

Hypha ROS RaceCar Project

Presenter : HaoChih, LIN

林浩鈇

Website: <https://hypharosworkshop.wordpress.com/contact/>

FB Page: <https://www.facebook.com/HyphaROS/>

Youku: <http://i.youku.com/hypha>

Email: hypha.ros@gmail.com



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2017.7.22~29
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3 m/s video

<http://i.youku.com/hypharos>



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- **About us**
- **Why RaceCar**
- **Hardware Configuration**
(odroid xu4, RPLidar, arduino, gy85, etc)
- **Basic Operation (Odroid x ROS)**
- **Software Implementation (ROS)**
(laser based odom, IMU, EKF, L1 controller)
- **How to build the track**
- **Q & A**



About us



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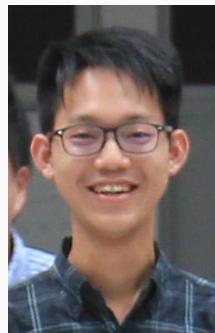


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About us

- Introduction

- Website: <https://hypharosworkshop.wordpress.com/>
- Github: <https://github.com/Hypha-ROS/hypha-racecar>
- Facebook: <https://www.facebook.com/HyphaROS/>
- Youtube: <https://www.youtube.com/watch?v=jgS6gpmWPoY>
- Youku: <http://i.youku.com/hypha>



<https://www.linkedin.com/in/eric-w-ko-835b1a145/>

<https://www.linkedin.com/in/haochih-lin/>

<https://www.linkedin.com/in/chien-liang-chu-32b636140/>



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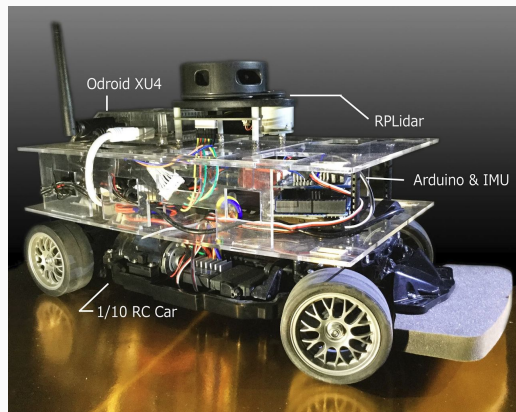


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About us

- Introduction

- Self-organized Workshop: 2
- Speech & Training: 4
- Technical supports: > 10 universities/labs & > 5 companies
- Product & Service [ROS]: Workshop, Technical Consultant, AGVs, Home robots, etc.



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Why RaceCar



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Why RaceCar

- **The requirements of the platform**
 - ROS fully support
 - Able to implement 2D Navigation stack (laser based)
 - Low cost (ARM SBC, low-cost lidar, mems imu, etc)
 - High performance
 - Robust & Safety
 - Algorithms evaluation/comparison
 - Modularization & Extensibility



Why RaceCar

- **The origin of RACECAR**

MIT: <https://mit-racecar.github.io/>

Youtube: <https://www.youtube.com/watch?v=9fzzp6oxid4>

1/10-scale Traxxas Rally Car

Nvidia Jetson TX 1

Hokuyo UST-10LX laser range finder

Stereolabs ZED stereo camera

Structure.io depth camera

Sparkfun IMU

Encoder + optical flow

realtime onboard 4 m/s



Total cost: around 3,600 USD



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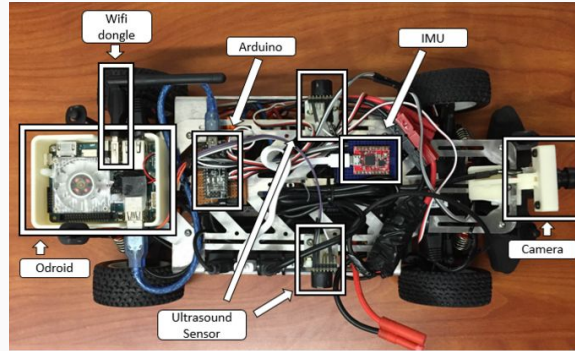
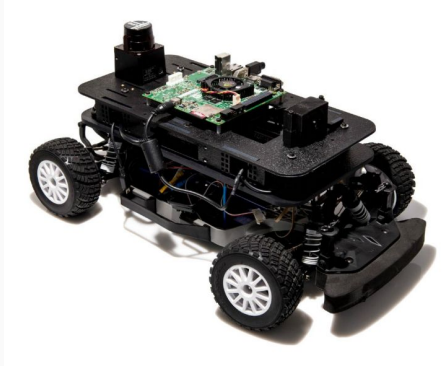
Why RaceCar

- Similar projects

Penn: <http://f1tenth.org/> [without slam, NAV]

UCB: <http://www.barc-project.com/projects/> [without laser]

Georgia Tech: <https://github.com/AutoRally> [for outdoor]



