Autoware Manual

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SCL Systems & Control Lab.

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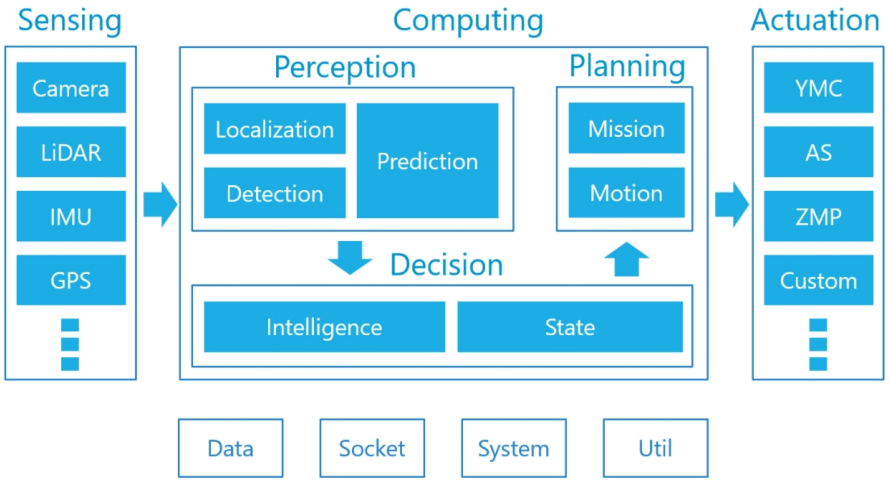
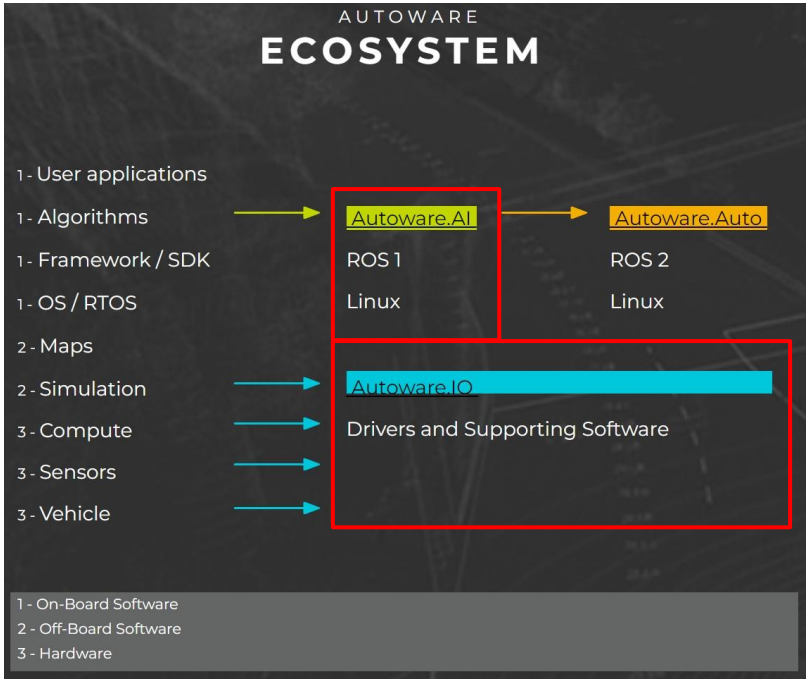
Autoware?

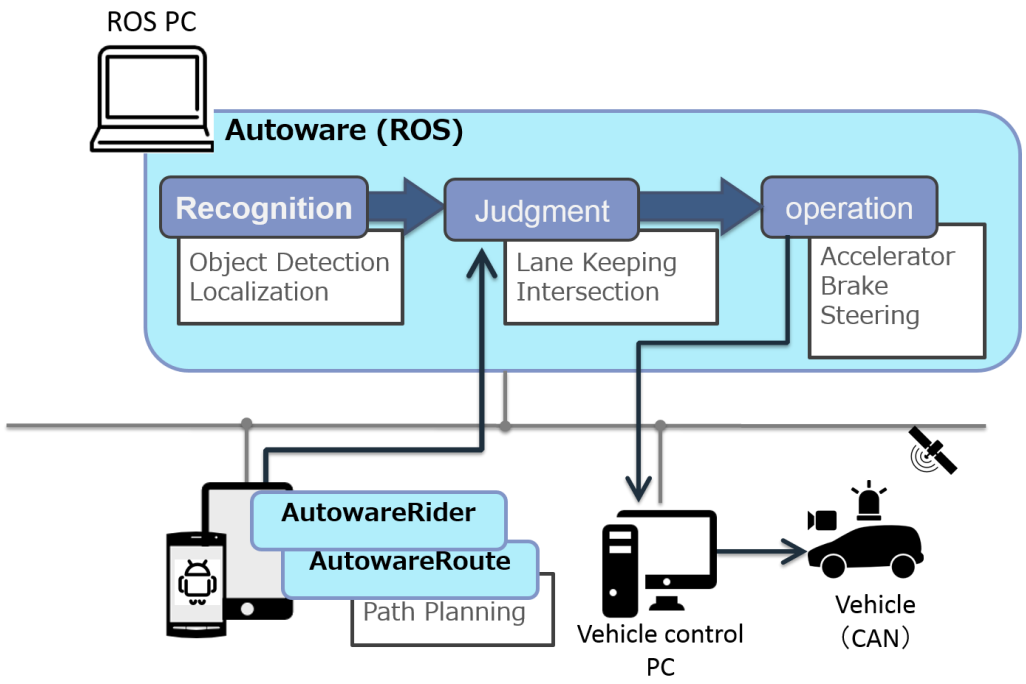




Keywords

- Localization
- Mapping
- Object Detection & Tracking
- Traffic Light Recognition
- Mission & Motion Planning
- Trajectory Generation
- Lane Detection & Selection
- Vehicle Control
- Sensor Fusion
- Cameras, LiDARs
- RADARs
- Deep Learning
- Rule-based System
- Connected Navigation
- Logging
- Virtual Reality

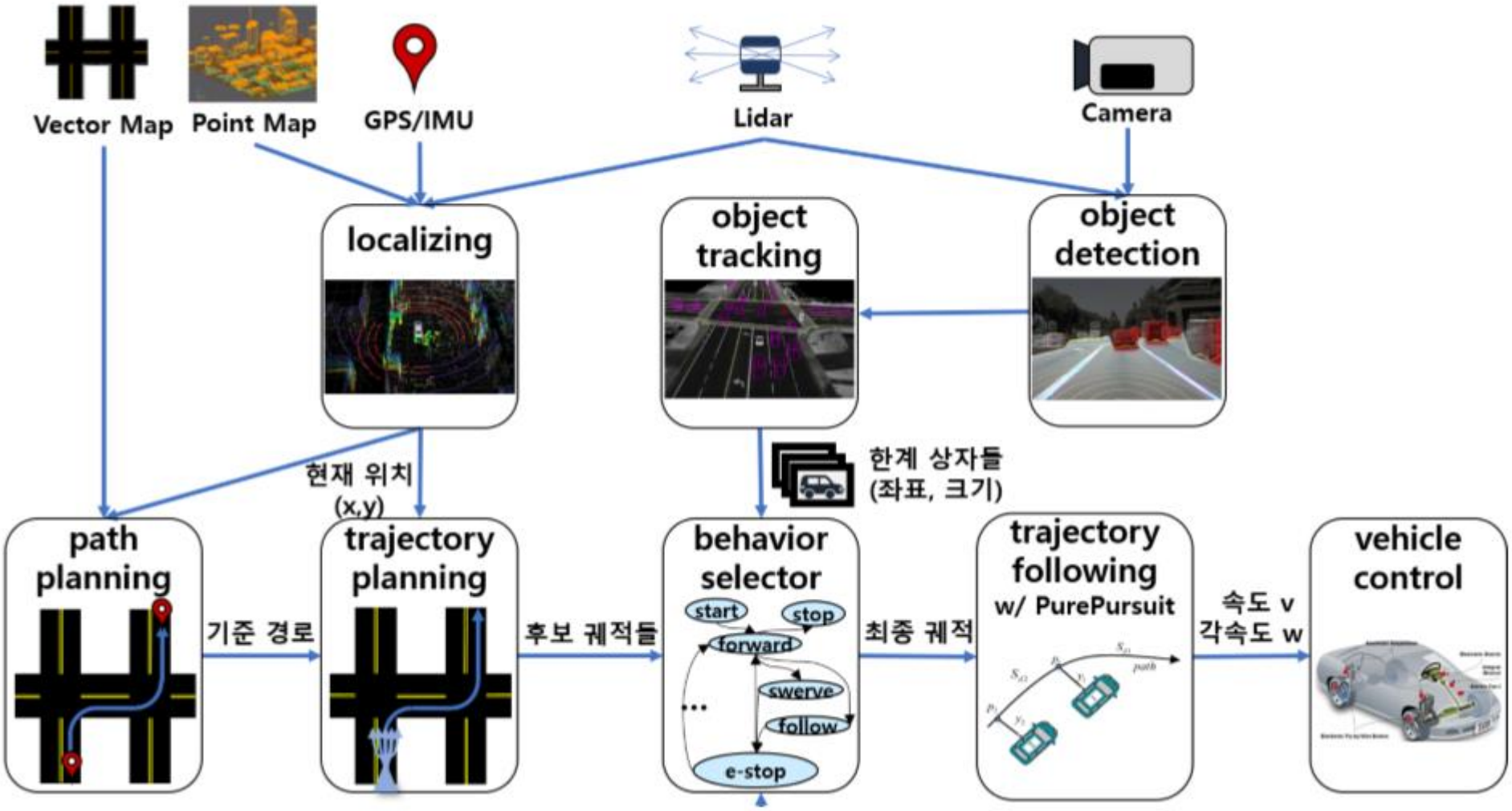
Autoware?



