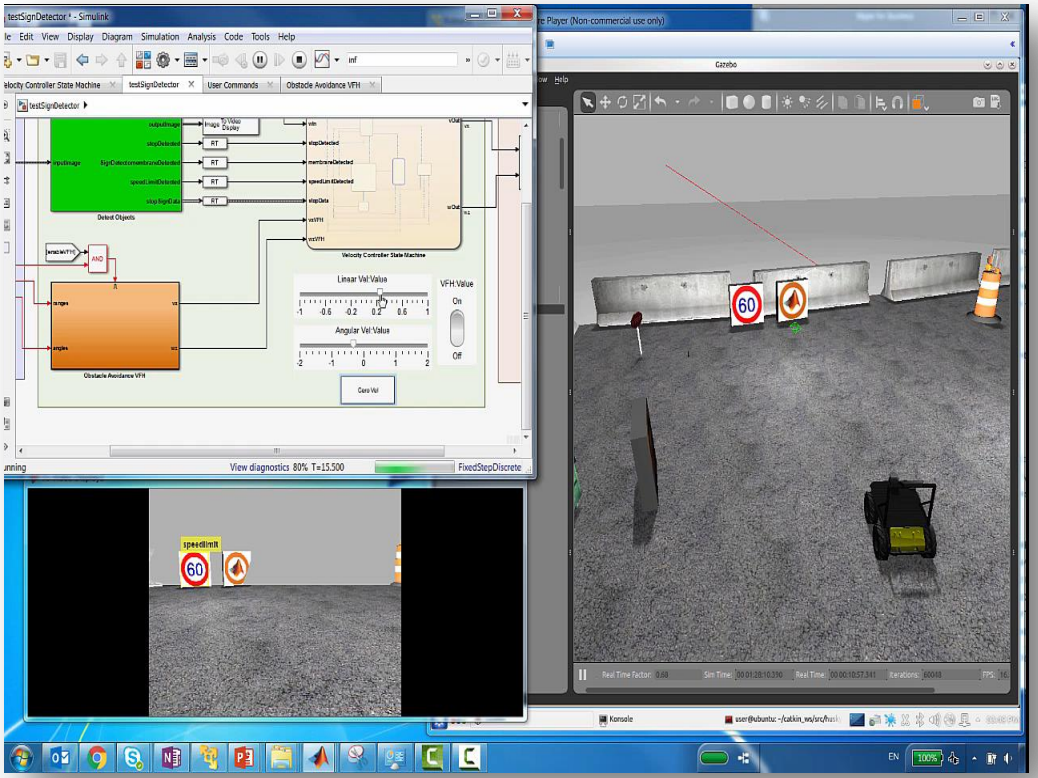
Advanced Robotics: Design, Simulation, and Implementation

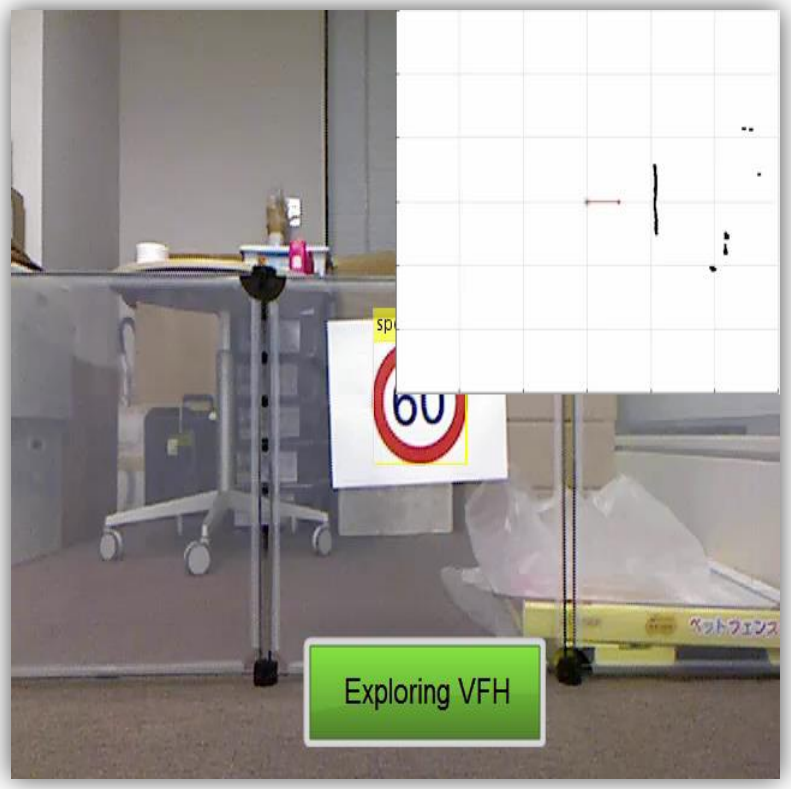




Collaborative robot arm autonomously playing checkers

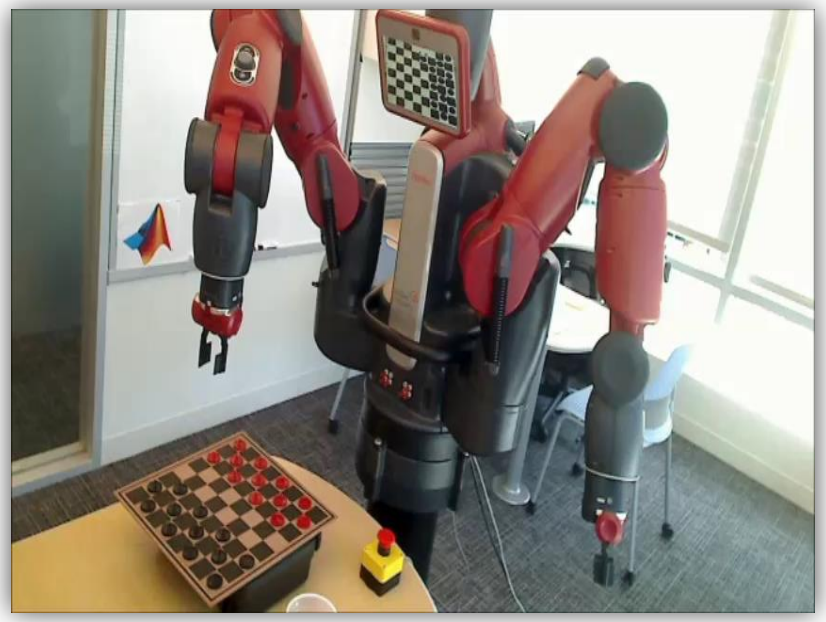
Advanced Robotics: Design, Simulation, and Implementation

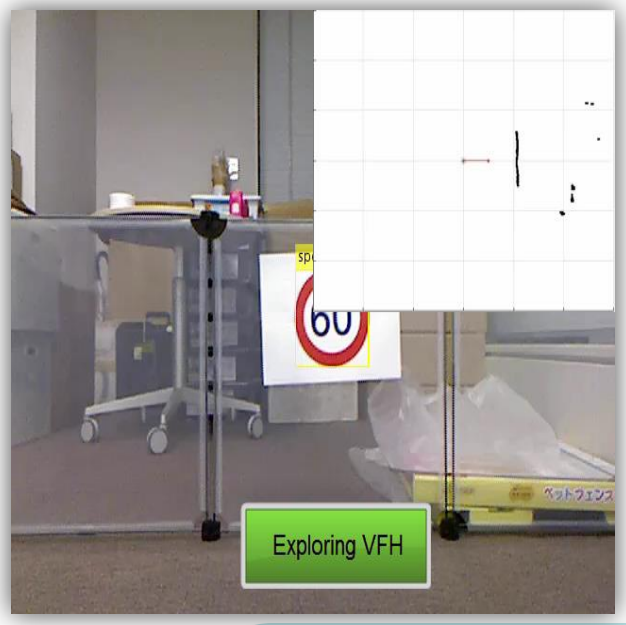




Sign Detection and Obstacle Avoidance

Robots Algorithms





Manipulators
- Rigid Body Trees
- Inverse Kinematics
- Force Control

Robotics General
- Coordinate Transformations
- Rate Objects
- ROS Connectivity
- State Machine Design

Mobile Robots
- Maps
- Path Planning
- Path Tracking
- Localization
- Obstacle Avoidance

以MATLAB做為"服務型機器人"大腦開發演算法的工具 (開發階段)