Hardware Configuration



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Hardware Configuration



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Hardware Configuration

ITEM	Quantity	ITEM	Quantity
1/10 ready to go car set	1	5v4A BEC	2
FUTABA S9151 數位伺服機	1	小型 DC to DC 模組	1
電池 7.4v 5000 mah 1:10 車用	1	Arduino UNO (建議原廠)	1
B6 IMAX 充電器	1	Arduino Nano (建議原廠)	1
電源 T插 (一對)	2	GY-85 IMU	1
Odroid XU4 (US plug)	1	M3 塑膠 6角柱 12mm	8
Odroid official wifi module 3	1	M3 金屬 螺絲 10mm	10
Odroid Cases	1	40P彩色杜邦線	1
rplidar A1 (A1m1 or A1m8)	1	壓克力夾板 (或其他材料)	1
USB 2.0 Hub	1	Total cost (around)	600 USD



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Basic Operation (Odroid x ROS)



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Basic Operation (Odroid x ROS)

- **[desktop] Download pkg from Hypha-ROS github**
 - \$ cd catkin_ws/src
 - \$ git clone https://github.com/Hypha-ROS/hypha-racecar
- **[desktop] SSH/Remmina to Odroid**
 - Wifi configuration (Hostname: hypharos0X, SSID: HyphaROS, pw: hypharos)
 - Ethernet configuration (default IP: 10.0.0.1)
 - ROS multi-machine env setting (in ~/.bashrc)
 - ssh: \$ ssh odroid@192.168.X.1 (pw: hypharos) [Adhoc]
 - File manager: Connect to server -> ssh://odroid@192.168.X.1
 - remmina (vino pw: 0000)
- **[odroid] Modify wifi setting**
 - change hostame: \$ sudo odroid-utility.sh (pw: hypharos)
 - ROS multi-machine env setting (in ~/.bashrc)



Basic Operation (Odroid x ROS)

- **[desktop] image backup**

- Read: In hypha-racecar/document/commands/
- `$ sudo fdisk -l /dev/sdb`
- `$ sudo dd if=/dev/sdb bs=512 count=29624319 of=~/HyphaROS_xu4_kinetic_20170610.img`
- Write: Ubuntu GUI

- **[odroid] Change adhoc setting**

- `$ sudo gedit /etc/network/interfaces` (pw: hypharos)

- **[odroid] Change git config**

- `$ cd catkin_ws/src`
- `$ git config --global user.name "YOUR NAME"`
- `$ git config --global user.email YOUR EMAIL`
- `$ git config --list` (to ckeck setting)



Basic Operation (Odroid x ROS)

- **[odroid] Create your own ROS pkg**

- `$ cd catkin_ws/src`
- `$ catkin_create_pkg PACKAGE_NAME geometry_msgs move_base tf roscpp rospy std_msgs visualization_msgs`

- **[odroid] Udev Setting**

- `$ lsusb` (check the idV and idP of each component)
- Select one for finding the ISB port
- `$ ls dev/ttyACM or ttyUSB`
- `$ udevadm info -a /dev/ttyUSB0`
- `$ sudo gedit /etc/udev/rules.d/99-NAME.rule`
- `⇒ KERNEL=="ttyUSB*", ATTRS{idProduct}=="ea60", ATTRS{idVendor}=="10c4", MODE="666", ATTRS{devpath}=="1.2.1.2", SYMLINK+="rplidar`



Software Implementation (ROS)



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2D Laser SLAM

- **Gmapping**

- needs external odom (in our case: laser odom fused with imu0)
- Rao-Blackwellized Particle Filter (RBPF)
- Loop closure

- **Hector SLAM**

- Gauss-Newton approach
- External odom is not necessary
- No loop closure
- Requires high quality sensor (e.g. UTM-30LX)
- Supports EKF fusion (imu)