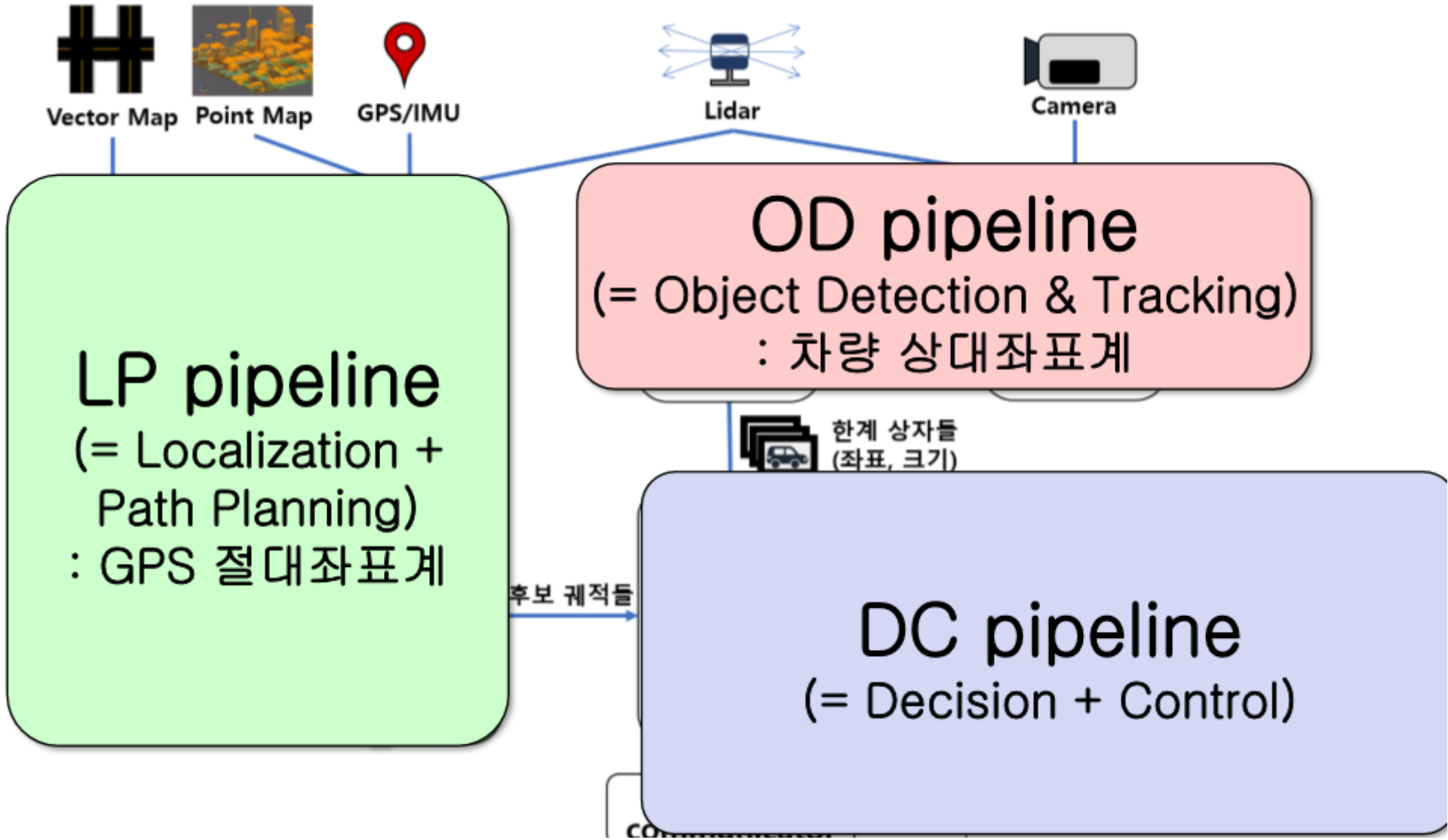
Autoware uses **LIDAR** and **on-vehicle cameras** to localize the ego-car position.

Autoware can detect surrounding objects,
such as **pedestrians, vehicles, traffic lights etc.**, by using **LIDAR** and **GNSS**.

Autoware?


Vector Map
Point Map
GPS/IMU
Lidar
Camera
localizing
object tracking
object detection
현재 위치 (x,y)
한계 상자들 (좌표, 크기)
path planning
기준 경로
trajectory planning
후보 궤적들
behavior selector
start
stop
forward
swerve
follow
e-stop
최종 궤적
trajectory following w/ PurePursuit
속도 v
각속도 w
vehicle control

Autoware?


Vector Map
Point Map
GPS/IMU
Lidar
Camera
LP pipeline
(= Localization + Path Planning)
: GPS 절대좌표계
OD pipeline
(= Object Detection & Tracking)
: 차량 상대좌표계
한계 상자들
(좌표, 크기)
후보 궤적들
DC pipeline
(= Decision + Control)

Installation

1. Install Dual boot Ubuntu 18.04.5 LTS
2. Install Autoware

1-1. Dual boot Ubuntu 18.04.5 LTS

1. Laptop Specs(BOSS MONSTER SCL3)

OS : Windows 10

CPU : I7-9750H

Graphic Card : GTX 2070

USER NAEM : scl

2. Format

Disk Format : Windows - 디스크 관리 - 디스크 삭제

USB Format : https://www.sdcard.org/downloads/formatter/eula_windows/index.html

Bootable USB : https://releases.ubuntu.com/18.04.5/ubuntu-18.04.5-desktop-amd64.iso https://rufus.ie/

(BIOS Setting) Secure boot, legacy mode : **Disabled**

Something else : **CHECK!**

SWAP partition(RAM's 10%) – Ext4 partition

1-1. Dual boot Ubuntu 18.04.5 LTS

3. CUDA & NVIDIA Driver

```
sudo apt-get install gcc
sudo apt-get update
sudo apt-get upgrade

sudo rm /etc/apt/sources.list.d/cuda*
sudo apt remove nvidia-cuda-toolkit
sudo apt purge nvidia-*
sudo apt update

sudo apt-key adv --fetch-keys  http://developer.download.nvidia.com/\
compute/cuda/repos/ubuntu1804/x86_64/7fa2af80.pub

sudo bash -c 'echo "deb http://developer.download.nvidia.com/\
compute/cuda/repos/ubuntu1804/x86_64 /" > /etc/apt/sources.list.d/cuda.list'

sudo apt update
sudo apt install cuda-10-0
```

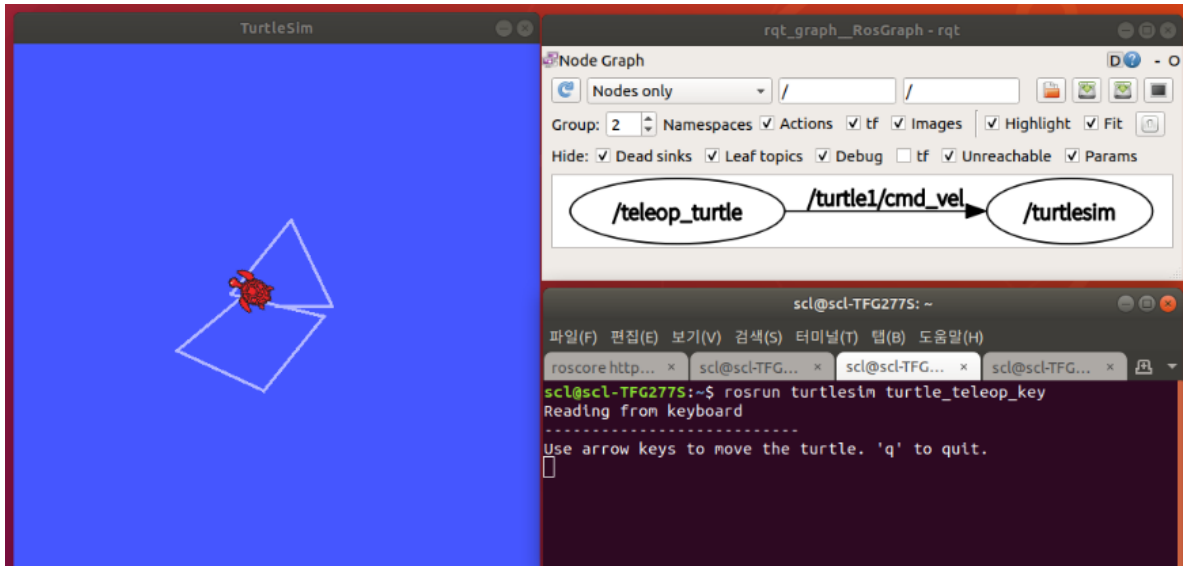
1-2. ROS Melodic Morenia

4. ROS Melodic Morenia

```
sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu $(lsb_release -sc) main" > /etc/apt/sources.list.d/ros-latest.list'
sudo apt-key adv --keyserver 'hkp://keyserver.ubuntu.com:80' --recv-key C1CF6E31E6BADE8868B172B4F42ED6FBAB17C654
sudo apt-get update
sudo apt install ros-melodic-desktop-full

sudo apt-get install python-pip
sudo -H pip install -U rosdep
echo "source /opt/ros/melodic/setup.bash" >> ~/.bashrc
source ~/.bashrc
sudo apt-get install python-rosinstall python-rosinstall-generator python-wstool build-essential python3-vcstools
sudo apt-get install python3-pip python3-vcstools python3-colcon-common-extensions
sudo apt install python-rosdep
sudo rosdep init
rosdep update
```

ROS test code

```
roscore
rosrun turtlesim turtlesim_node
rosrun turtlesim turtle_teleop_key
rqt_graph
```



1-3. Eigen 3.3.7

5. Eigen 3.3.7

```
cd && wget https://gitlab.com/libeigen/eigen/-/archive/3.3.7/eigen-3.3.7.tar.gz

mkdir eigen && tar --strip-components=1 -xzvf eigen-3.3.7.tar.gz -C eigen

cd eigen && mkdir build && cd build && cmake .. && make

sudo make install

cd && rm -rf eigen-3.3.7.tar.bz2 && rm -rf eigen
```

1-4. Autoware.ai

```
mkdir -p autoware.ai/src && cd autoware.ai

wget -O autoware.ai.repos https://gitlab.com/autowarefoundation/autoware.ai/autoware/raw/1.14.0/autoware.ai.repos?inline=false

vcs import src < autoware.ai.repos

rosdep update

rosdep install -y --from-paths src --ignore-src --rosdistro $ROS_DISTRO

sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu 'lsb_release –cs' main" > /etc/apt/sources.list.d/ros-latest.list'

sudo apt-key adv --keyserver 'hkp://keyserver.ubuntu.com:80' --recv-key C1CF6E31E6BADE8868B172B4F42ED6FBAB17C654

sudo apt update

sudo apt install python3-colcon-common-extensions

AUTOWARE_COMPILE_WITH_CUDA=1 colcon build --cmake-args -DCMAKE_BUILD_TYPE=Release     # cuda build

colcon build --cmake-args -DCMAKE_BUILD_TYPE=Release     #without cuda build
```

2. Install Autoware.ai

Autoware Version	Ubuntu 14.04	Ubuntu 16.04	Ubuntu 18.04
v1.14.0			x
v1.13.0			X
v1.12.0		X	X
v1.11.1		X	
v1.11.0		X	
v1.10.0		X	
v1.9.1	X	X	
v1.9.0	X	X	

Product	Ubuntu 14.04	Ubuntu 16.04	Ubuntu 18.04
ROS	Indigo	Kinetic	Melodic
Qt	4.8.6 or higher	5.2.1 or higher	5.9.5 or higher
CUDA (optional)	8.0GA(?)	9.0	10.0
FlyCapture2 (optional)			
Armadillo (optional)			

Install Process

ROS Melodic –> Eige 3.3.7 –> autoware.ai 1.12.0

Autoware.AI Wiki GitLab : https://gitlab.com/autowarefoundation/autoware.ai/autoware/-/wikis/Source-Build

If you install Autoware source build, error will occur.

Error : CUDA, eigen, 의존성, 호환성

Docker 설치 방법은 추후 수정 예정.

