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ZERO

Robotics Development Framework, Workspace & Workflow

https://tinyurl.com/5b5s9ham

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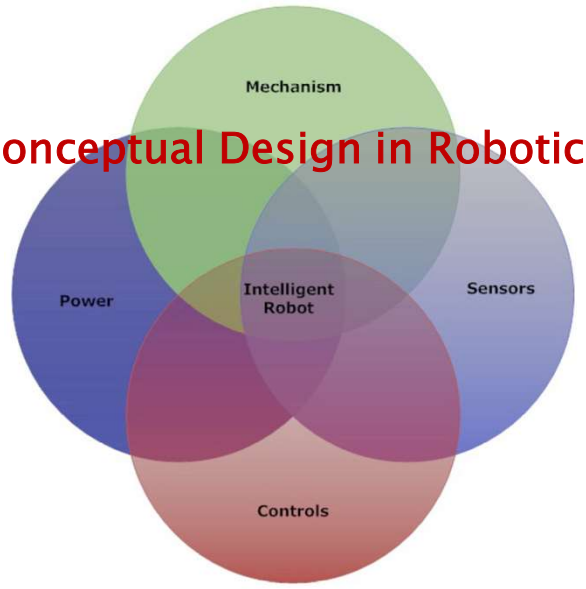
Conceptual Design in Robotics



2

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The requirements for a robot that collects table tennis balls:

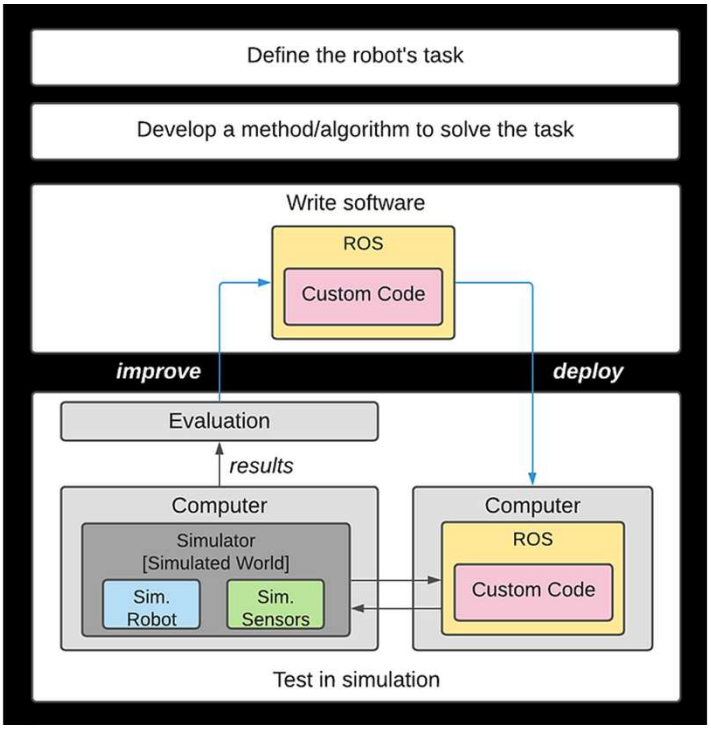
(a) It should be applicable to the setting of general table tennis courts, with a size of 8 m × 16 m;

(b) It can collect at least 30 table tennis balls within a reasonable time as well as show the number of table tennis balls collected;

(c) When no one is inside the table tennis court, it can be activated to start the process for collecting table tennis balls automatically within the designated area;

(d) There should a basket to hold the collected table tennis balls and allow players to take out the balls easily to continue practising.

3



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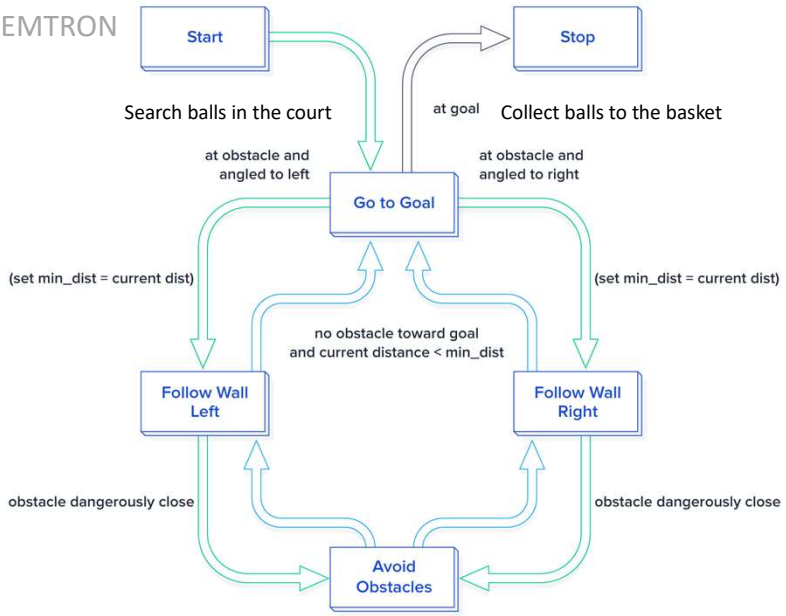