- **MRPT-ICP SLAM**

- ICP algorithm
- For small to mid-sized maps
- External odom is not necessary



2D Laser SLAM

- **Gmapping**

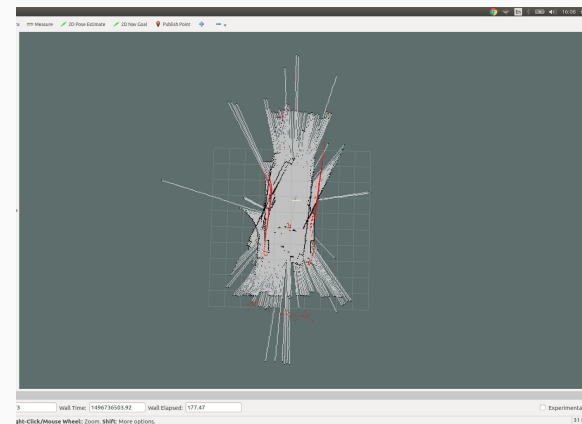
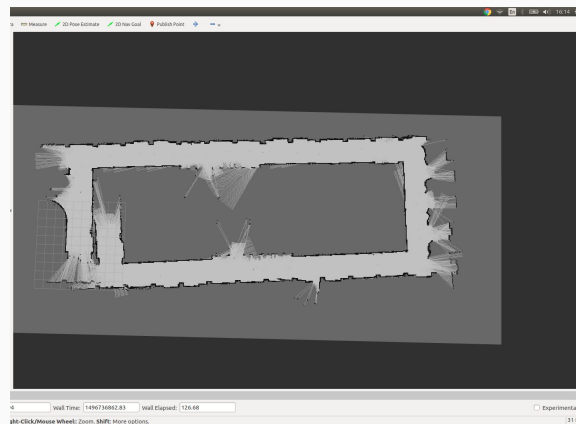
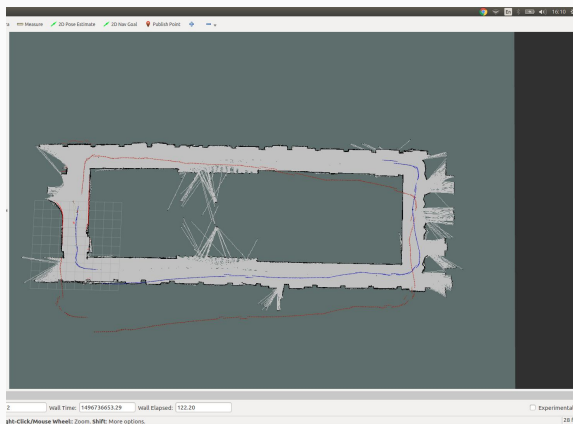
- \$ roslaunch hypha_racecar desktop_gmapping.launch

- **MRPT-ICP SLAM**

- \$ roslaunch hypha_racecar desktop_icp_mapping.launch

- **Hector SLAM**

- \$ roslaunch hypha_racecar Test_hector_rplidar.launch



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Laser Odom (EKF IMU)

Odometry resource selection

- **Wheel encoder**

- Most reliable (in low speed)
- Slip/Drifting Issue
- Custom codes

- **Laser odometry**

- Performance depends on laser resolution/environment features
- Good estimates in translation, awful in rotation
- Better system portability

- **Visual Odometry (or Visual Inertial Odometry)**

- Low robust
- High computational loading
- Case by case tuning
- Highly depends on sensor type/quality



Laser Odom (EKF IMU)

- rf2o laser odom package

- <http://mapir.isa.uma.es/mapirwebsite/index.php/mapir-downloads/papers/217>
- range flow constraint equation $\dot{r} \simeq R_t + R_\alpha \dot{\alpha} = R_t + R_\alpha k_\alpha \dot{\theta}$
- Iteratively Reweighted Least Squares (IRLS)

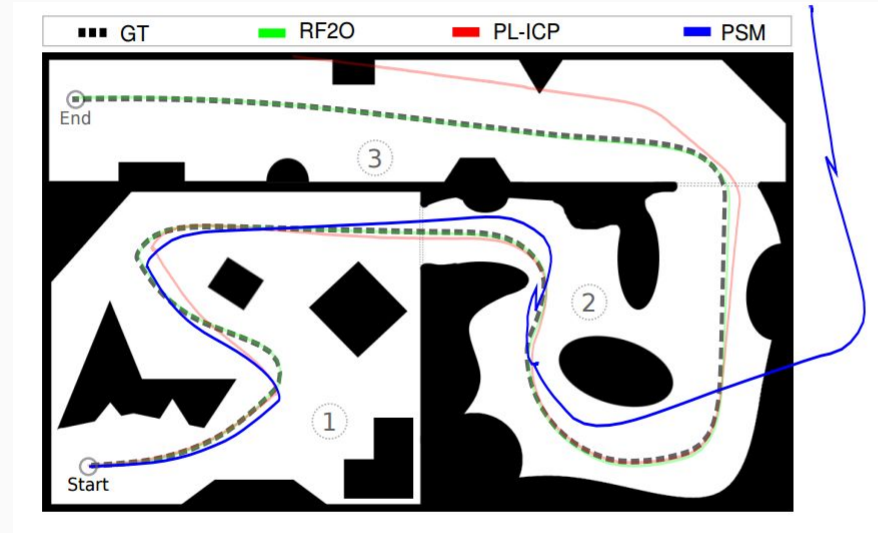
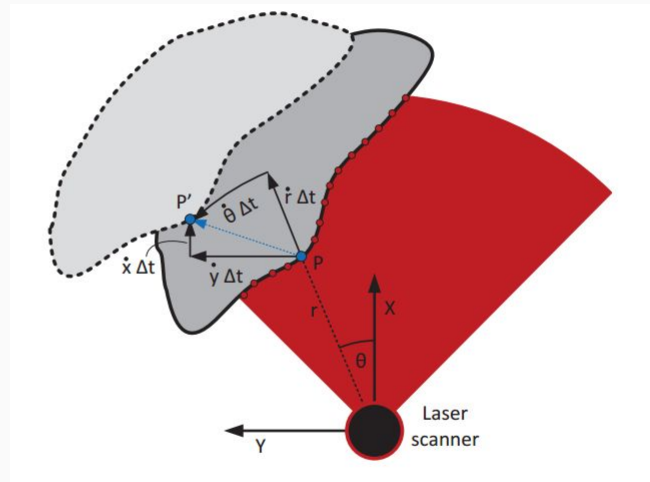


figure source:



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Laser Odom (EKF IMU)

- **Problem of rf2o**

- Performance of rf2o is bad in rotation behavior
- Needs external measurement to estimate yaw motion (gy85)

- **ROS EKF Package**

- robot_pose_ekf
 - move_base built-in pkg
 - for 2D, low flexibility
- robot_localization
 - all params are adjustable, well documented
 - 3D model based
 - supports multi-sensors (including GPS, imu, vo, etc)
- ethzasl_msf
 - ESKF architecture (imu derived model)
 - good for VO measurement
 - best choice for drone



Laser Odom (EKF IMU)

- **robot_localization pkg**

- http://wiki.ros.org/robot_localization
- https://github.com/cra-ros-pkg/robot_localization
- [document] http://docs.ros.org/indigo/api/robot_localization/html/index.html
- [video] <https://vimeo.com/142624091>
- All state estimation nodes track the 15-dimensional state of the vehicle:

$(X, Y, Z, roll, pitch, yaw, \dot{X}, \dot{Y}, \dot{Z}, \ddot{X}, \ddot{Y}, \ddot{Z})$

- Implementation (See example file: "[hypha_ekf_params.yaml](#)")
Vx, Vy from rf2o, yaw from imu, custom covariance settings

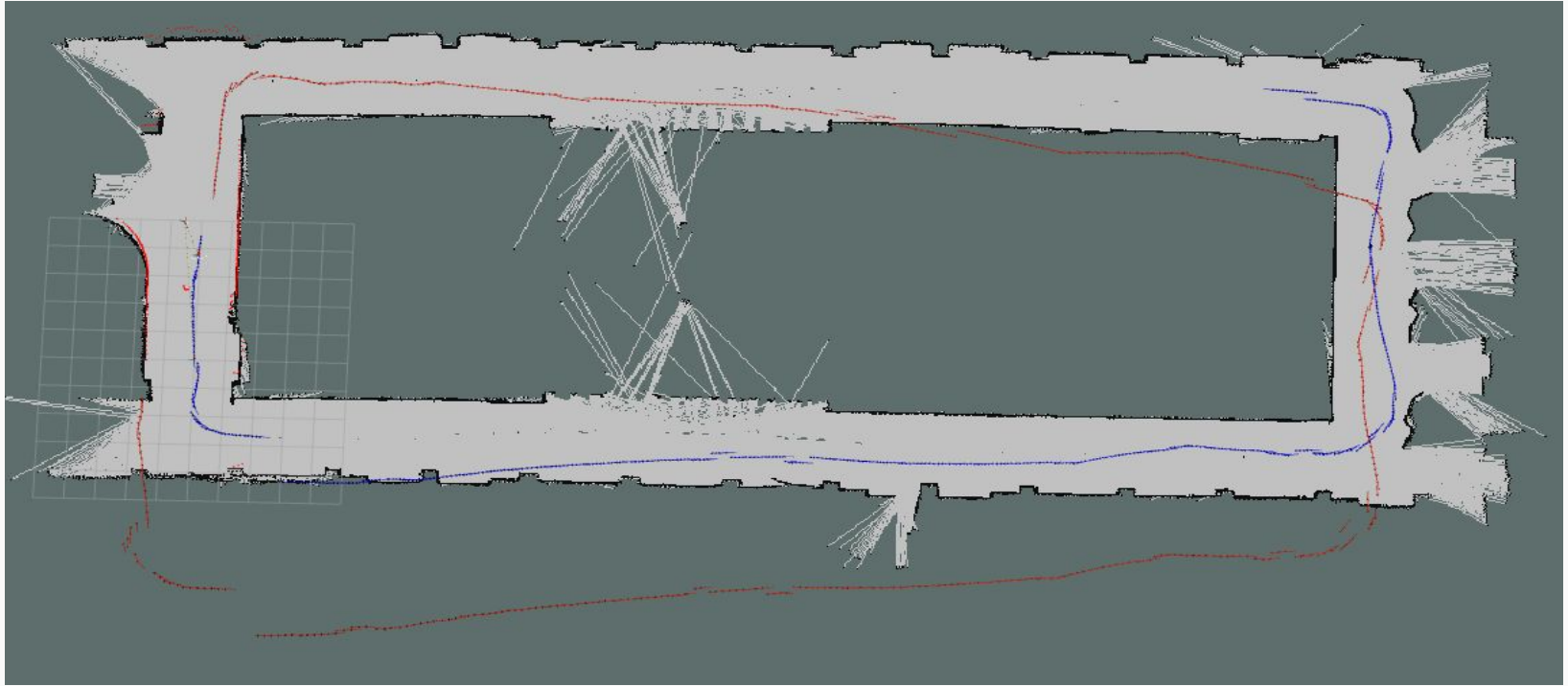


Laser Odom (EKF IMU)