1-2. Install Dual boot Ubuntu 18.04.5 LTS

6. Install Chrome

```
wget -q -O - https://dl-ssl.google.com/linux/linux_signing_key.pub | sudo apt-key add -

sudo sh -c 'echo "deb [arch=amd64] http://dl.google.com/linux/chrome/deb/ stable main" >>
/etc/apt/sources.list.d/google.list'

sudo apt-get update

sudo apt-get install google-chrome-stable

sudo rm -rf /etc/apt/sources.list.d/google.list

sudo apt-get clean
```

7. Ubuntu Time Zone

```
timedatectl set-local-rtc 1

sudo gedit /etc/default/rcS

UTC=no in gedit tool
```

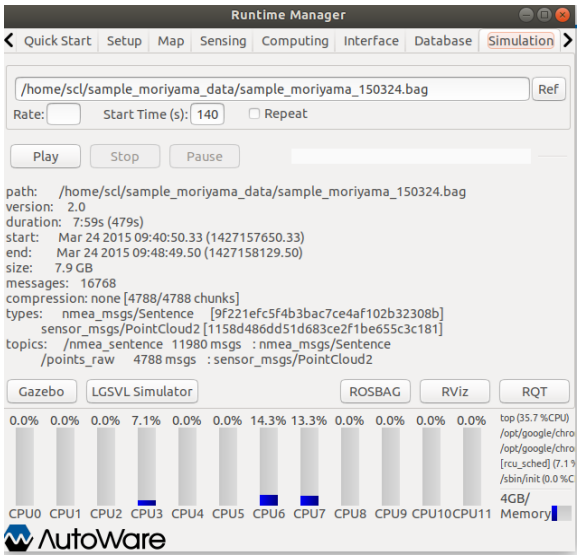
8. Boot's Loader (Default : Windows Boot Manager)

```
sudo gedit /etc/default/grub

GRUB_DEFAULT=saved in gedit tool

sudo update-grub

sudo grub-set-default 2

grub-editenv list

saved_entry=2
```

2-4. Autoware Demo

```
wget https://autoware-ai.s3.us-east-2.amazonaws.com/sample_moriyama_data.tar.gz

wget https://autoware-ai.s3.us-east-2.amazonaws.com/sample_moriyama_150324.tar.gz

cd ~

mkdir .autoware

cd .autoware

cp ~/Downloads/sample_moriyama_* .

tar zxfv sample_moriyama_150324.tar.gz

tar zxfv sample_moriyama_data.tar.gz

cd autoware.ai

source install/setup.bash

roslaunch runtime_manager runtime_manager.launch
```

2-4. Autoware Demo



Quick Start Tap
autoware.ai/src/autoware/documentation/autoware_quickstart_examples/launch/**rosbag_demo/ ***

Simulation Tap
Set the start time to 140, click Play and Pause just after it has started playing

Launch RViz through the RViz button in the bottom-right corner of the runtime manager

Ctrl + O

autoware.ai/src/autoware/documentation/autoware_quickstart_examples/launch/**rosbag_demo/default.rviz**

2-5. Trouble shooting

1. CUDA downgrade(latest ver is CUDA 11.1)

GPU support on ROS Melodic requires CUDA≤10.0,
CUDA 9.0 is not supported(GCC error)

2. runtime manager WARNING

bash: ./../../../setup.bash: 그런 파일이나 디렉터리가 없습니다

mkdir: `/home/scl/.rviz' 디렉토리를 만들 수 없습니다: 파일이 있습니다

3. Runtime manager GUI WARNING

(runtime_manager_dialog.py:12993): Gtk-WARNING **: 16:38:32.618: Negative content width -15 (allocation 1, extent
s 8x8) while allocating gadget (node entry, owner GtkEntry)

(runtime_manager_dialog.py:12993): Gtk-WARNING **: 16:38:32.632: for_size smaller than min-size (0 < 3) while mea
suring gadget (node trough, owner GtkScale)

(runtime_manager_dialog.py:12993): Gtk-CRITICAL **: 16:38:32.632: gtk_box_gadget_distribute: assertion 'size >= 0' f
ailed in GtkScale

4. Simulation ERROR

Failed connect to /tmp/autoware_proc_manager

2-5. Trouble shooting

5. dpkg frontend lock

E /var/lib/dpkg/lock-frontend 잠금파일을 얻을 수 없습니다. -open

E Unable to acquire the dpkg frontend lock

```
sudo rm /var/lib/apt/lists/lock

sudo rm /var/cache/apt/archives/lock

sudo rm /var/lib/dpkg/lock*

sudo dpkg --configure –a

sudo apt update

sudo reboot
```

6. Docker Graphics Driver

-> 도커를 설치하면 엔비디아 드라이버, 쿠다를 연결해줄 수 없다는 오류가 나타남
-> 엔비디아, 쿠다가 없으면 colcon build가 안됨.
-> 도커는 나중에 다시 정리

VLP-16

1. Features
2. Data packets

1. CAN

샤시(Chassis)				
엔진	동력전달장치	조향장치	제동장치	현가장치
엔진 본체	클러치	조향 핸들	상용 브레이크	섀시 스프링
냉각 장치	변속기	조향 기어	주차 브레이크	쇼크 옵서버
윤활 장치	추진축	링크 기구	보조 브레이크	스테빌라이서
과급 장치	차동기	앞 바퀴		
흡배기 장치	차축			
연료 장치	바퀴			

Chassis CAN(샤시캔) :
차량의 클러스터(CLU),
YRS(Yaw Rate Sensor)엔진,
미션, ABS(Anti-lock Breaking System),
ECU(Engine Control Unit),
TCU(Transmission Control Unit)와
같은 고속으로 데이터를 전송하는 용도로 사용되며 통신 속도는 500kbps

1. CAN

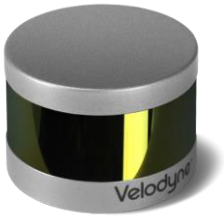
The main features of the VN1630A interface are:

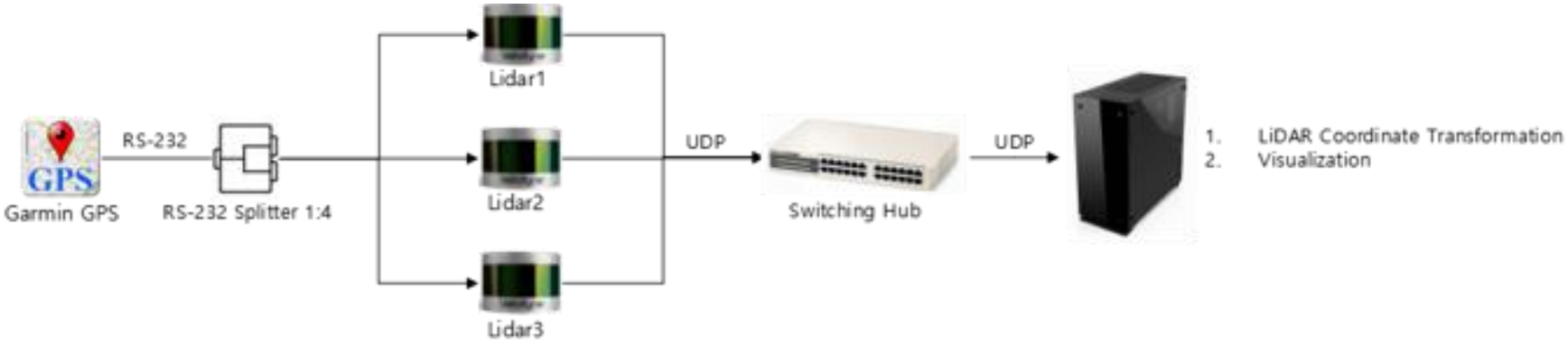
- 2x CAN high-speed 1051cap transceiver (capacitively decoupled)
- 2x additional plug-in location for CAN-/LINpiggies
- Fifth channel for dedicated digital-analog input/output tasks
- Five LEDs indicating bus activities and status
- Software sync
- Hardware sync (via SYNCcableXL)

2-1. Features of VLP-16

Channel	16 channels
Horizontal Field of View(FOV)	360°
Rotational speed	5-20 rotations per second
Vertical Field of View(FOV)	30°
Operating rage	up to 100 meters
Angular resolution(vertical)	2°
Angular resolution(horizontal)	0.1° - 0.4°

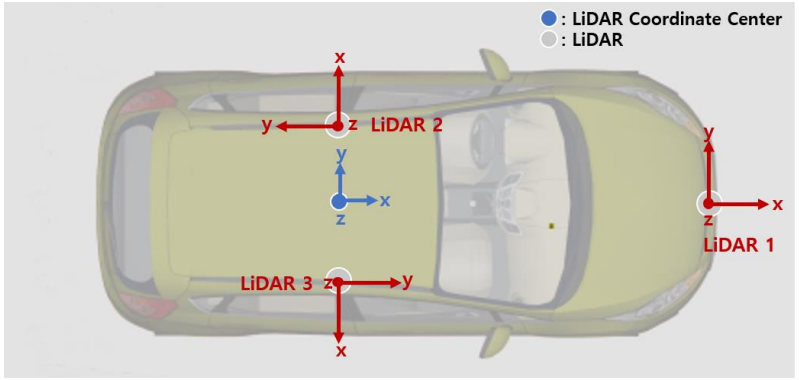
Velodyne LiDAR Puck

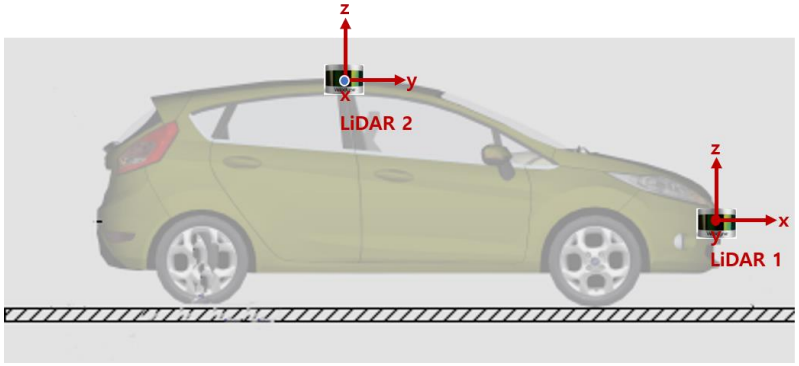




2-1. Features of VLP-16

IP address
Lidar1(Front) : 192.168.1.109
Lidar2(Left) : 192.168.1.110
Lidar3(Right) : 192.168.1.201