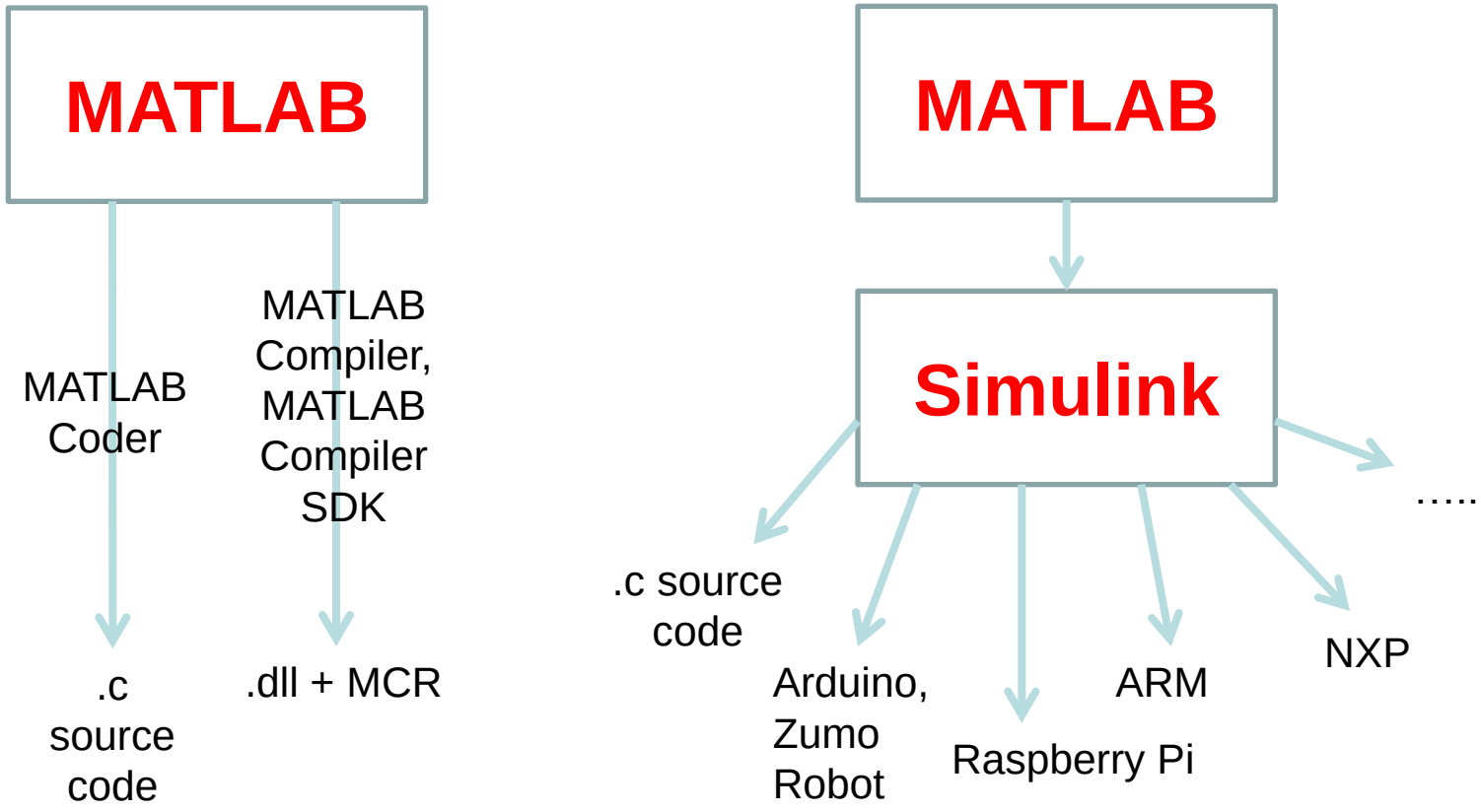
Many devices, interface

ROS Network

C API, Support Package
Ethernet, RS-232, …

以MATLAB做為服務型機器人大腦開發演算法的工具 (實現階段)

- MATLAB/Simulink Deployment



Agenda

- How MATLAB acquire Mobile Robot sensor data (Point Cloud Sensors, Camera, ROS, …)
- How MATLAB support Robot Simulator such as GAZEBO
- Mobile Robot Control Algorithms
  - Mapping
  - Path Planning
  - Path Following
  - SLAM

Image Acquisition Toolbox

Acquire images/videos into MATLAB and Simulink

- Manage device properties
- GUI or functional interface
- Supports over 30 hardware vendors
- Synchronize multimodal devices
- Configure, acquire, and preview live video data using a graphical interface

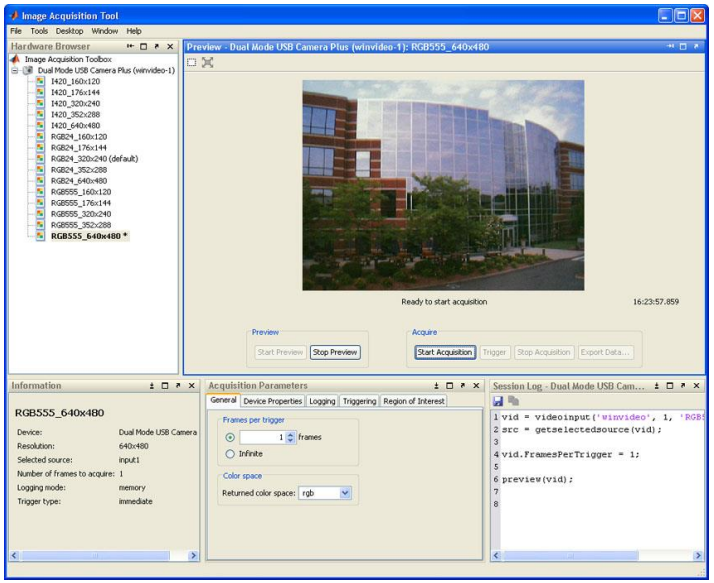


Image Acquisition Toolbox Hardware Support

- Industry standard support:
  - Frame grabbers
    - Analog
    - Camera Link (BitFlow, Imperx, Matrox Imaging, NI, Teledyne DALSA)
  - DCAM compatible FireWire (IIDC 1394)
  - GigE Vision
  - GenlCam GenTL (USB3 camera)
  - OS Generic Video interface
    - Direct Show (for Windows)
    - Video4linux2/Gstreamer (for Linux)
    - QuickTime (for Mac)

For more information, check out the following:
http://www.mathworks.com/products/imaq/

Image Acquisition Toolbox Hardware Support

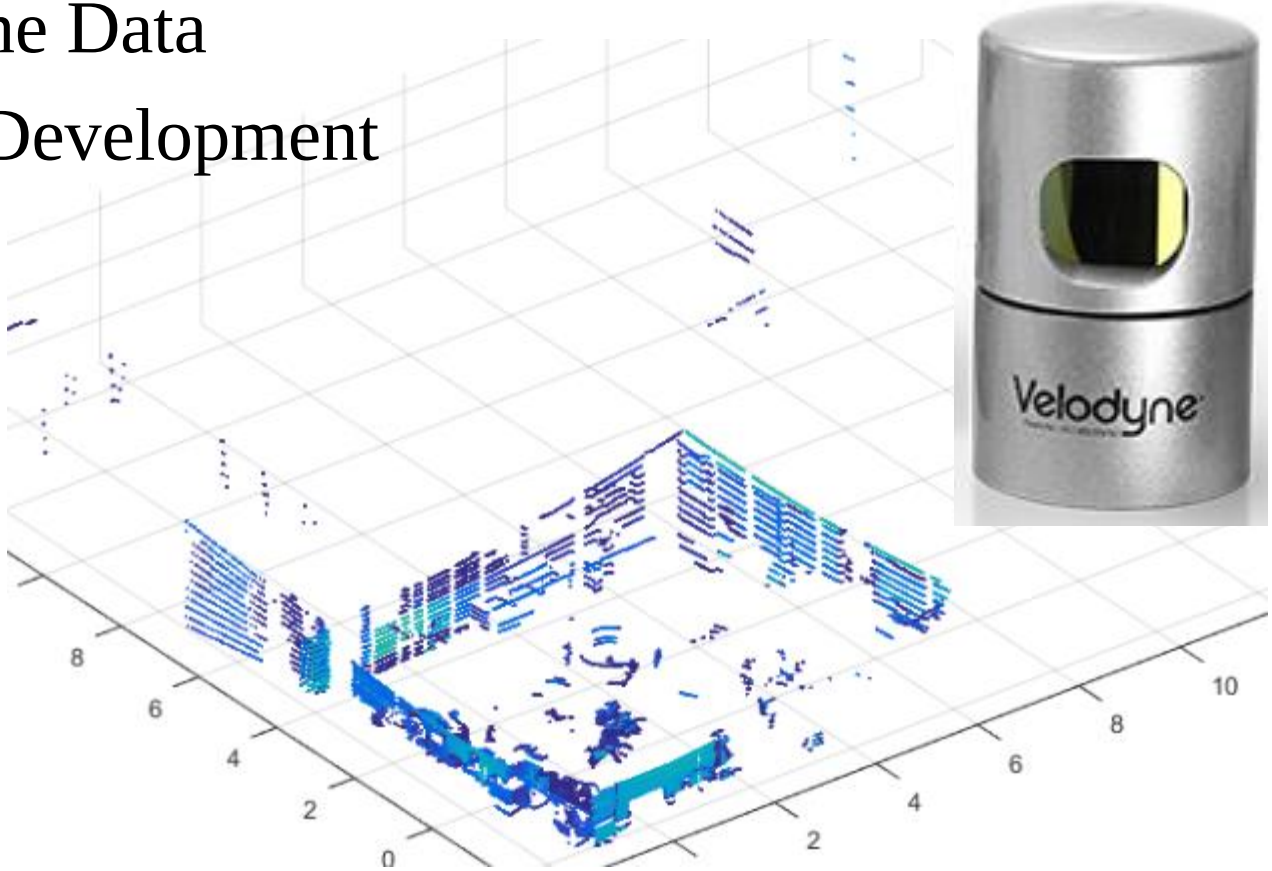
- Manufacturer-Specific Support
  - Kinect for Windows Sensor
  - Point Grey
  - Hamamatsu
  - QImaging
  - Matrox Frame Grabbers
  - National Instruments Frame Grabbers
  - Teledyne DALSA Sapera
  - Teledyne DALSA IFC