Define robot's tasks

5

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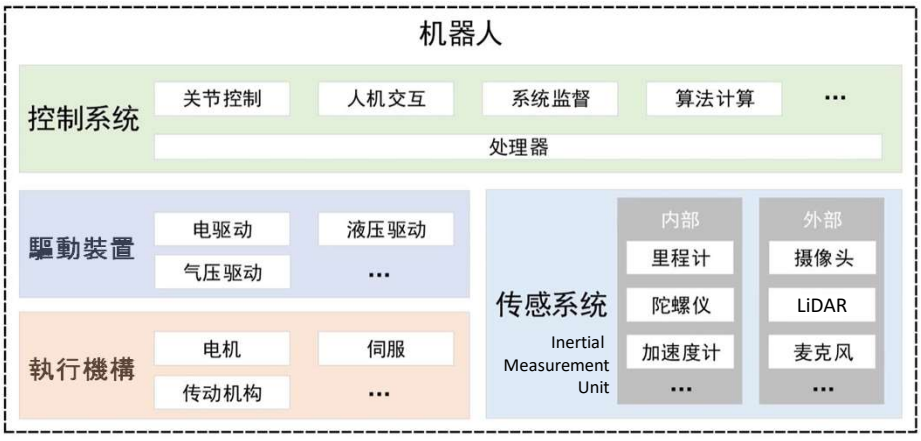

Define robot's functions & behaviour

6

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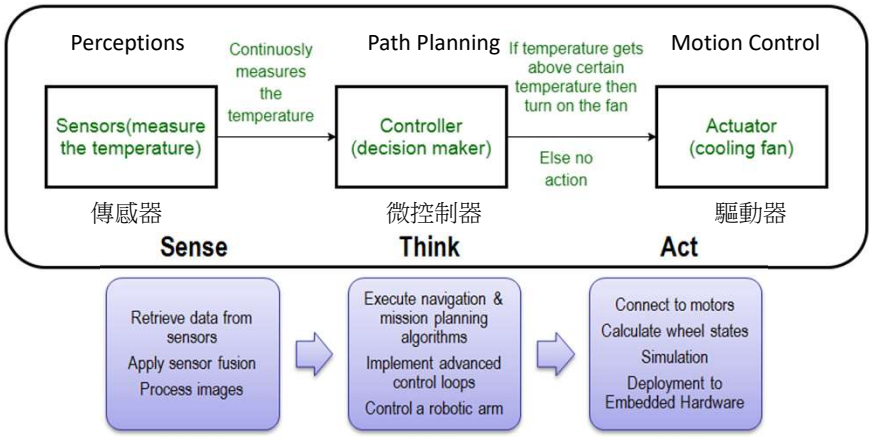
NVIDIA JETSON Raspberry pi



Robotics in physical computing

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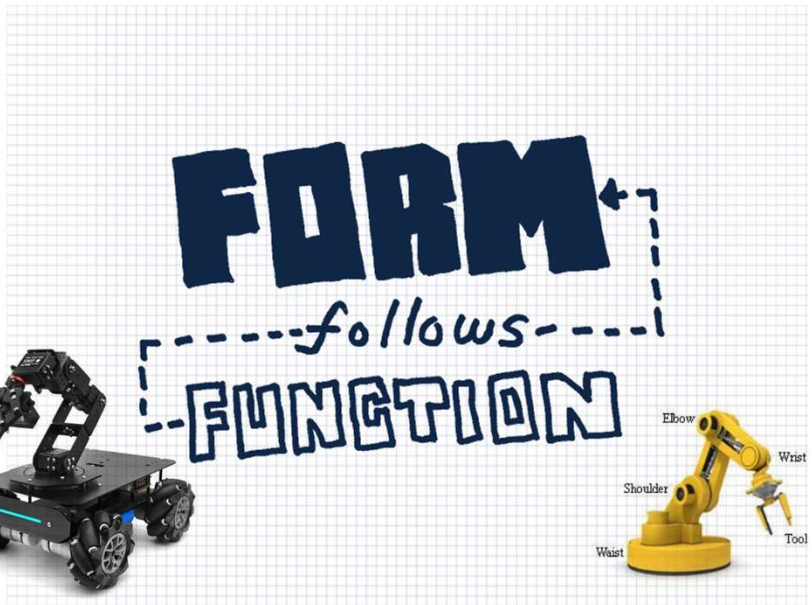