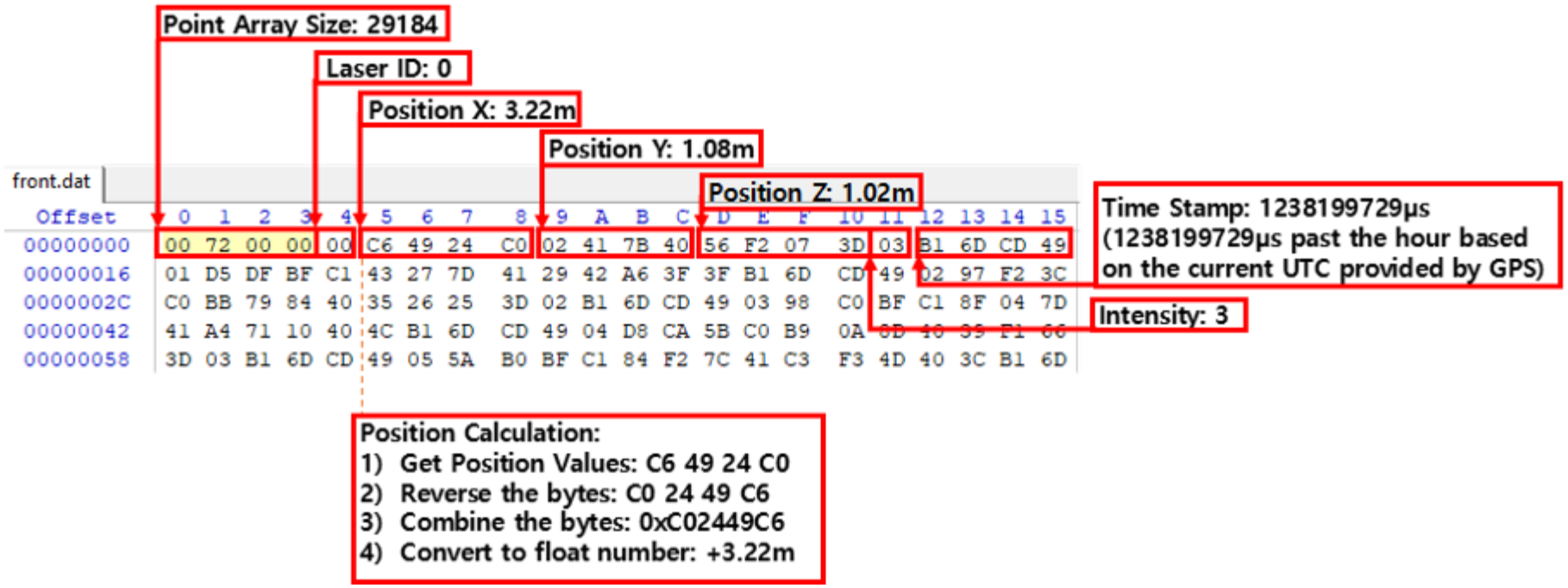




Top view Lidar offset from LiDAR coordinate center

	Lidar1 (Front)	Lidar2 (Left)	Lidar3 (Right)
X(mm)	0	-500	500
Y(mm)	2500	0	0
Z(mm)	820	1.77	1.77
Roll(º)	0	0	0
Pitch(º)	0	13	13
Yaw(º)	0	-92	92

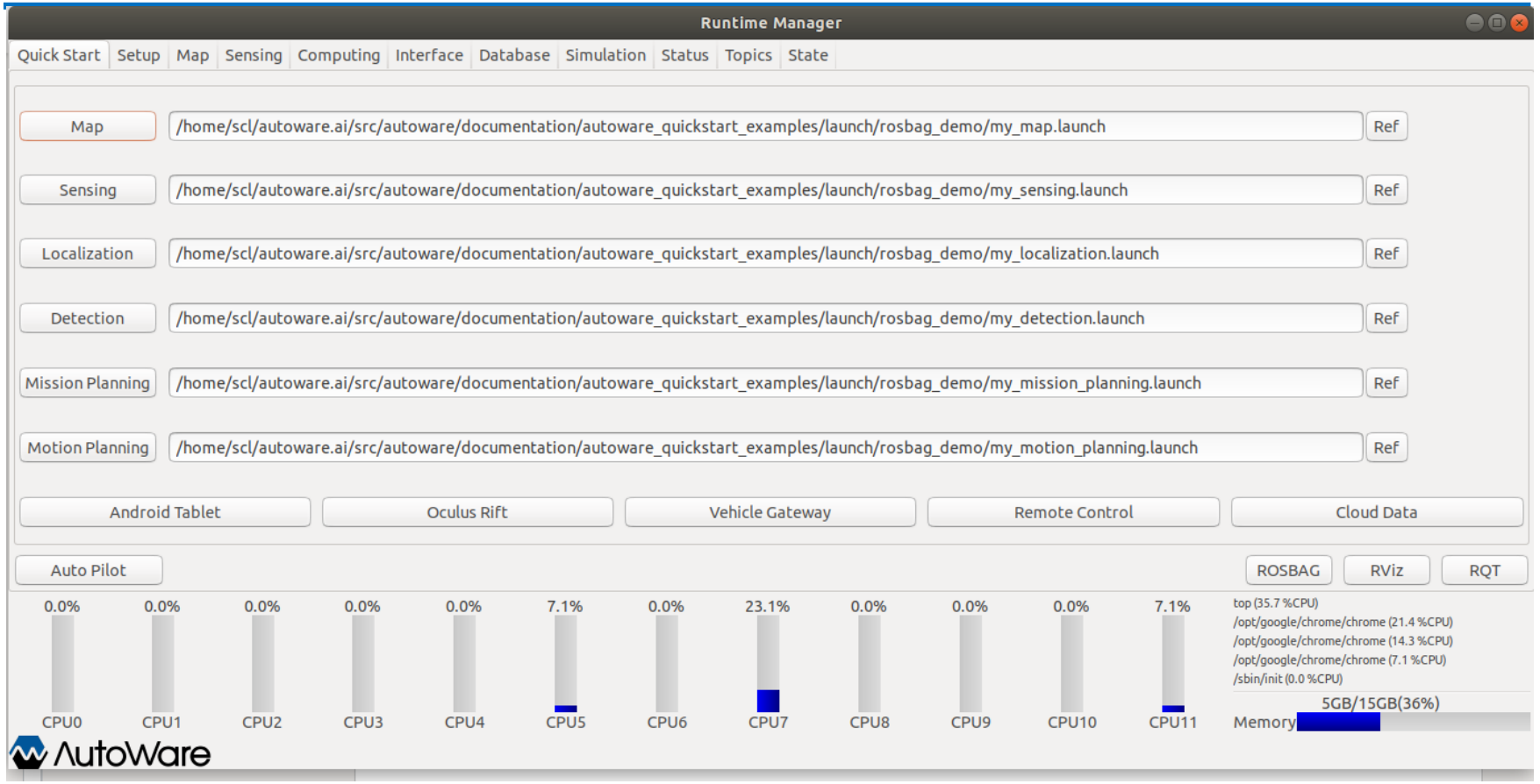
2-2. Packet


Point Array Size: 29184
Laser ID: 0
Position X: 3.22m
Position Y: 1.08m
Position Z: 1.02m
front.dat
Offset 0 1 2 3 4 5 6 7 8 9 A B C D E F 10 11 12 13 14 15
00000000 00 72 00 00 00 C6 49 24 C0 02 41 7B 40 56 F2 07 3D 03 B1 6D CD 49
00000016 01 D5 DF BF C1 43 27 7D 41 29 42 A6 3F 3F B1 6D CD 49 02 97 F2 3C
0000002C C0 BB 79 84 40 35 26 25 3D 02 B1 6D CD 49 03 98 C0 BF C1 8F 04 7D
00000042 41 A4 71 10 40 4C B1 6D CD 49 04 D8 CA 5B C0 B9 0A
00000058 3D 03 B1 6D CD 49 05 5A B0 BF C1 84 F2 7C 41 C3 F3 4D 40 3C B1 6D
Time Stamp: 1238199729µs
(1238199729µs past the hour based on the current UTC provided by GPS)
Intensity: 3
Position Calculation:
1) Get Position Values: C6 49 24 C0
2) Reverse the bytes: C0 24 49 C6
3) Combine the bytes: 0xC02449C6
4) Convert to float number: +3.22m

Program Manual

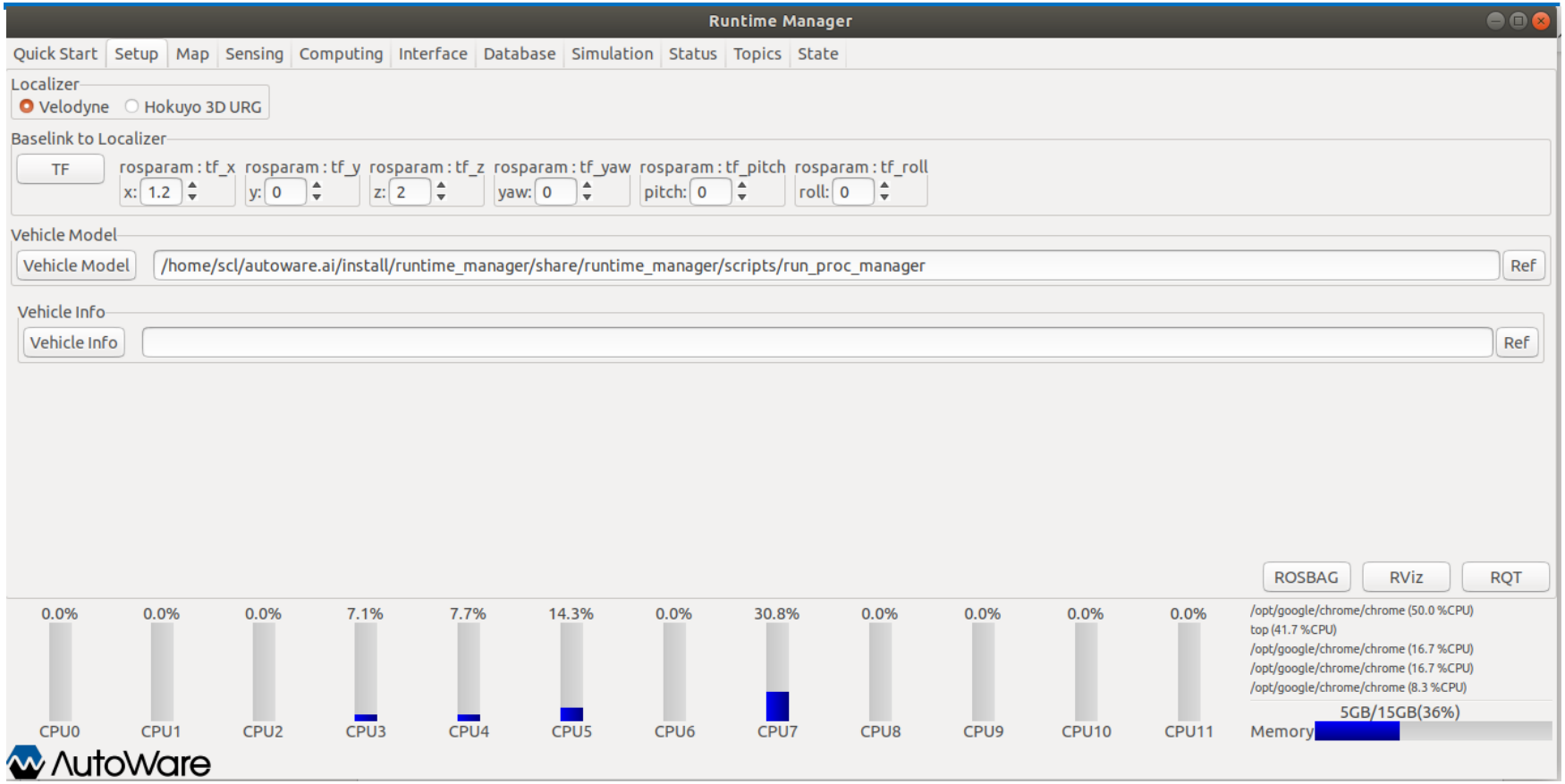
1. Runtime Manager
2. Multi Lidar Calibrator