HAMAMATSU

NATIONAL INSTRUMENTS

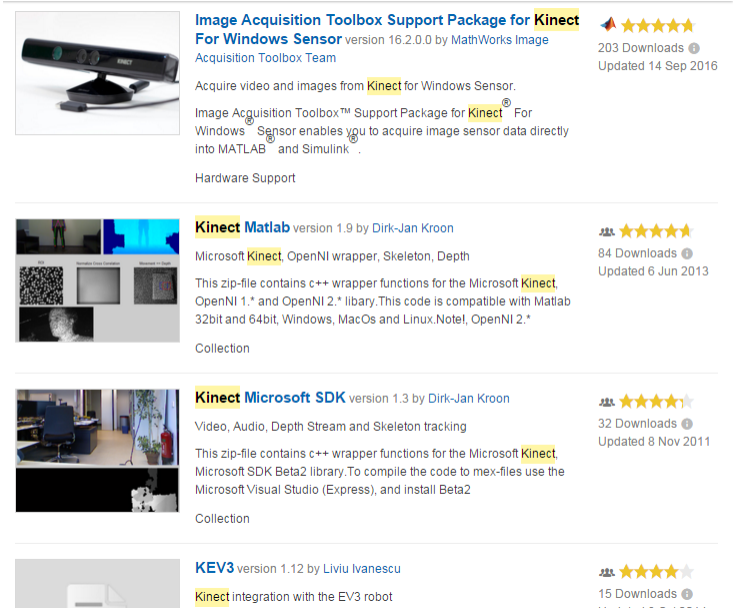
Velodyne example

- Collecting data through Ethernet in MATLAB
- Decoding the Data
- Algorithm Development



Kinect example

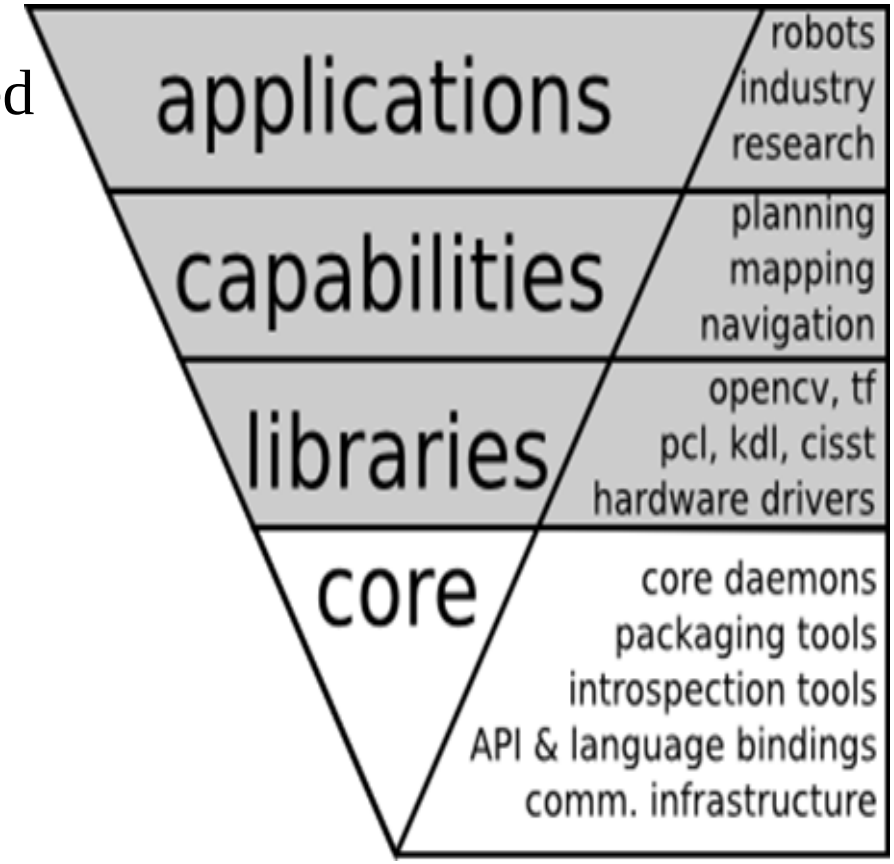
- Hardware Support Package



- Raw Data Acquisition Speed : ~20 frames / sec

What is ROS (Robot Operating System)?

- An architecture for distributed inter-process communication
- Packages for common algorithms and drivers
- Multilanguage interface
- (C++, Python, Lua, Java and **MATLAB**)