- **IMU yaw reading**
 - [arduino] http://wiki.ros.org/razor_imu_9dof (file: [hypha-racecar/document/arduino](#))
 - [odroid] gy85 with modified **pySerial** code
 - Using gyro_z raw data for integration directly instead of output data from ekf
 - See example (file: [imu_auto.py](#))
- **ROS bag Testing**
 - Try to modify ekf param file ([desktop_gmapping.launch](#))
- **Realtime onboard testing**
 - [Test_laser_odom.launch](#)
 - [Test_gmapping.launch](#)
- **rf2o bug**
 - replace file: CLaserOdometry2D.cpp ([hypha-racecar/document/replace_files/rf2o/](#))



Laser Odom (EKF IMU)



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Communication & Control

- **roserial arduino**

- [setup] http://wiki.ros.org/roserial_arduino/Tutorials/Arduino%20IDE%20Setup
- racecar_uno.ino [[hypha-racecar/document/arduino/racecar_uno/](#)]

- **Teleop testing**

- [roslaunch] \$ roslaunch roserial_python serial_node.py /dev/uno
- [roslaunch] \$ roslaunch roserial_python serial_node.py _port:=/dev/uno _baud:=57600
- [roslaunch]

<!-- Arduino -->

<node pkg="roserial_python" type="serial_node.py" name="serial_node">

<param name="port" value="/dev/uno"/>

<param name="baud" value="57600"/>

</node>

- \$ roslaunch hypha_racecar racecar_teleop.py



Communication & Control

- Overview of ROS Navigation

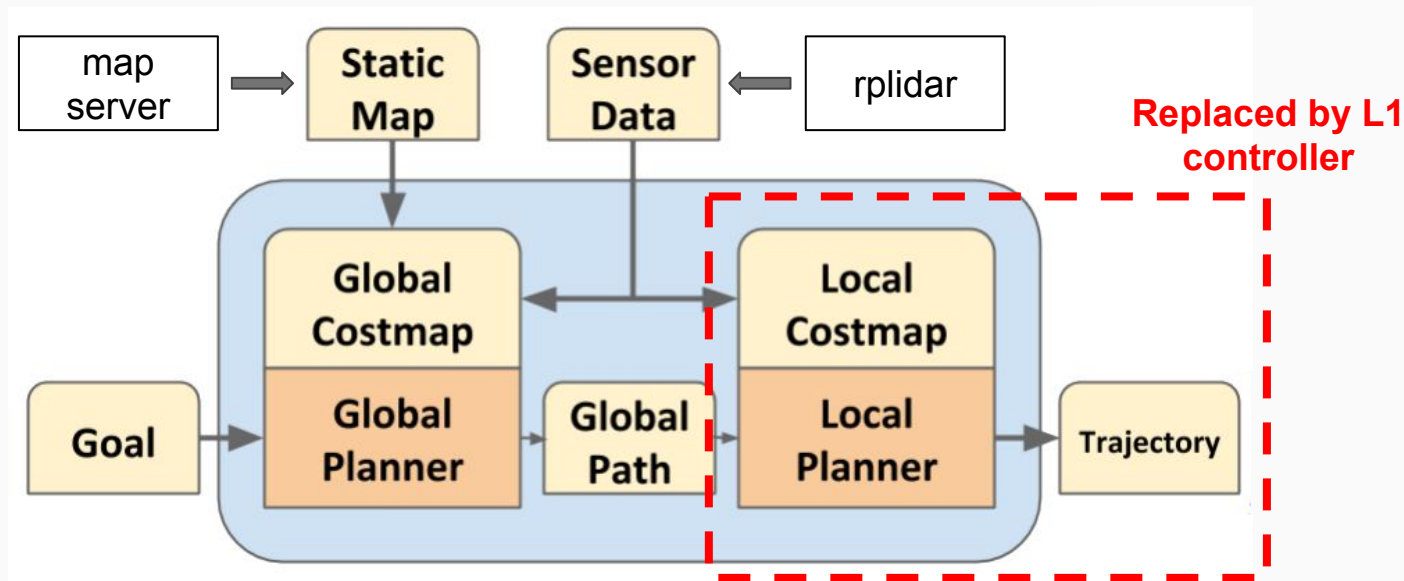


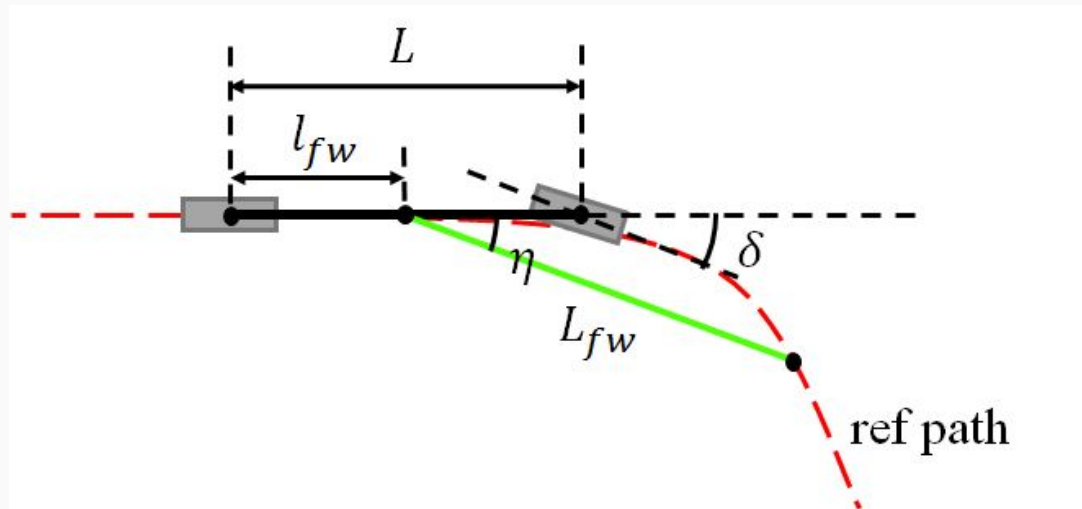