1. Runtime Manager



Map : TF, Point Cloud, Vector Map
Sensing : calibration file path, HDL-32e
Localization : setting path parameter, Setup, points downsampler, nmea2tfpose, ndt_matching

1. Runtime Manager

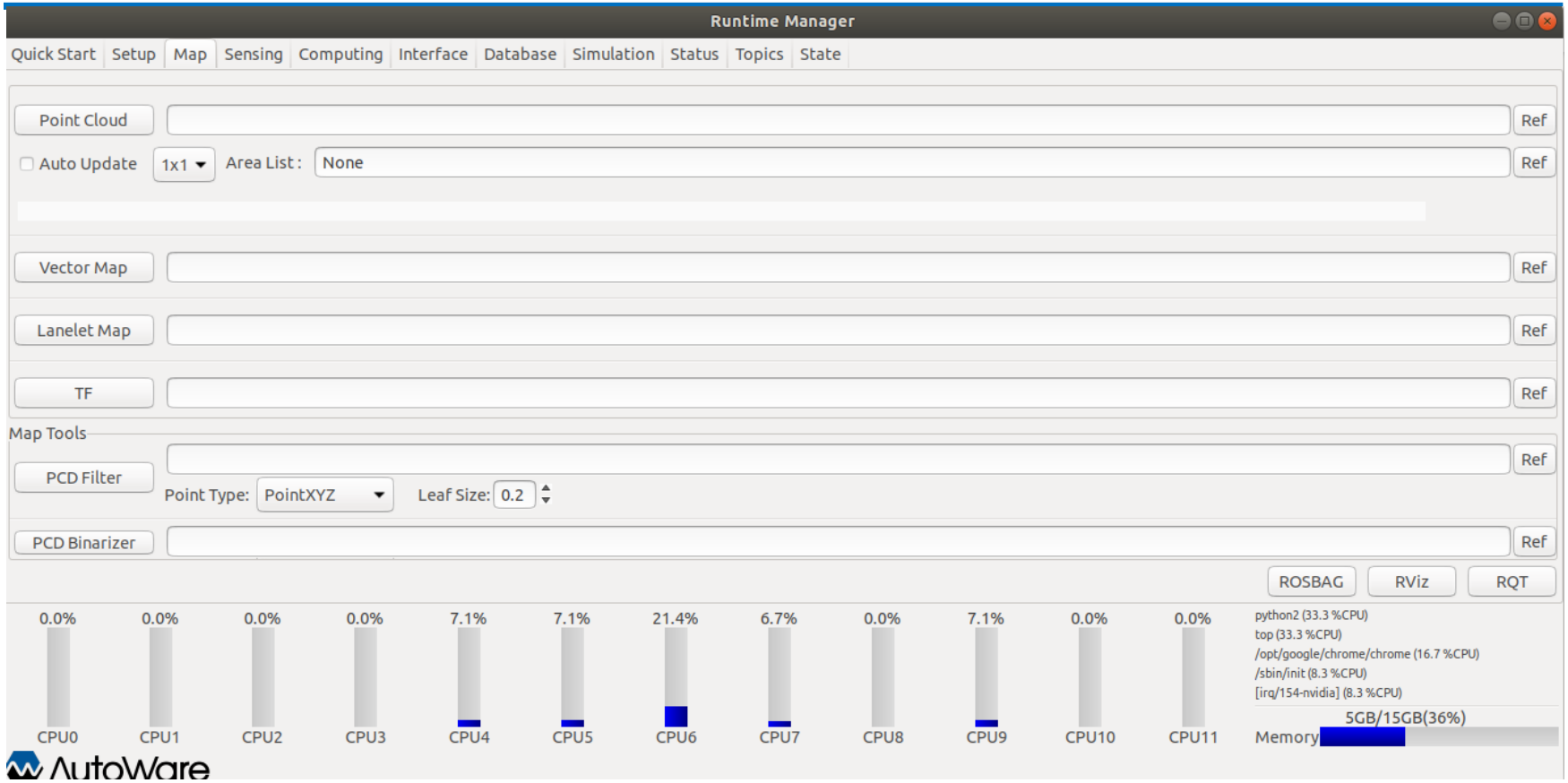


TF : base_link → Velodyne position(velodyne)