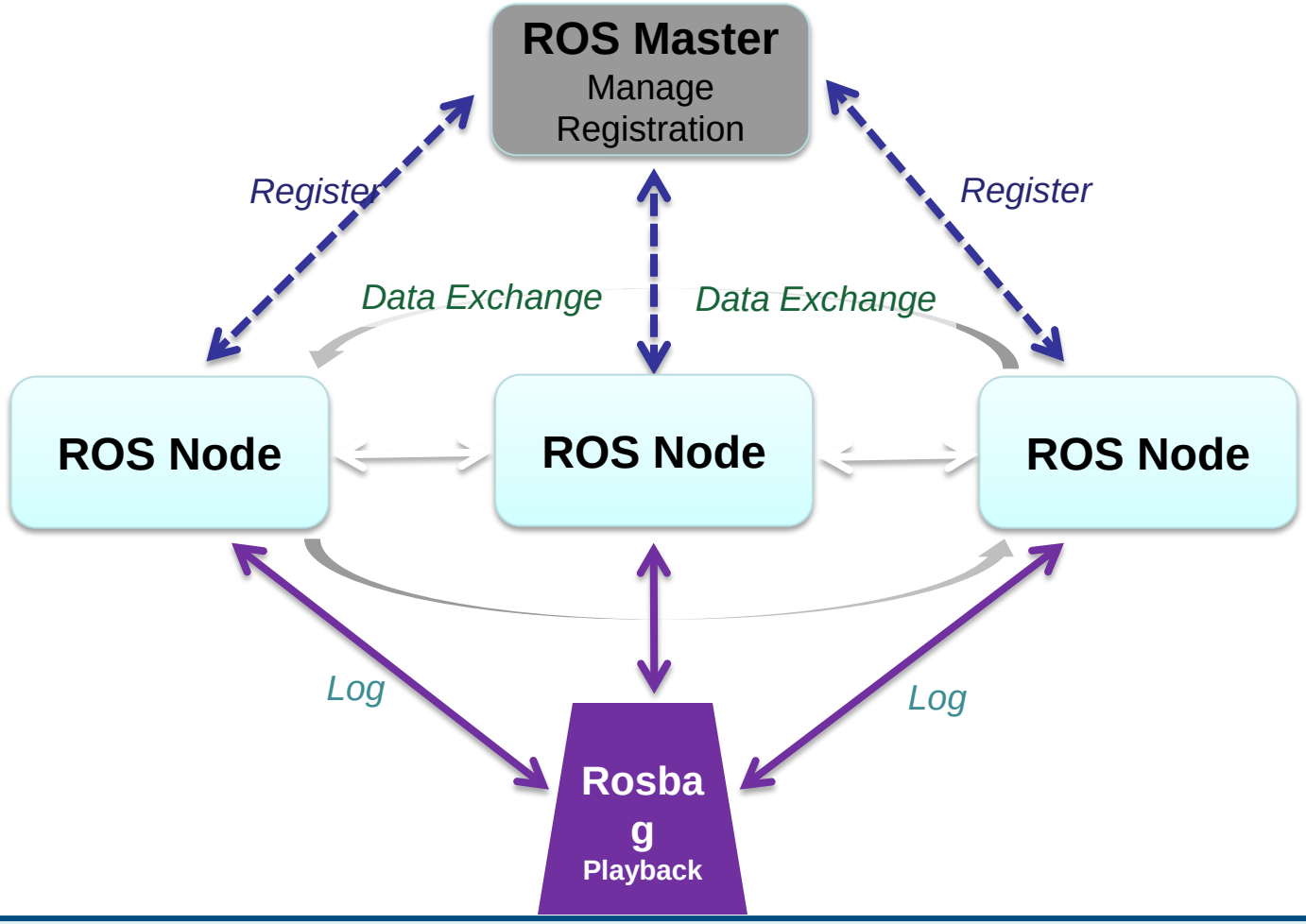
ROS Trends in Robotics Development

- #1 middleware for robotics applications development
- Popular in research and gaining great momentum in industry

CURRENT ROS-INDUSTRIAL CONSORTIUM MEMBERS

http://rosindustrial.org/ric-americas/

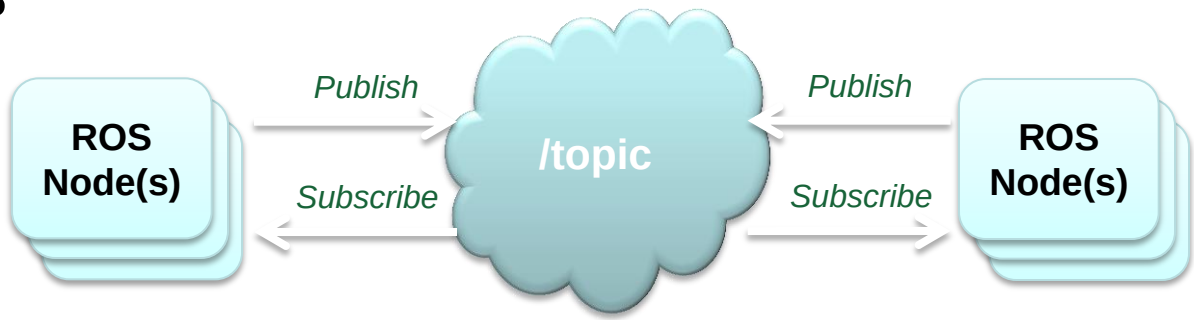
ROS Network Overview



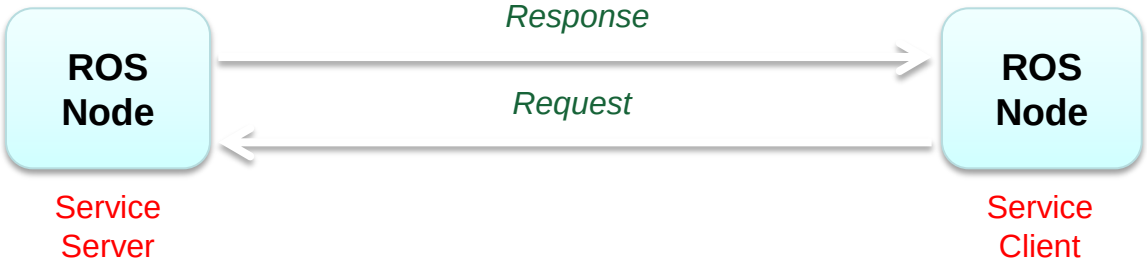
Management of data transmissions through the ROS network

ROS Node Communication Methods

- Topics



- Services

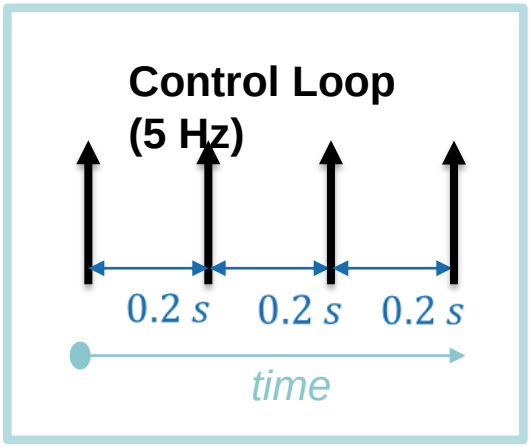


ROS message selection based on data usage and needs

Fixed-Rate Execution

Run MATLAB code at a fixed rate

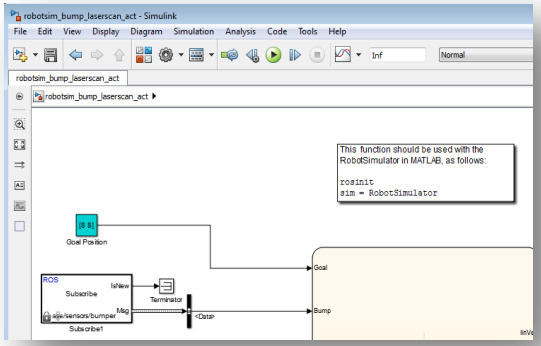
- Run your MATLAB code at a constant rate. The object compensates for any user code to maintain the rate.
- Collect statistics about the timing of the loop iterations.
- Use published simulation time when connected to a Robot Operation System (ROS) network



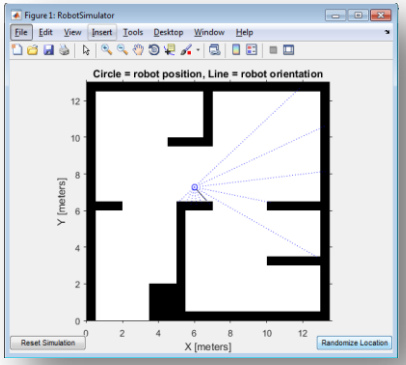

```
r = robotics.Rate(5);

% Run loop at 5 Hz
while(1)
    runUserCode();
    waitfor(r);
end
```