figure source: http://roscon.ros.org/2014/wp-content/uploads/2014/07/ROSCON2014_DLu.pdf



Communication & Control

- **L1 controller**

- paper: <http://acl.mit.edu/papers/KuwataTCST09.pdf>
- paper: <http://acl.mit.edu/papers/KuwataGNC08.pdf>



- δ : steering angle
- L_{fw} / L_{rv} : forward/reverse look-ahead distance
- l_{fw} / l_{rv} : forward/reverse anchor distance
- ref path: Path to follow
- R : Rotation radius
- L : distance of wheels
- η : heading of the look-ahead point



Communication & Control

- **L1 controller Implementation**

- [source code] L1_controller_v2.cpp

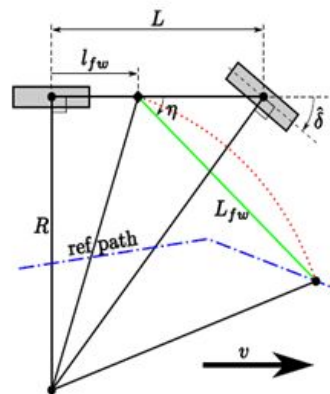
- Speed control:
$$u = K_p (v_{cmd} - v) + K_i \int_0^t (v_{cmd} - v) d\tau$$

- current version => constant speed

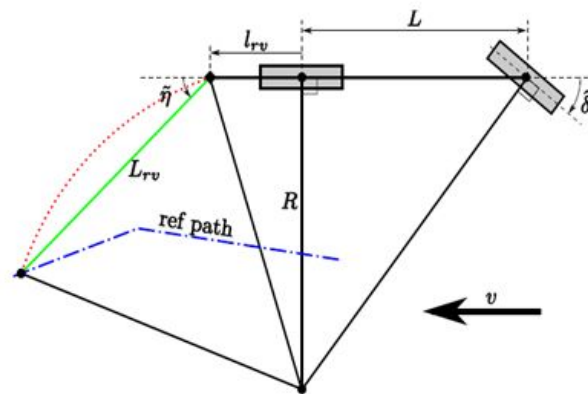
- **Path planning test**

- RACECAR_amcl_nav.launch

- u : motor command
- V_{cmd} : desired velocity
- V : current velocity



(a) Forward Drive



(b) Reverse Drive



Communication & Control

- **L1 controller launch file**

```
<!-- L1 controller -->  
<node pkg="hypha_racecar" type="L1_controller_v2" respawn="false" name="L1_controller_v2"  
output="screen">  
  <!-- L1 -->  
  <param name="Vcmd" value="1.0" />  
  
  <!-- ESC -->  
  <param name="baseSpeed" value="1440"/>  
  
  <!-- Servo -->  
  <param name="baseAngle" value="90.0"/>  
  <param name="AngleGain" value="-3.5"/>  
  
  <remap from="/move_base_node/NavfnROS/plan" to="/move_base/NavfnROS/plan" />  
</node>
```