x, y, z, yaw, pitch, roll : Enter the relative position of velodyne to base_link

Vehicle Model : *Autoware/ros/src/.config/model/default.urdf*

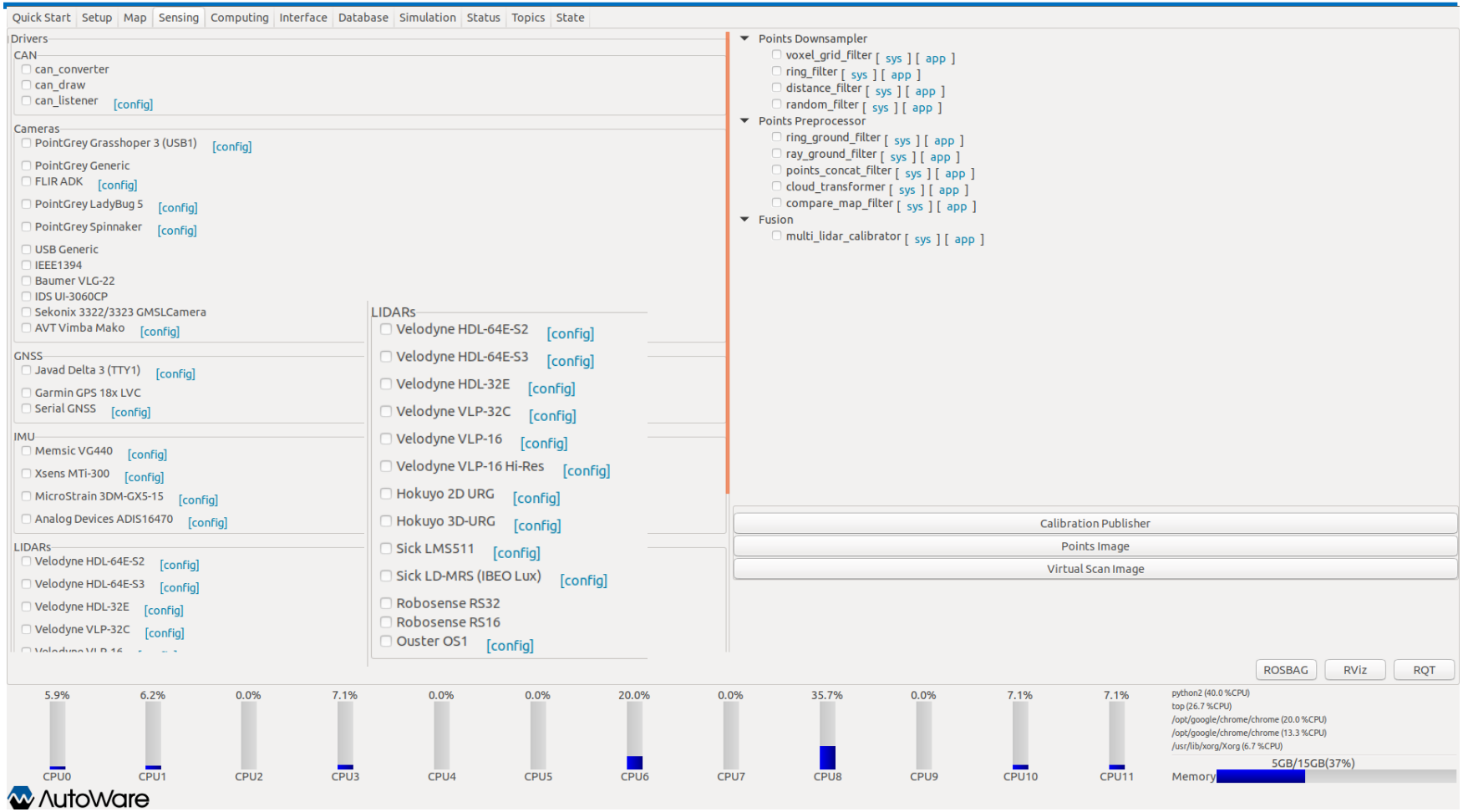
1. Runtime Manager



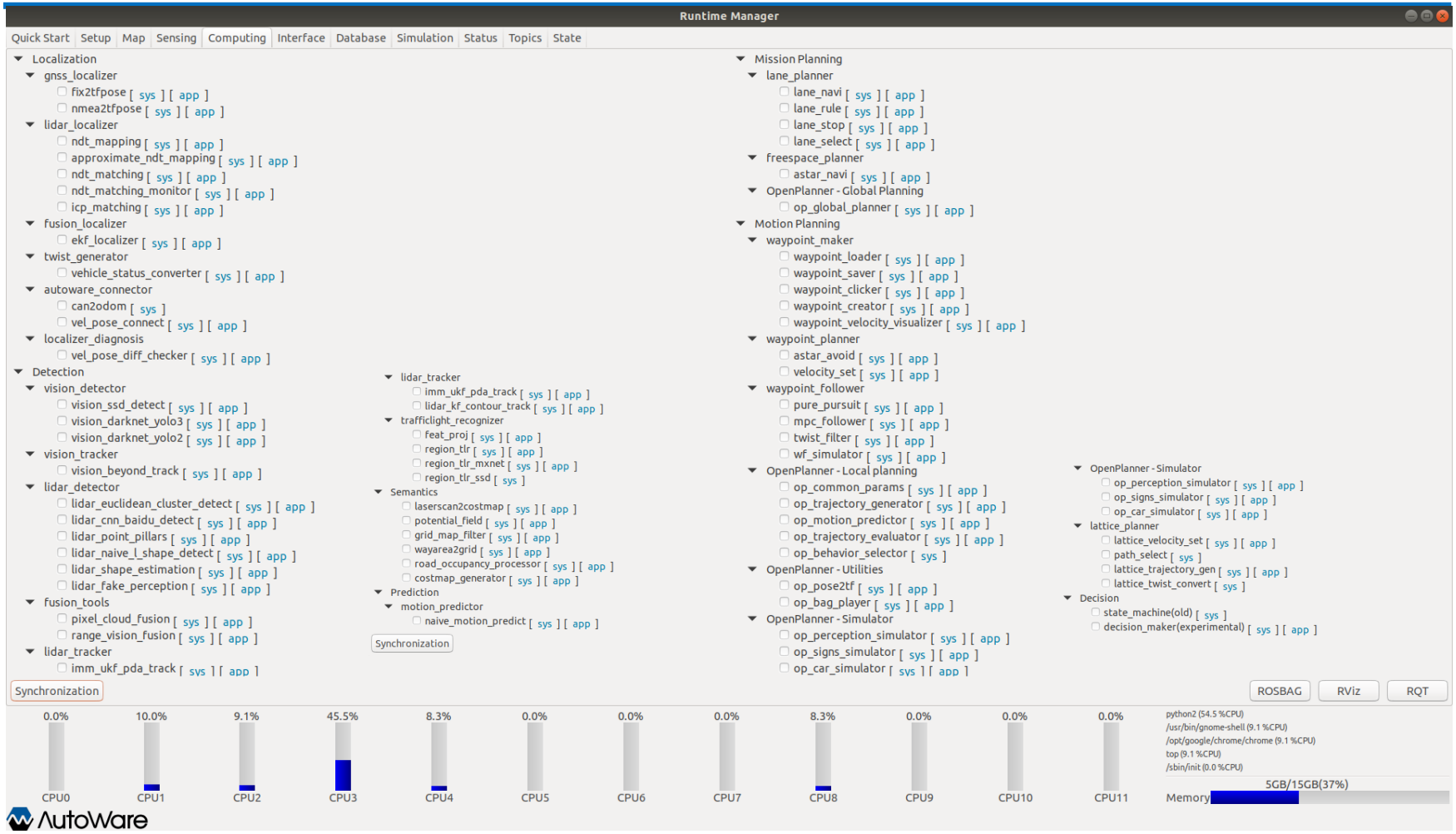
TF : ~/.autoware/data/tf/tf.launch

나머지는 정보가 없음 추후 업데이트 예정

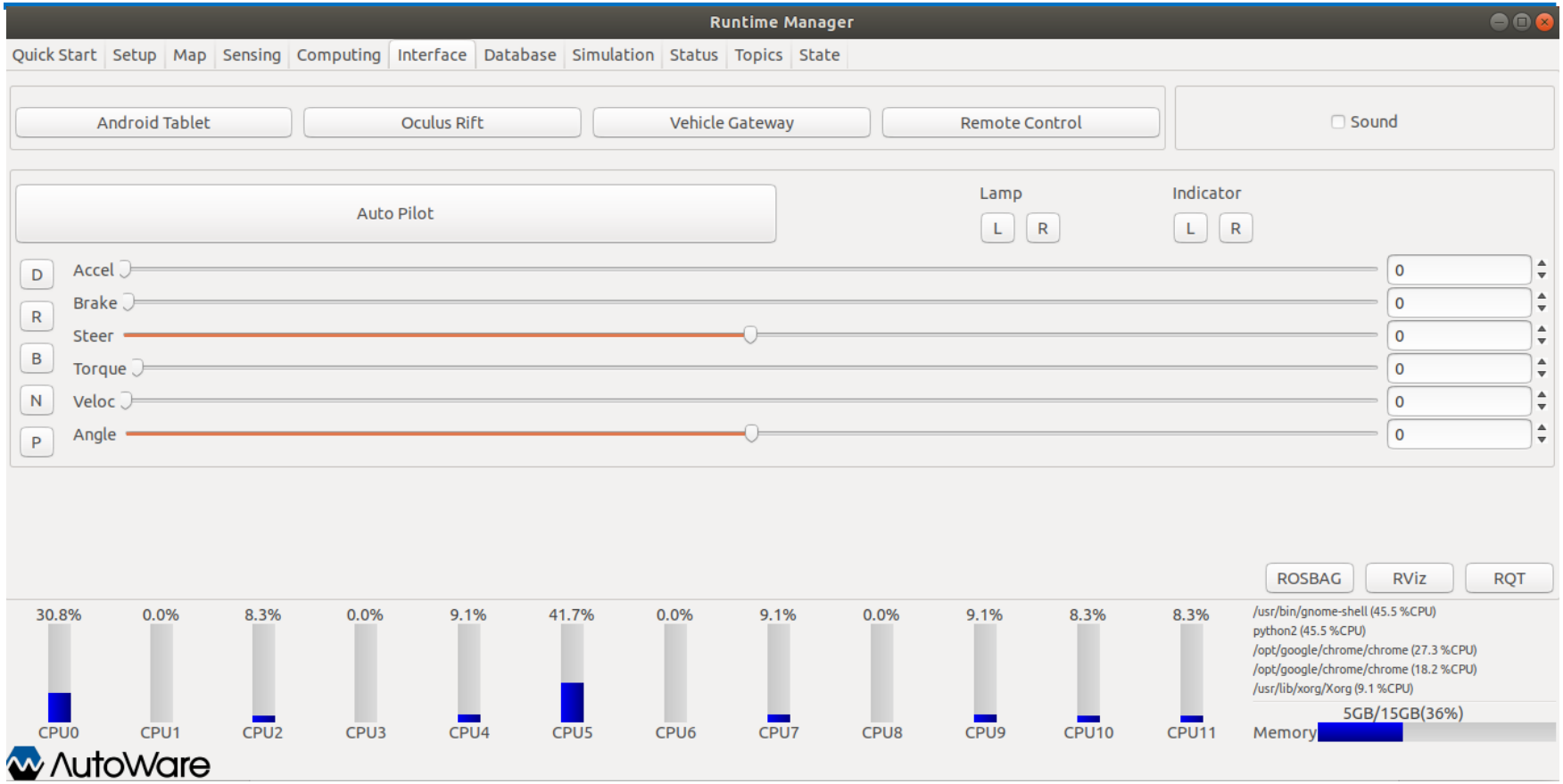
1. Runtime Manager



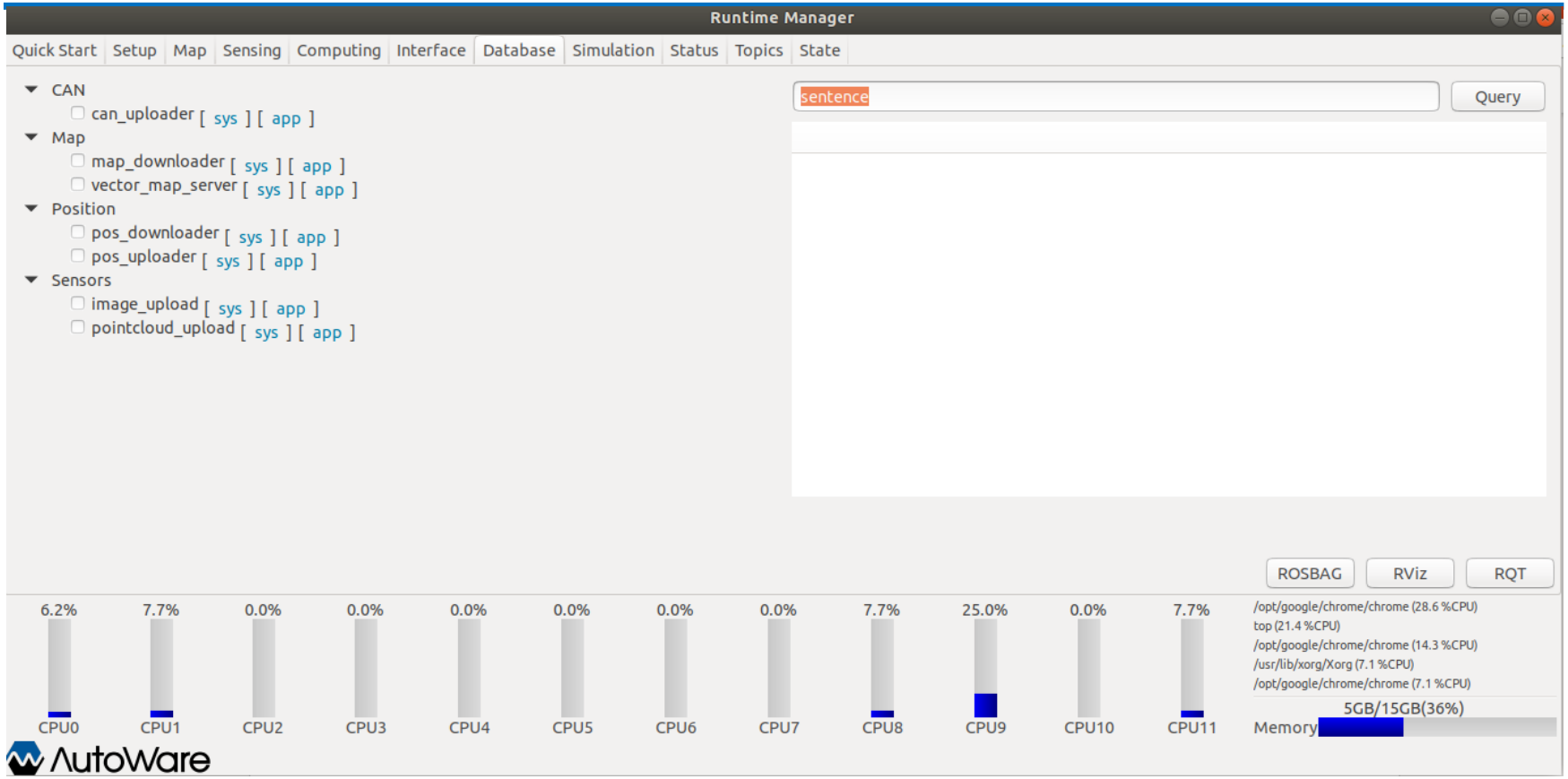
1. Runtime Manager



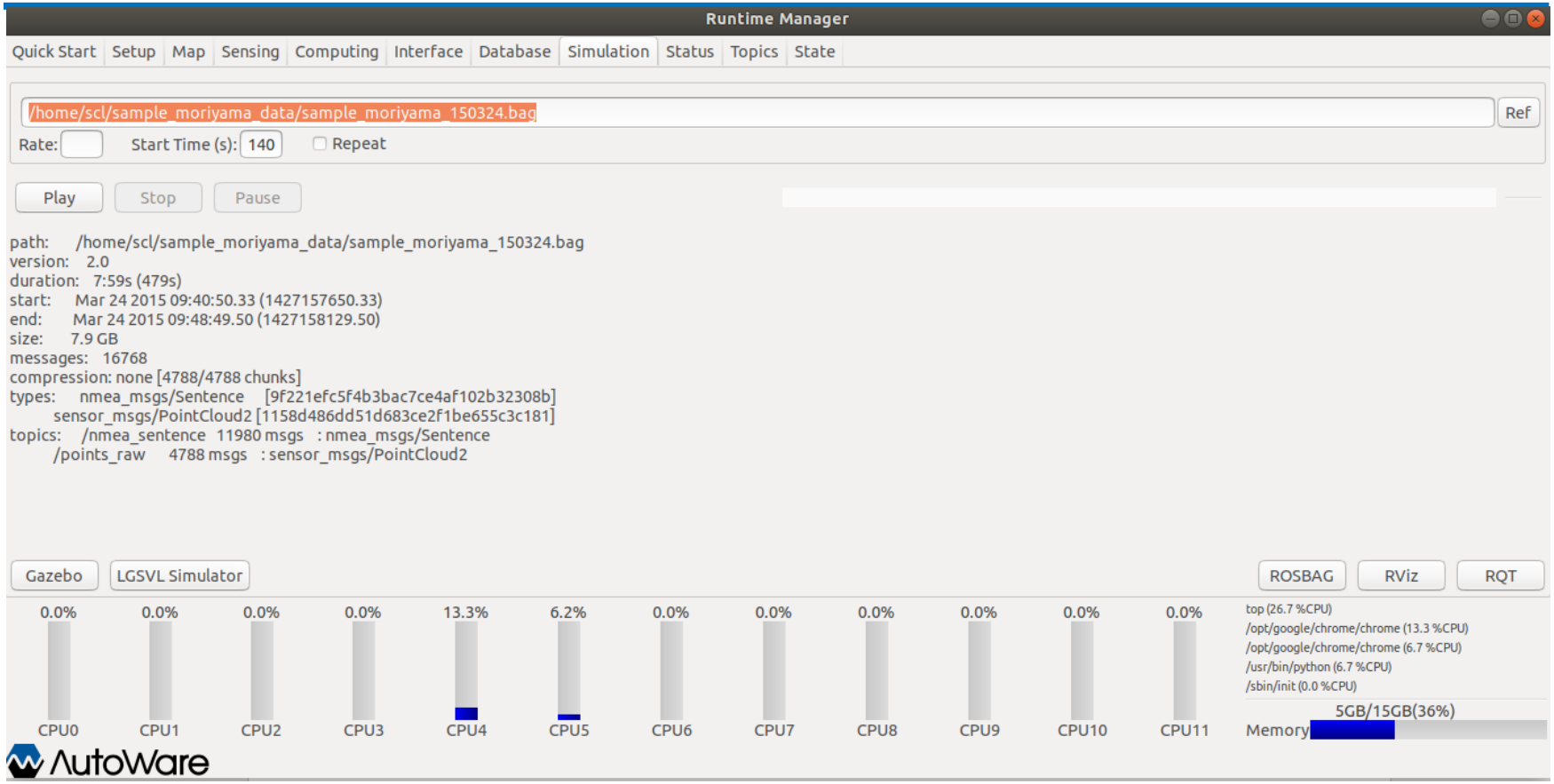
1. Runtime Manager



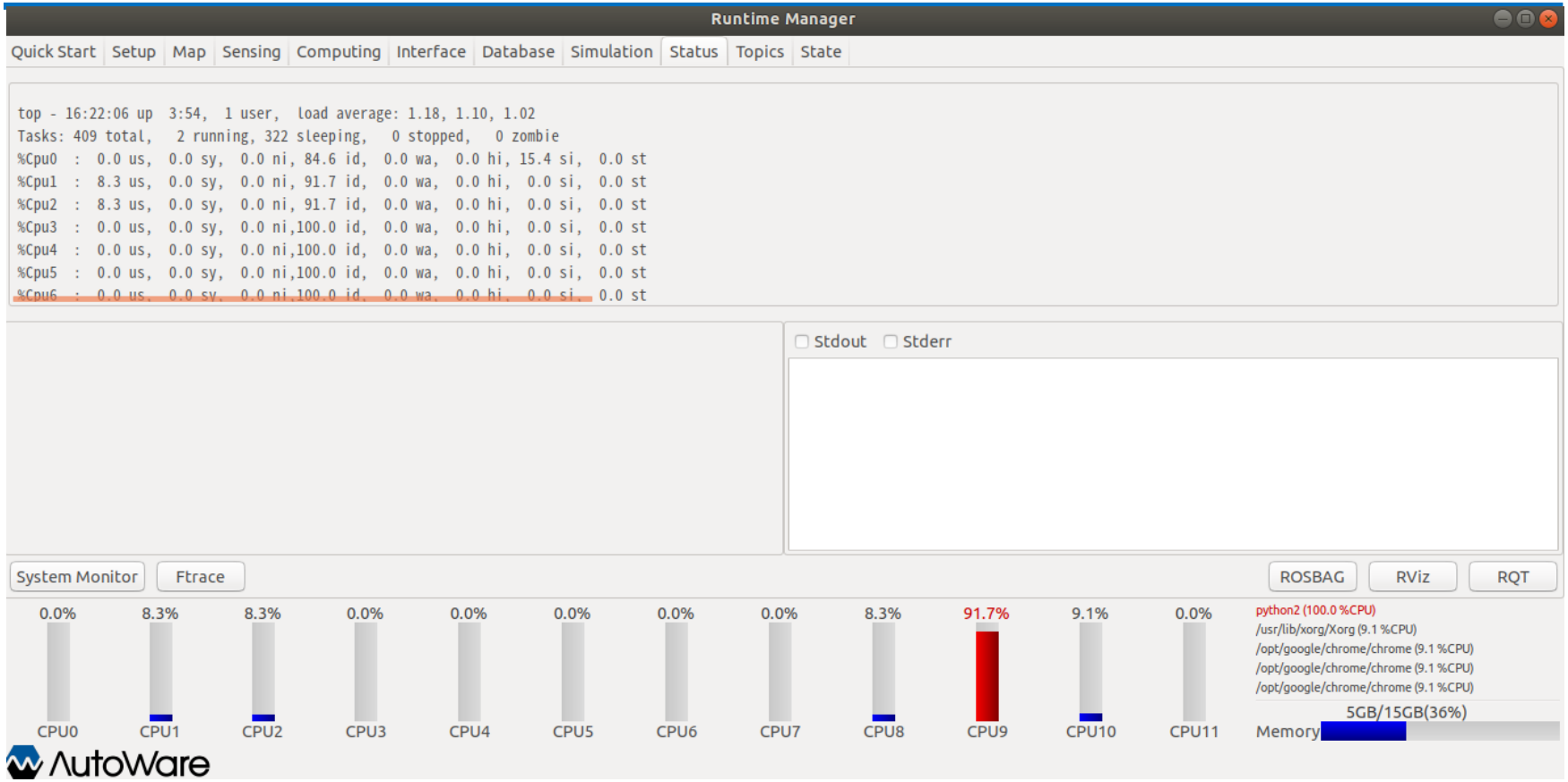
1. Runtime Manager



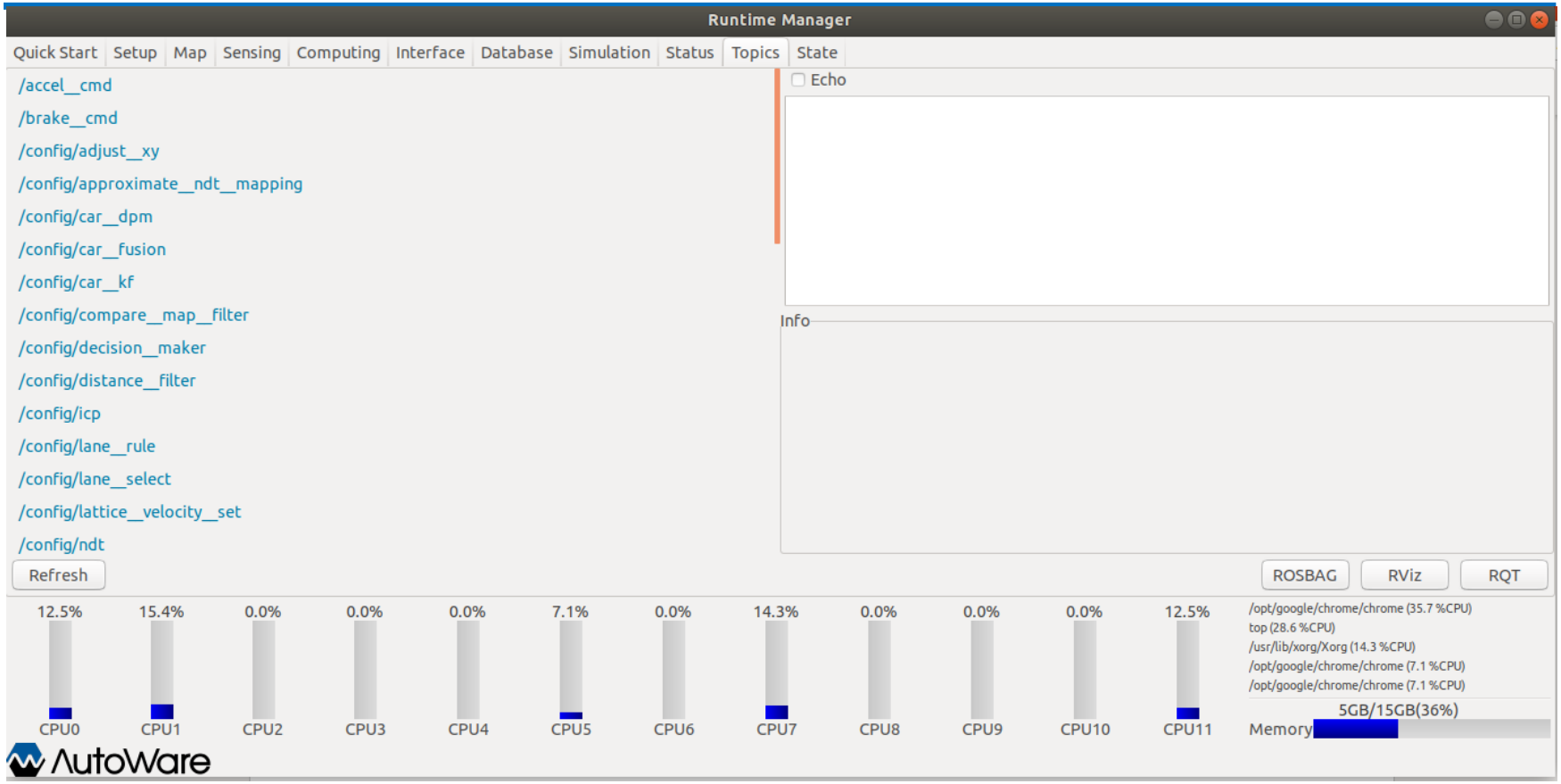
1. Runtime Manager



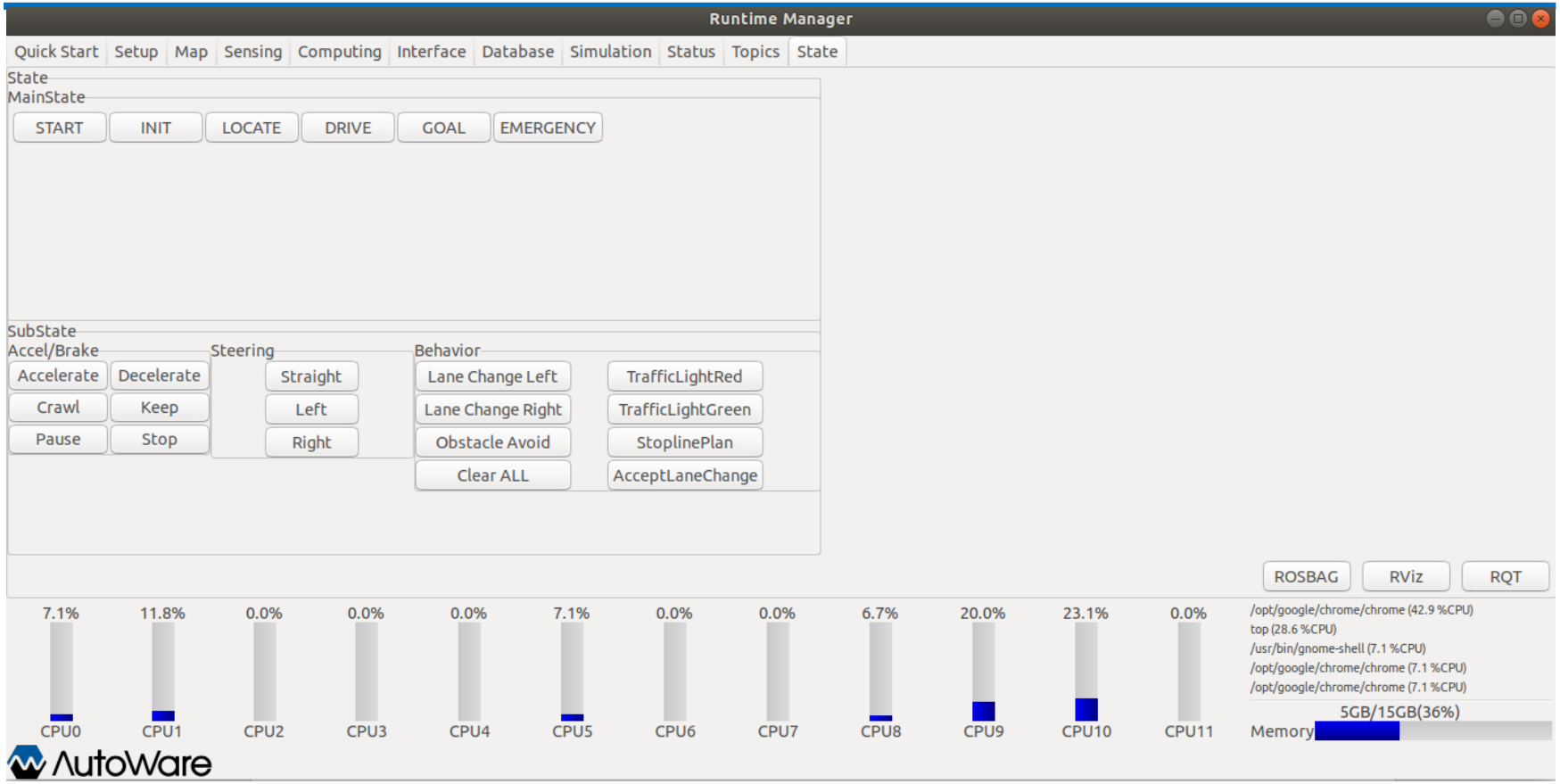
1. Runtime Manager



1. Runtime Manager



1. Runtime Manager



2. NDT(Normal Distribution Transform)

1. NDT mapping (Map generation)

Transform the LiDAR point cloud into a piecewise continuous and differentiable probability density (NDT).

The probability density contains a set of the normal distributions where each point in point cloud is assigned to a voxel.

A voxel is a 3D lattice cube to which points are assigned depending upon their coordinate value.

The Point cloud is divided into k ND voxels clouds and are combined together , and also the voxel grid filter is used to decrease the computation cost and to reduce the noise from the 3D map

2. NDT matching (Localization)

A search problem where we have to find a transform that maximizes NDT sum to match the different point clouds, a variety of minimization functions can be used for this. Newton nonlinear optimizer is used to find the best 6-DOF pose.

3. Multi Lidar Calibrator

Q . SLAM in AUTOWARE using 3 VLP16

A. Unfortunately, if Autoware.AI does not currently support this feature we cannot provide support for it. Additionally, Autoware.AI has stopped accepting new features and is now in "maintenance mode" (only accepting bug fixes and clean-ups). See this discourse post for more details.

End-of-Life dates for Autoware.AI

■ Autoware

gbiggs Regular — 1 Apr 21

As most Autoware users now know, the Autoware Foundation is working on the next generation of Autoware, known as Autoware.Auto 20.

In order to focus our development resources on Autoware.Auto, the Autoware Foundation's Technical Steering Committee has taken a decision on the end-of-life date for Autoware.AI (the current generation of Autoware).

The dates have been set as follows:

- **From now**: Only minor releases will be made (1.14, 1.15, 1.16, …) with the number of releases to be determined by the maintainers based on having something to release.
  - This means that API-breaking features cannot be released.
- **End of 2020**: Autoware.AI will enter maintenance mode. This means that:
  - No new features will be added