Workflow for Deploying to a ROS Target

Prototype algorithm in MATLAB/Simulink

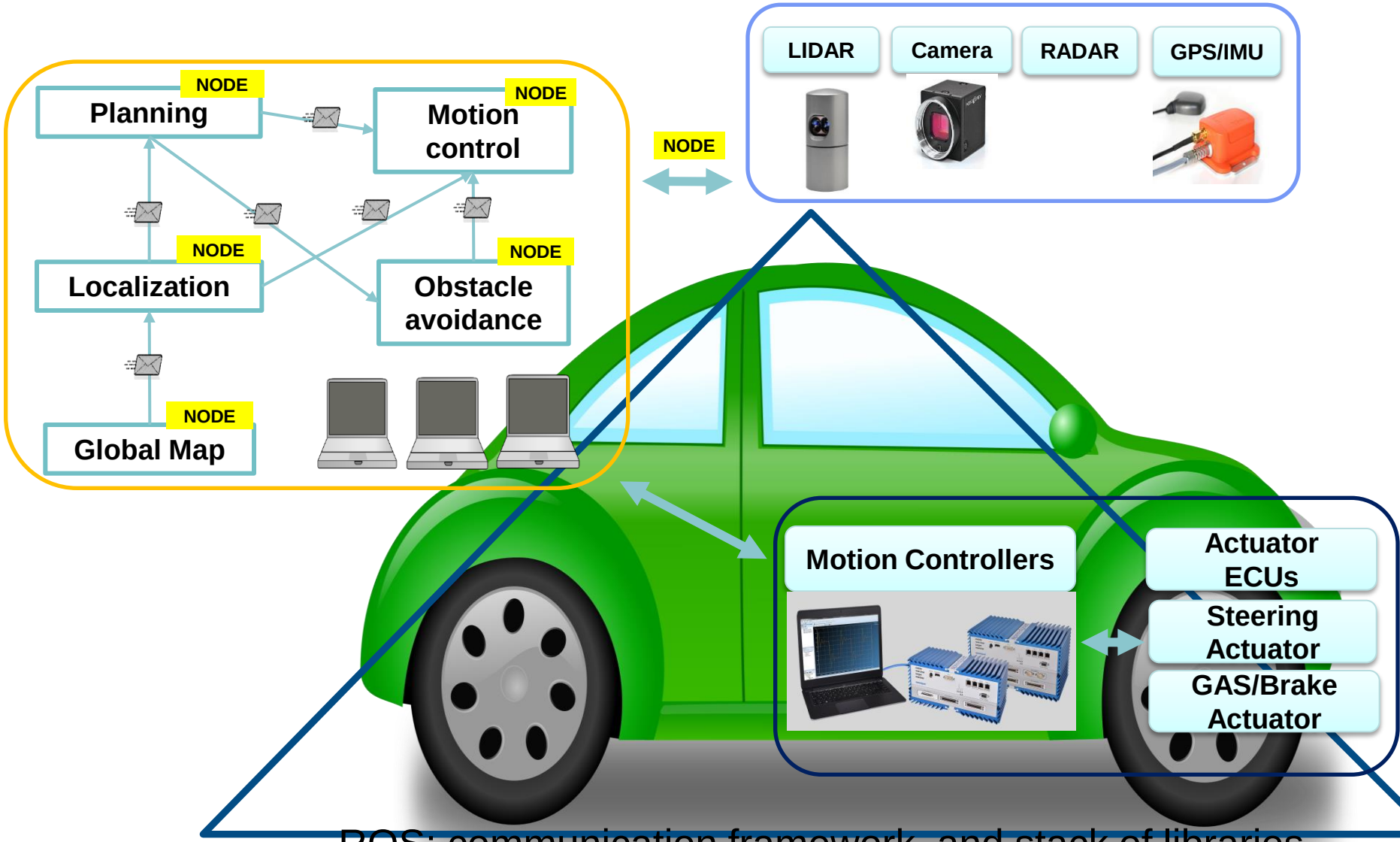


Test algorithm with a ROS-enabled Simulator or Robot



Generate a standalone ROS node from Simulink

Autonomous Vehicle as an Advanced Robotics System



ROS: communication framework and stack of libraries

Automated Driving R&D with ROS at BMW

**** MICHAEL AEBERHARD, BMW,** ROSCON 2015

Automated Driving R&D with ROS at BMW

Using Robotics System Toolbox

ROSCon 2015
Hamburg, Germany

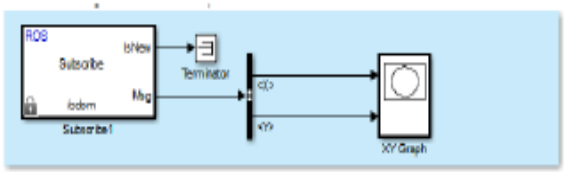
AUTOMATED DRIVING WITH ROS AT

MICHAEL AEBERHARD, THOMAS KÜHBECK, BERNHARD SEIDL, MA
JULIAN THOMAS, OLIVER SCHEICKL.

BMW GROUP

USING MATLAB/SIMULINK WITH ROS.

- MathWorks released the Robotics System Toolbox this year for ROS integration with Matlab/Simulink.
- Easily read and analzye data from ROS Bags → useful for evaluating the system.
- Some of our software is implemented as a Simulink model.
  - Use the Toolbox to easily integrated this software into the ROS eco-system:



http://www.mathworks.com/products/robotics/

MathWorks Tools in Autonomous Driving

DAIMLER

BMW GROUP

Agenda

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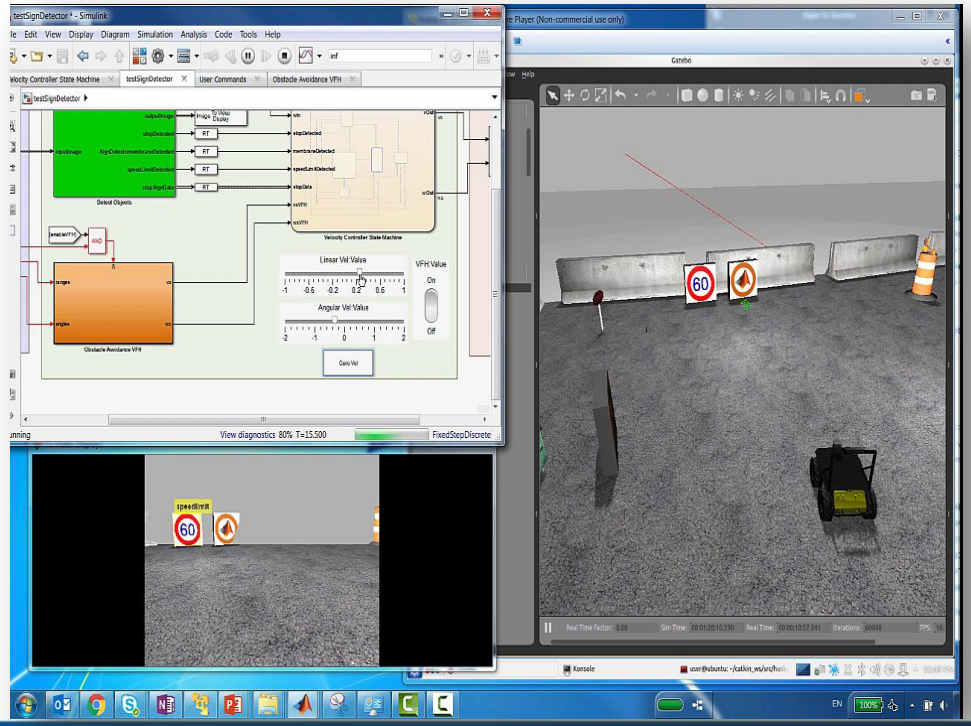
  - Path Planning
  - Path Following
  - SLAM

What is Gazebo?

- Open source
- Gazebo is a simulator that allows you to test and experiment realistically with physical scenarios.
- MATLAB® connects to Gazebo through the ROS interface.



Connect MATLAB to Gazebo Simulator

- In Ubuntu virtual machine:

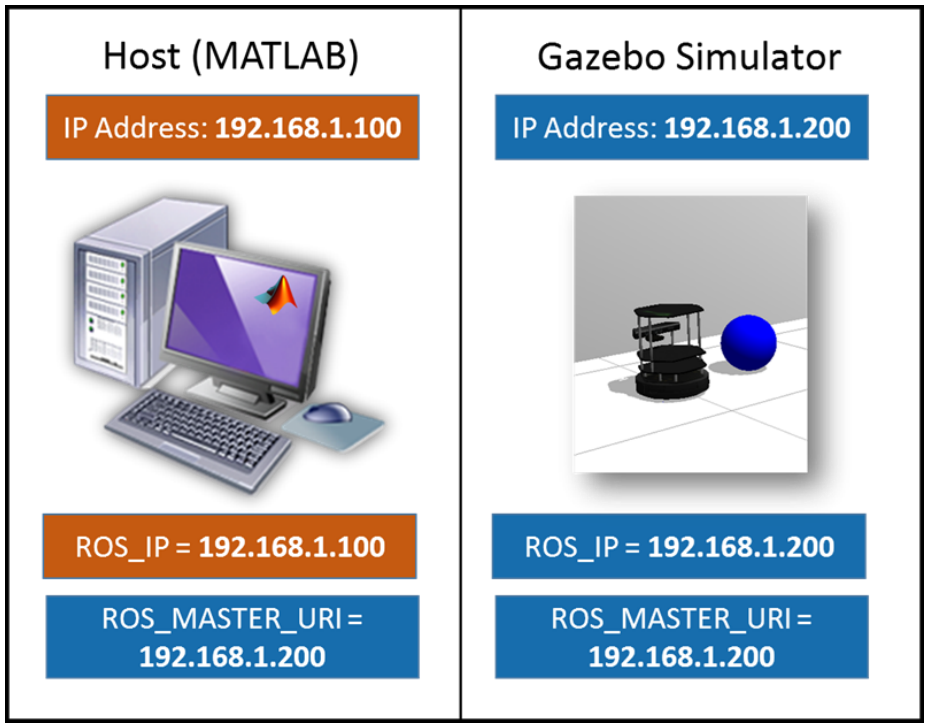
1. Get IP address: 192.168.1.200
2. Set up Two ROS environment variables:

echo export **ROS_MASTER_URI**=http://192.168.1.200:11311 >> ~/.bashrc

echo export **ROS_HOSTNAME**=192.168.1.200 >> ~/.bashrc

- In Host Computer:

>> rosinit('192.168.1.200')