How to build the track



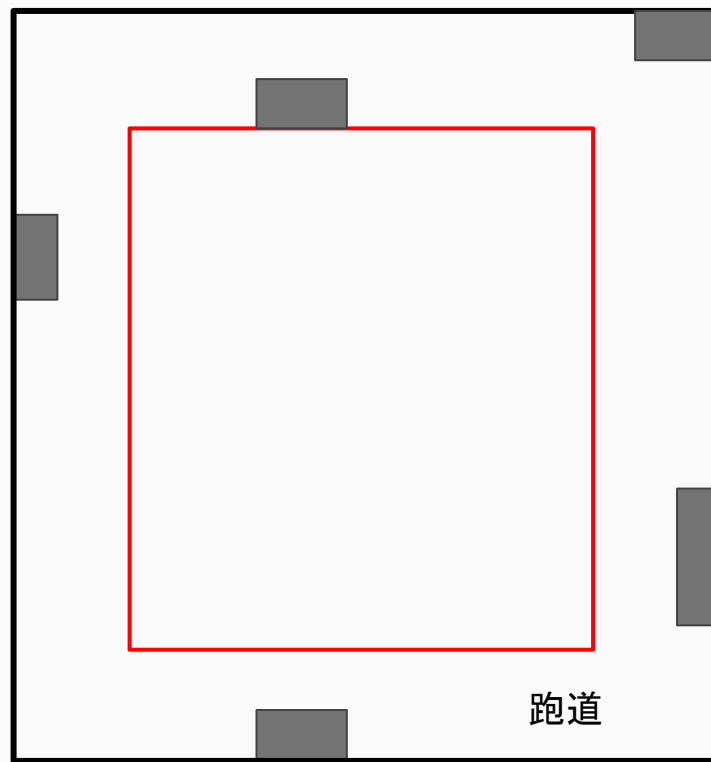
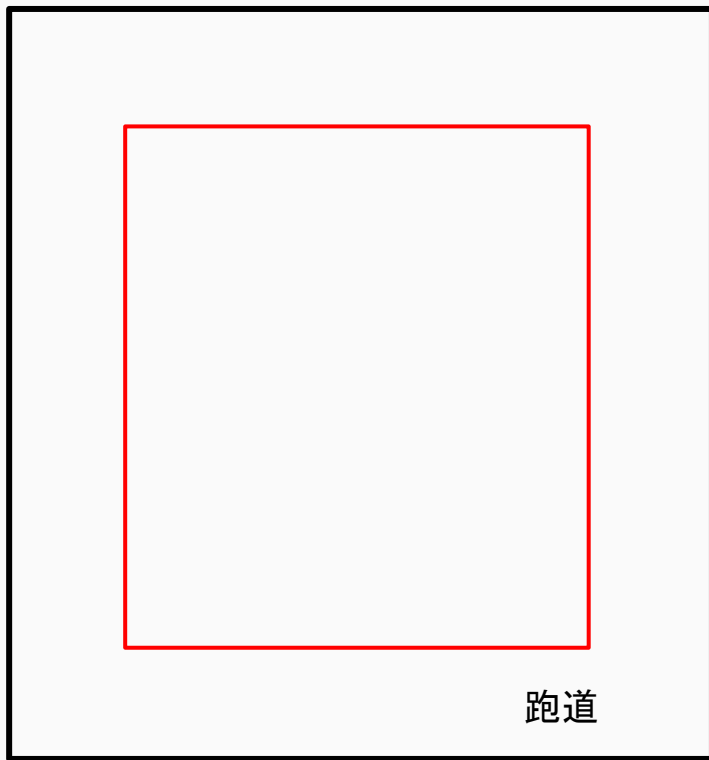
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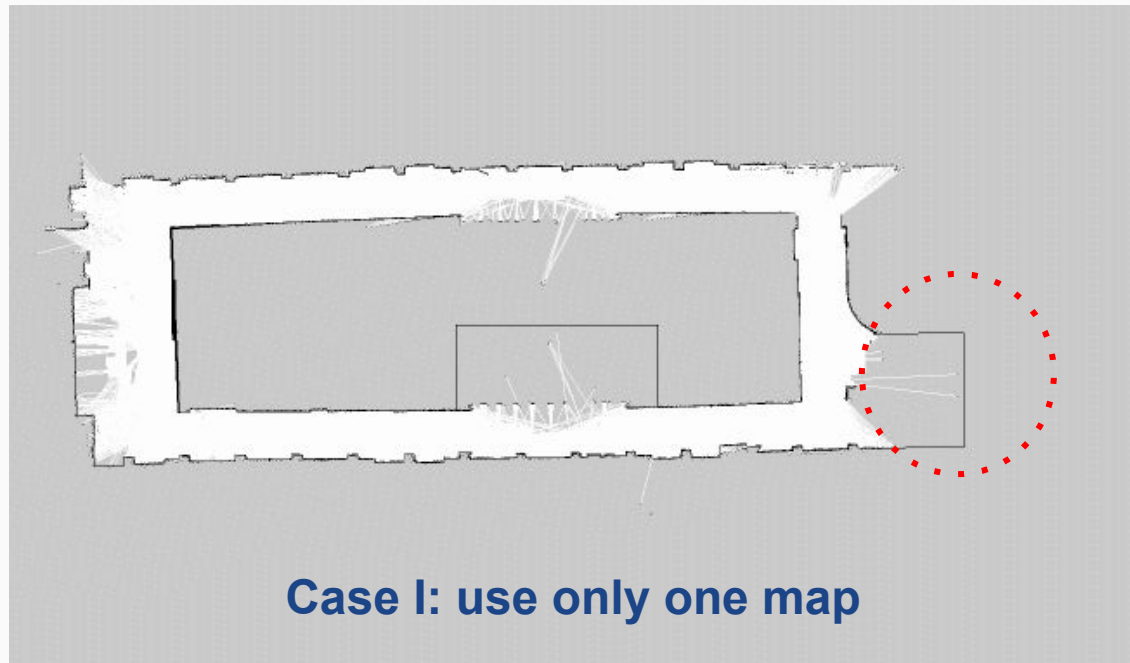