  - Bug fixes will be made if necessary (e.g. critical bugs, safety-relevant bugs)
  - Only patch releases (1.15.1, 1.15.2, etc.) will be made
- **End of 2022**: End of life. No releases will be made and no merge requests accepted. The source will still be available if someone wishes to fork and maintain it themselves, but the Autoware Foundation will not commit any resources to maintaining Autoware.AI beyond this date.

We currently expect to reach feature parity between Autoware.Auto and Autoware.AI by the end of 2020. Users of Autoware.AI are encouraged to begin planning their transition to Autoware.Auto this year so that they can be fully transitioned by the end of 2022.

We also encourage any current and future contributors to consider making their contributions to Autoware.Auto rather than Autoware.AI.

3. Multi Lidar Calibrator

This package allows to obtain the extrinsic calibration between two PointClouds with the help of the NDT algorithm.

The **multi_lidar_calibrator** node receives two PointCloud2 messages (parent and child), and an initialization pose.
If possible, the transformation required to transform the child to the parent point cloud is calculated, and output to the terminal.

How to launch
1. You'll need to provide an initial guess, otherwise the transformation won't converge.
2. In a sourced terminal:

Using rosrun
```
rosrun multi_lidar_calibrator multi_lidar_calibrator _points_child_src:=/ lidar_child/points_raw _points_parent_src:=/lidar_parent/points_raw _x:=0.0 _y:=0.0 _z:=0.0 _roll:=0.0 _pitch:=0.0 _yaw:=0.0
```

Using roslaunch
```
roslaunch multi_lidar_calibrator multi_lidar_calibrator points_child_src:=/ lidar_child/points_raw points_parent_src:=/lidar_parent/points_raw x:=0.0 y:=0.0 z:=0.0 roll:=0.0 pitch:=0.0 yaw:=0.0
```

1. Play a rosbag with both lidar data /lidar_child/points_raw and /lidar_parent/points_raw
2. The resulting transformation will be shown in the terminal as shown in the Output section.
3. Open RViz and set the fixed frame to the Parent
4. Add both point cloud /lidar_parent/points_raw and /points_calibrated
5. If the algorithm converged, both PointClouds will be shown in rviz.

Input topics

Output
1. Child Point cloud transformed to the Parent frame and published in /points_calibrated.

2. Output in the terminal showing the X,Y,Z,Yaw,Pitch,Roll transformation between child and parent.
These values can be used later with the static_transform_publisher.

3. Multi Lidar Calibrator

Error list

Runtime manager – multi lidar calibrator

['roslaunch', 'multi_lidar_calibrator', 'multi_lidar_calibrator.launch', 'points_parent_src:=lidar0/points_raw', 'points_child_src:=lidar1/points_raw', 'ndt_epsilon:=0.01', 'ndt_step_size:=0.1', 'ndt_resolution:=1', 'ndt_iterations:=400', 'x:=0', 'y:=0', 'z:=0', 'roll:=0', 'pitch:=0', 'yaw:=0']