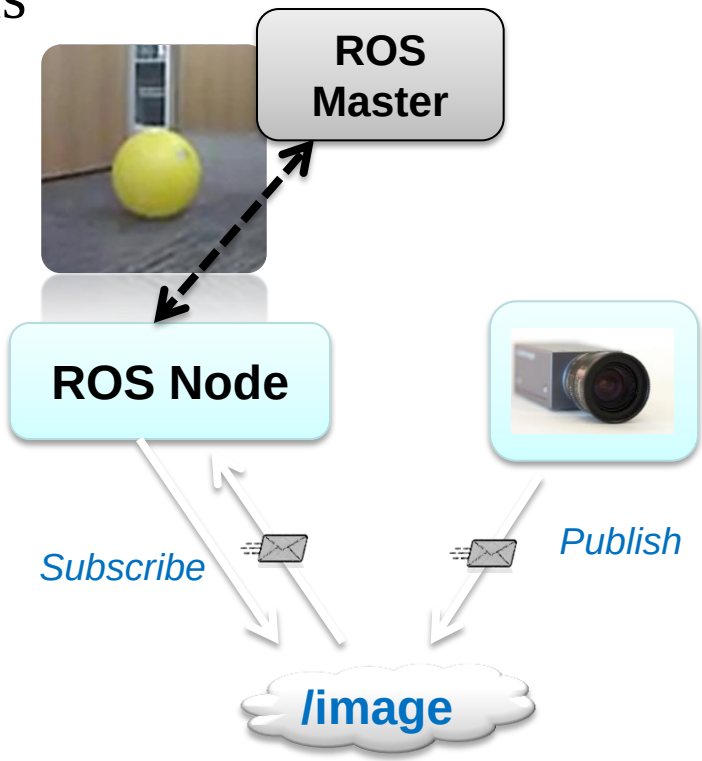


Interaction between MATLAB and Gazebo

- Add and Remove the Model
- Add Link or Joint to a Model
- Return a List of All Spawned Models
- Pause/Resume/Reset Simulation
- Set Simulation Physics Properties
- Reset the World

More and more…

- ROS instruction:
  - Publish/Subscribe/Service/Client



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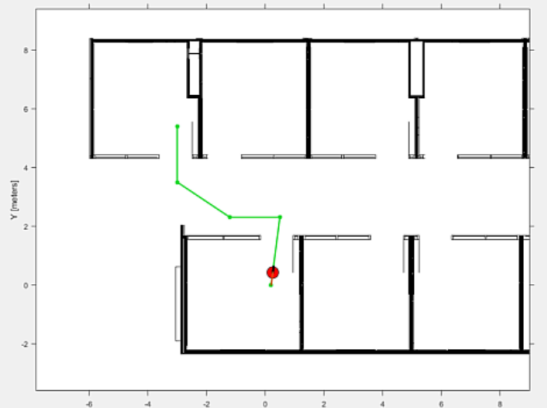
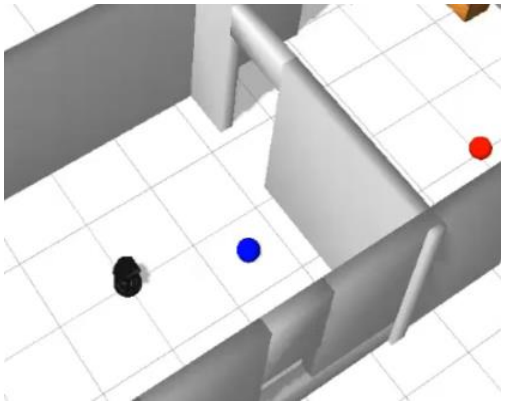
Overview: Design and Test Robotics Algorithms

Prototype algorithms (e.g., Path Planning) in MATLAB



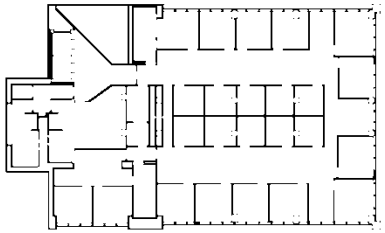
Test algorithms with ROS-enabled Simulators such as Gazebo



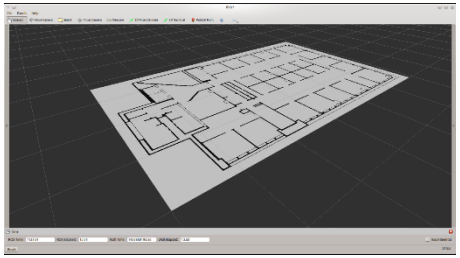
Test algorithms on a Robot and analyze the performance with rosbag