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How to build the track



How to build the track



Case I: use only one map



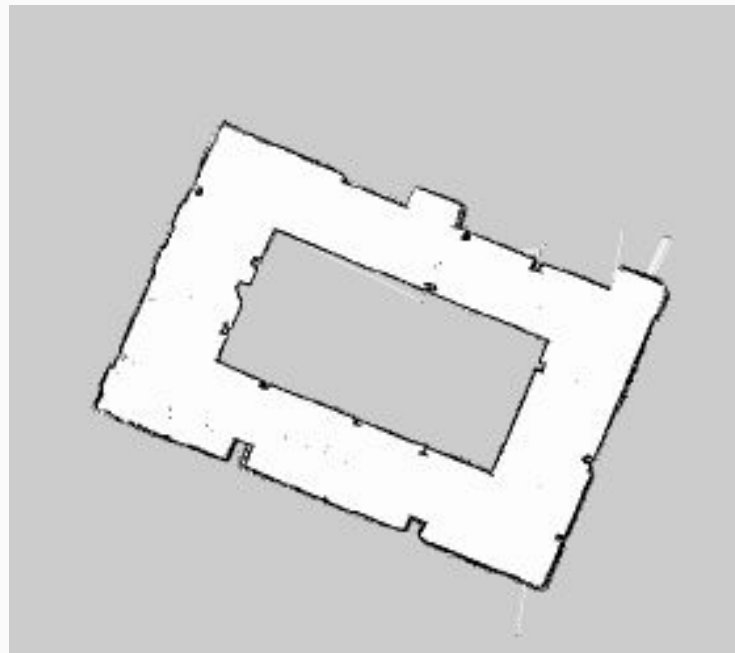
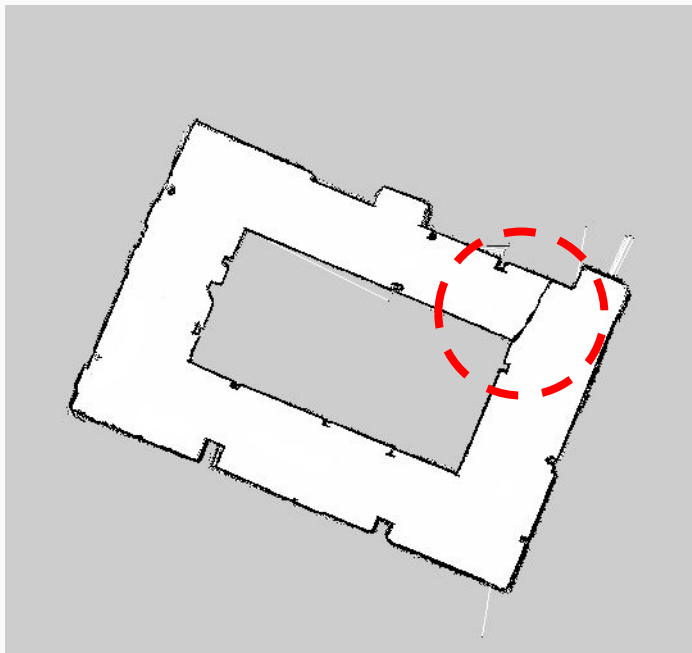
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How to build the track



**Case II: use two maps, one
for amcl, one for nav**



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Competition

Procedures

- [mapping] realtime, onboard
 - Test_gmapping.launch OR Test_icp_mapping.launch
- [mapping] realtime, desktop
 - Needs to modify launch file
- [mapping] offline, desktop
 - odroid: RACECAR_bag_record.launch
 - desktop: RACECAR_bag_icp.launch OR RACECAR_bag_gmapping.launch
- [edit map]
 - \$ rosrune map_server map_saver
 - GIMP to edit map [support png and pgm]
- [navigation]
 - RACECAR_amcl_nav.launch



Q & A



Hypha ROS Workshop

Website: <https://hypharosworkshop.wordpress.com/>

Github: <https://github.com/Hypha-ROS/hypha-racecar>

Gmail: hypha.ros@gmail.com



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