pid=12463
sched policy=OTHER prio=0
Failed connect to /tmp/autoware_proc_manager

Terminal

rosrun multi_lidar_calibrator multi_lidar_calibrator _points_child_src:=/lidar_child/points_raw _points_parent_src:=/lidar_parent/points_raw _x:=0.0 _y:=0.0 _z:=0.0 _roll:=0.0 _pitch:=0.0 _yaw:=0.0

[INFO] [1606969888.585903549]: [multi_lidar_calibrator] points_parent_src: /lidar_parent/points_raw
[INFO] [1606969888.586813307]: [multi_lidar_calibrator] points_child_src: /lidar_child/points_raw
[INFO] [1606969888.587108717]: [multi_lidar_calibrator] ndt_epsilon: 0.10
[INFO] [1606969888.587329276]: [multi_lidar_calibrator] voxel_size: 0.01
[INFO] [1606969888.587565770]: [multi_lidar_calibrator] ndt_step_size: 0.10
[INFO] [1606969888.587790699]: [multi_lidar_calibrator] ndt_resolution: 1.00
[INFO] [1606969888.587967571]: [multi_lidar_calibrator] ndt_iterations: 400
[INFO] [1606969888.589968550]: [multi_lidar_calibrator] Initialization_Transform **x: 0.00 y: 0.00 z: 0.00 roll: 0.00 pitch: 0.00 yaw: 0.00**
[INFO] [1606969888.590926706]: [multi_lidar_calibrator] Subscribing to... /lidar_parent/points_raw
[INFO] [1606969888.591959543]: [multi_lidar_calibrator] Subscribing to... /lidar_child/points_raw
[INFO] [1606969888.592214832]: [multi_lidar_calibrator] Publishing PointCloud to... /points_calibrated
[INFO] [1606969888.592253502]: [multi_lidar_calibrator] Ready. Waiting for data...

3. Multi Lidar Calibrator

static_transform_publisher

static_transform_publisher x y z yaw pitch roll frame_id child_frame_id period_in_ms

Publish a static coordinate transform to tf using an x/y/z offset in meters and yaw/pitch/roll in radians.

The period, in milliseconds, specifies how often to send a transform. 100ms (10hz) is a good value.

static_transform_publisher is designed both as a command-line tool for manual use, as well as for use within roslaunch files for setting sta
tic transforms.
For example:

```
<launch>
  <node pkg="tf" type="static_transform_publisher" name="link1_broadcaster" args="1 0 0 0 0 0 1 link1_parent link1 100" />
  </launch>
```

3. Multi Lidar Calibrator

How to use two VLP16(velodyne) with just one computer at a same time
https://github.com/ros-drivers/velodyne/issues/108

Evaluation of multiple lidar placement on a self-driving car in Autoware
https://iseauto.ttu.ee/wp-content/uploads/2018/06/Mihkel_Vali_Multiple_lidar_analysis.pdf

Setting up and calibrating multiple LiDAR sensors
https://wowelec.wordpress.com/2019/06/18/setting-up-and-calibrating-multiple-lidar-sensors/

Welcome to Autoware's documentation!
https://autoware.readthedocs.io/en/feature-documentation_rtd/index.html

https://github.com/AbangLZU/multi_lidar_calibration/tree/master/include

https://github.com/themathgeek13

https://github.com/JeongJae0815/Multi_Velodyne