Map representation using occupancy grid

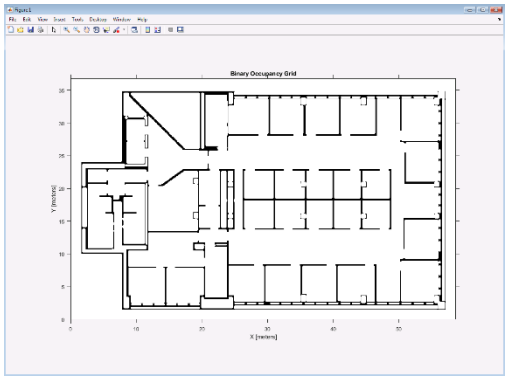
Image



ROS



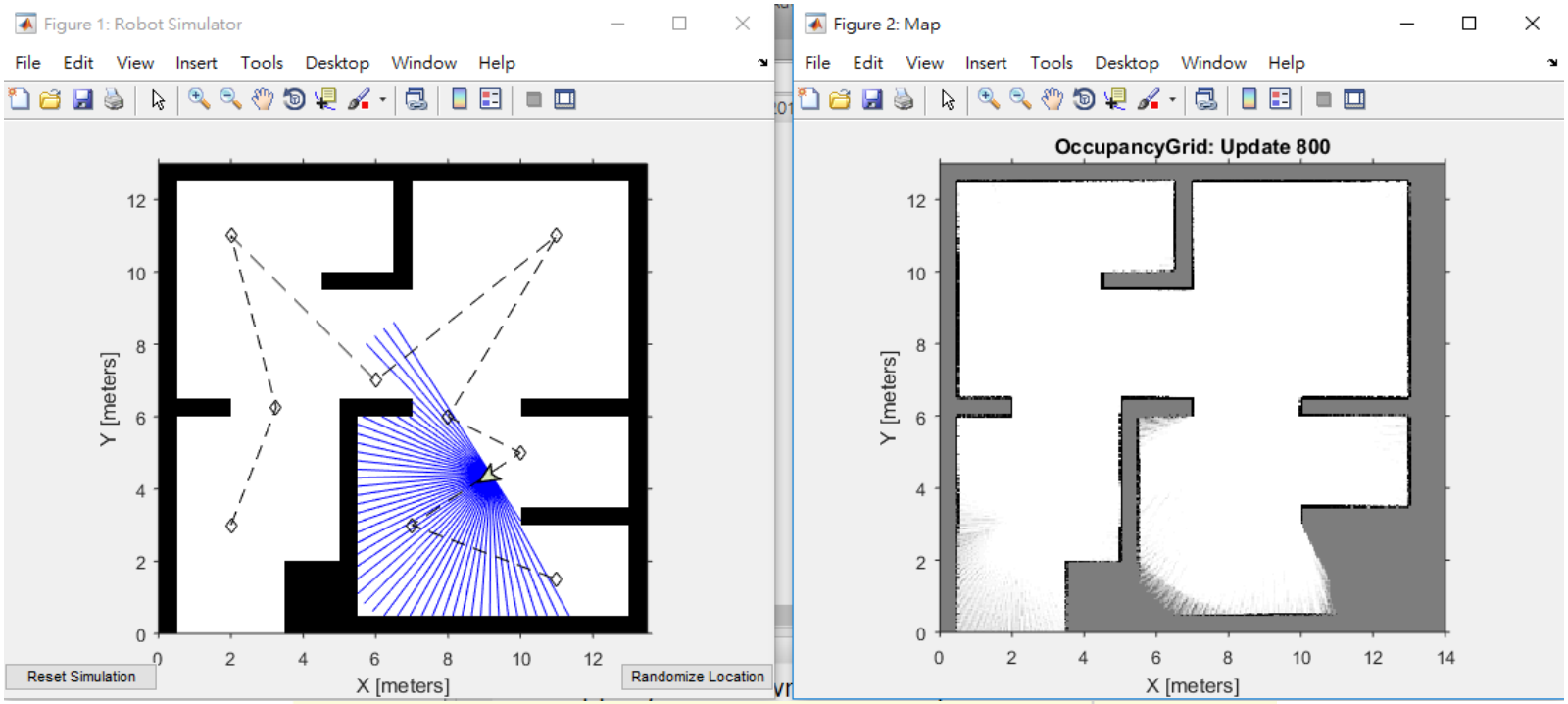
LIDAR



Binary
Occupancy Grid

Mapping With Known Poses

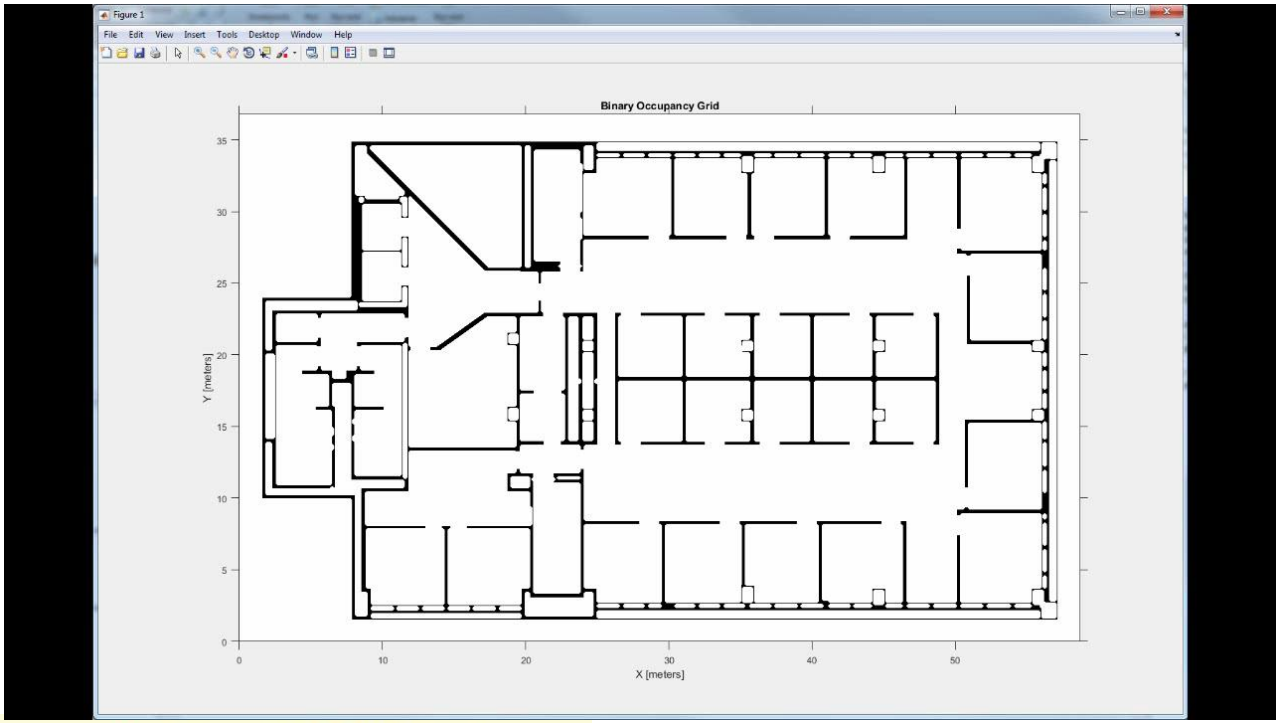
- Create a map of the environment using range sensor readings




```
%% Define an Empty Map
map = robotics.OccupancyGrid(14,13,20);
% Insert the laser range observation in the map
insertRay(map,robotpose,ranges,angles,maxrange)
```

Path Planning using Probabilistic Roadmap

- Plan obstacle-free path between locations on 2D map

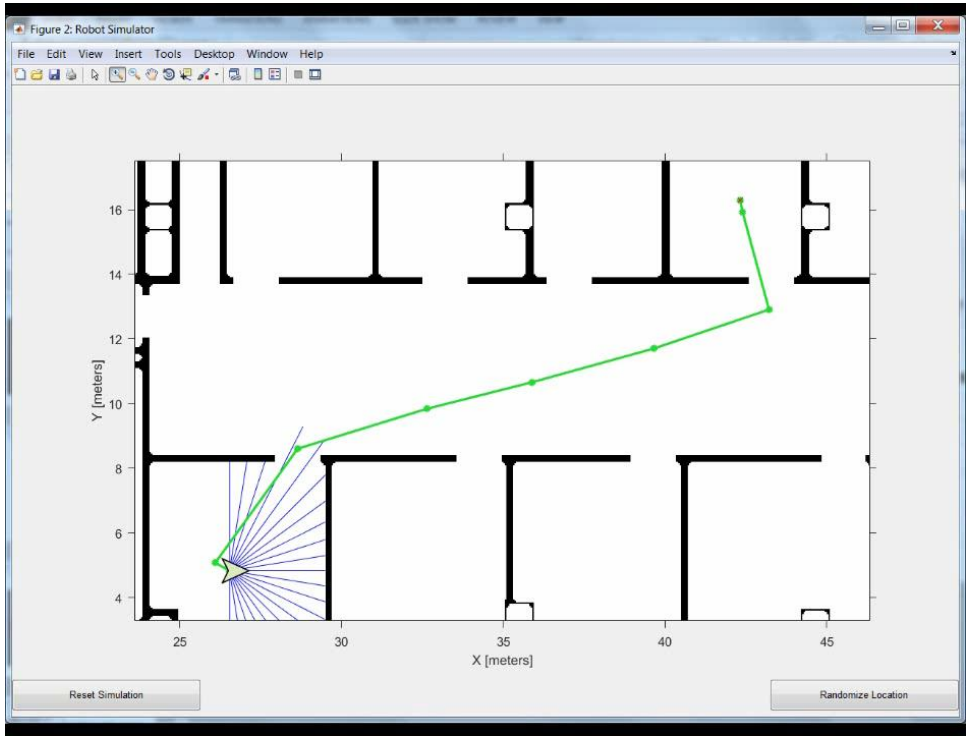



```
prm = robotics.PRM(Map);
prm.NumNodes = 300;
prm.ConnectionDistance=inf;
```

```
start = [0 0]; % starting position
goal = [4.5 -3.0]; % ending position
path = findpath(prm,start, goal);
```

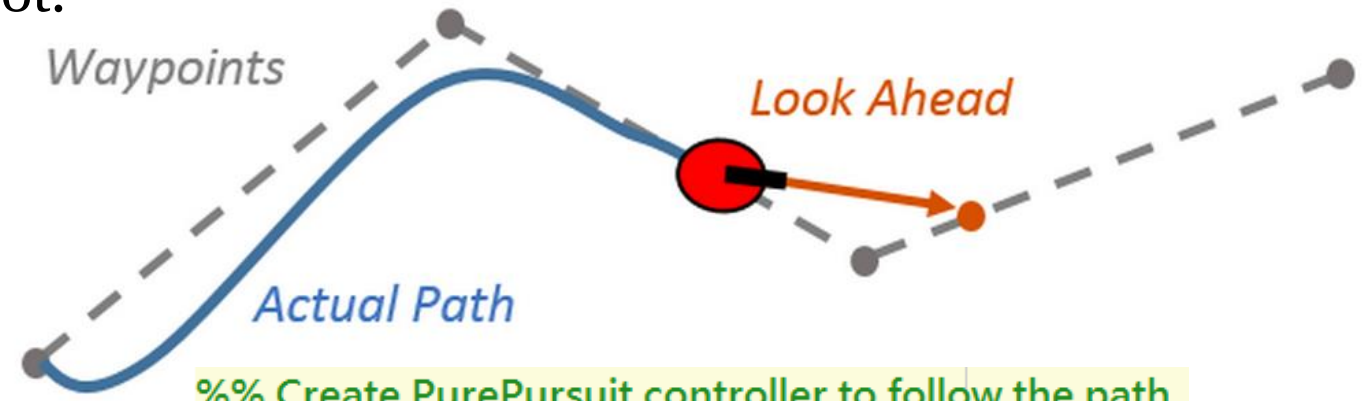
Path Tracking using Pure Pursuit

- Create controller to follow set of waypoints



PurePursuit Controller

- Compute linear and angular velocity commands for a mobile robot.

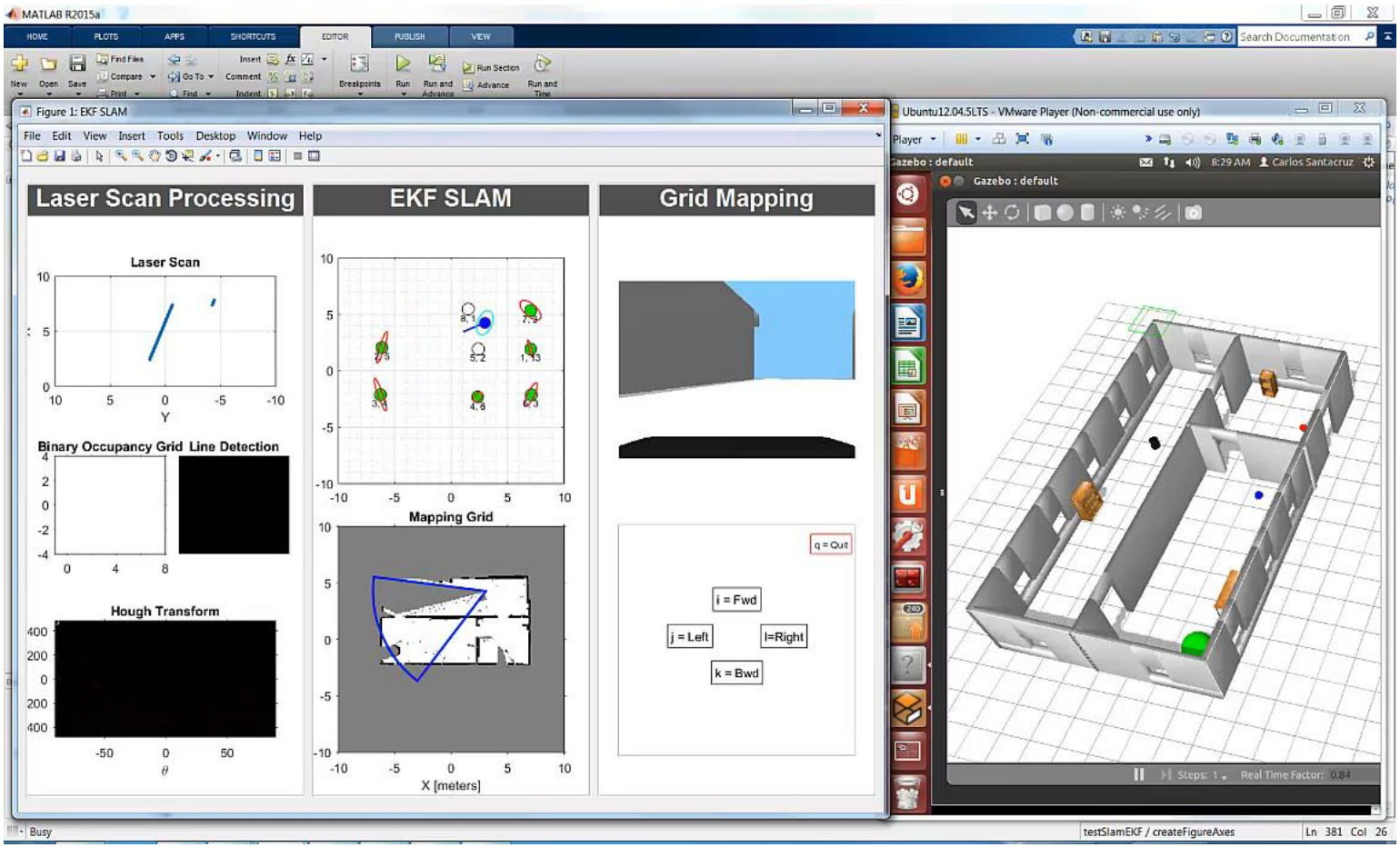



```
%% Create PurePursuit controller to follow the path

controller = robotics.PurePursuit;
controller.Waypoints = path;
controller.DesiredLinearVelocity = 0.3;
controller.MaxAngularVelocity = 2;
controller.LookaheadDistance = 0.6;

% Compute the controller outputs
 [v, omega] = step(controller, robot.CurrentPose);
```

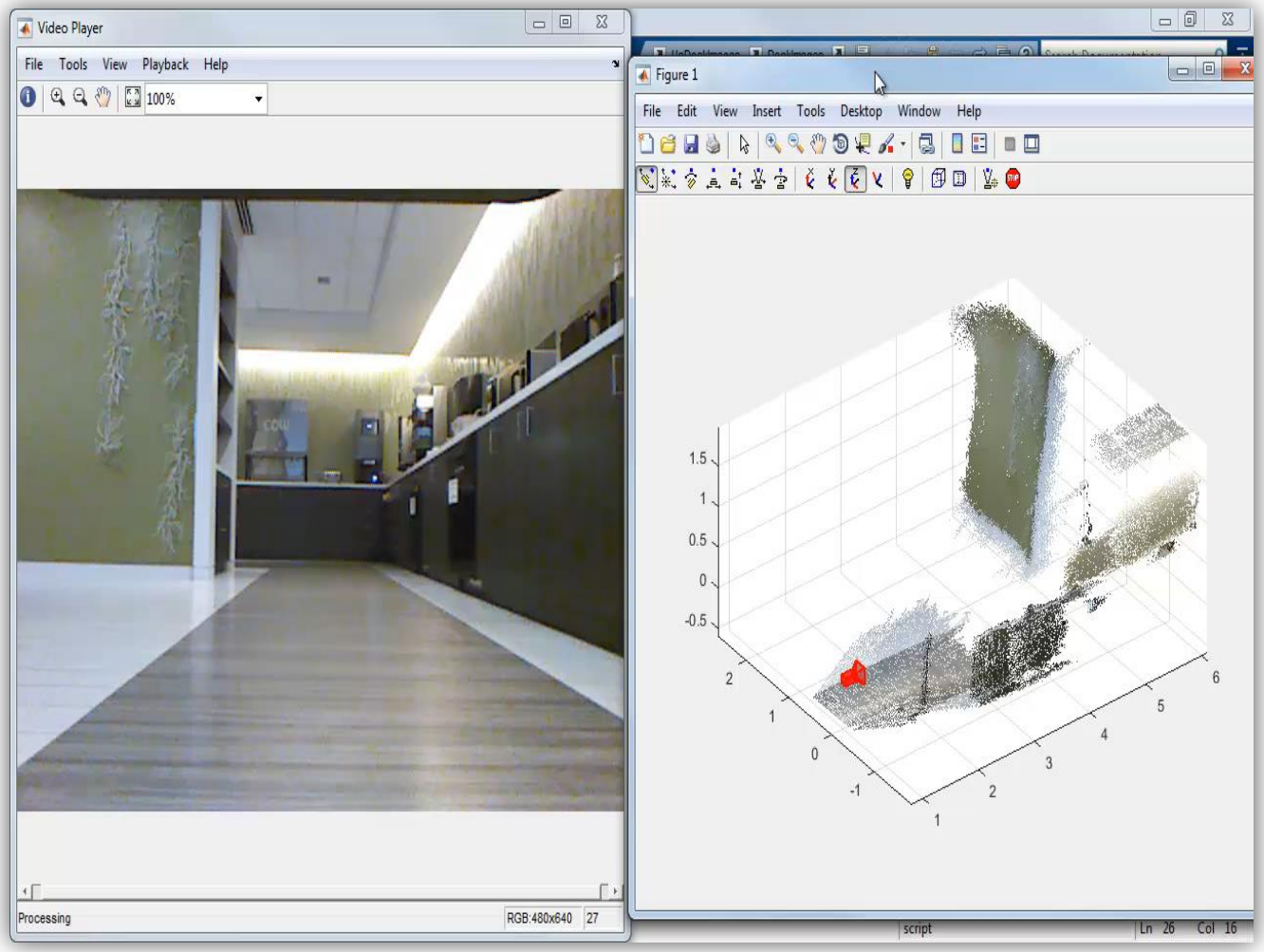
Algorithm Capabilities in RST

Mapping	• Map representation using Occupancy Grid
Path Planning	• Probabilistic Roadmaps • Avoid obstacles using vector field histogram
Kinematics and Control	• Pure Pursuit path controller for differential-drive robots
State Estimation	• Monte Carlo Localization
Utilities	• Conversions between different rotation and translation representations

EKF SLAM


MATLAB R2015a
Figure 1: EKF SLAM
File Edit View Insert Tools Desktop Window Help
Laser Scan Processing
Laser Scan
Binary Occupancy Grid Line Detection
Hough Transform
EKF SLAM
Mapping Grid
X [meters]
Grid Mapping
q = Quit
i = Fwd
j = Left
l=Right
k = Bwd
Ubuntu12.04.5LTS - VMware Player (Non-commercial use only)
Gazebo : default
Busy
testSlamEKF / createFigureAxes
Ln 381 Col 26

Visual SLAM



Computer Vision System Toolbox™

Summary

- MATLAB can directly connect to many devices: Lidar, Kinect and other supported cameras.
- MATLAB/Simulink-ROS Interface provide an easy way to develop and test robotic algorithms.
- Automatically build and deploy generated Simulink ROS node to a robot or other supported hardware.

2016

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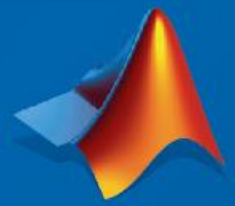

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