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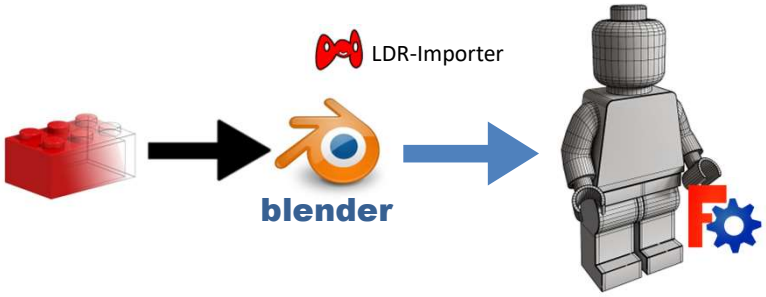
LDraw.org
Centralised LDraw Resources



Parametric modeling

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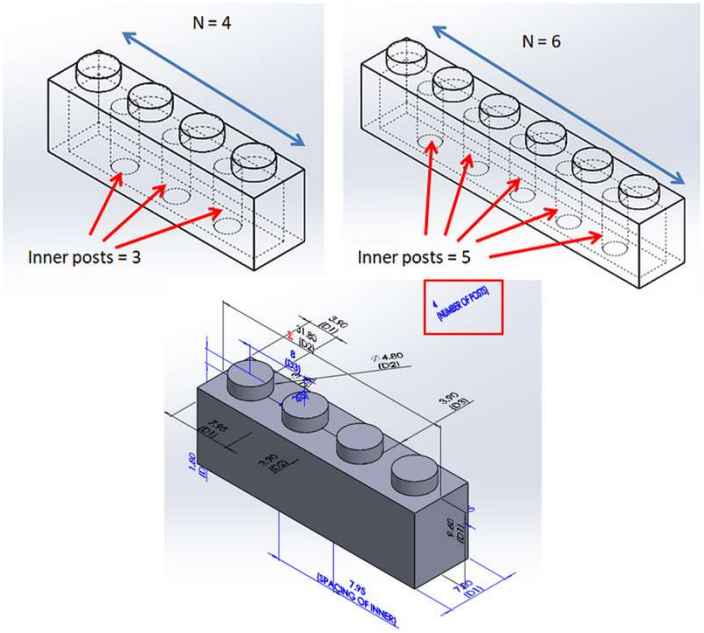

Parametric modeling

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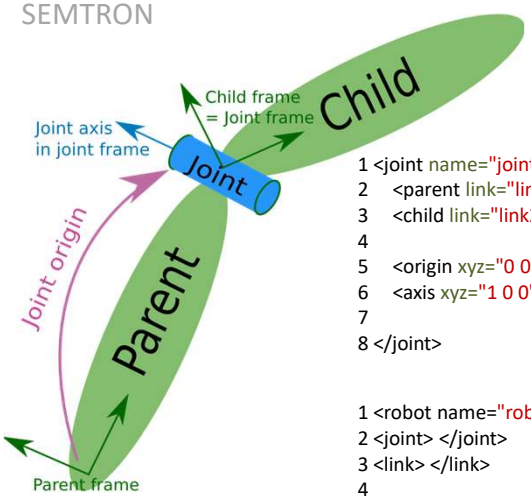



```
1 <joint name="joint_name" type="continuous">
2    <parent link="link1"/>
3    <child link="link2"/>
4
5    <origin xyz="0 0 0" rpy="0 0 0"/>
6    <axis xyz="1 0 0"/>
7
8 </joint>
```

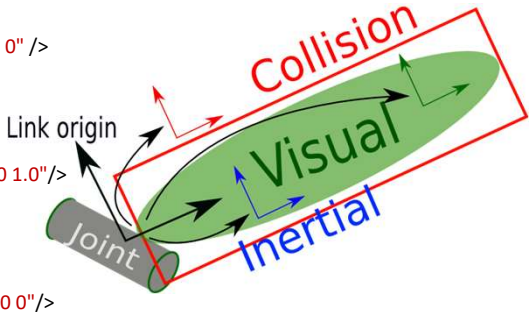
```
1 <robot name="robot_name">
2 <joint> </joint>
3 <link> </link>
4
5 <link> </link>
6 <joint> </joint>
7 </robot>
```

URDF modeling


```
1 <link name="link_name">
2  <inertial>
3     <origin xyz="0 0 0.5" rpy="0 0 0“ />
4     <mass value="1“ />
5     <inertia ixx="100" ixy="0" ixz="0"
            iyy="100" iyz="0"
            izz="100" />
6  </inertial>
7
8  <visual>
9     <origin xyz="0 0 0" rpy="0 0 0" />
10    <geometry>
11          <box size="1 1 1" />
12    </geometry>
13    <material name="Cyan">
14          <color rgba="0 1.0 1.0 1.0"/>
15    </material>
16  </visual>
17
18  <collision>
19     <origin xyz="0 0 0" rpy="0 0 0"/>
20     <geometry>
21          <cylinder radius="1" length="0.5"/>
22     </geometry>
23  </collision>
24 </link>
```

$$\begin{pmatrix} \mathbf{ixx} & \mathbf{ixy} & \mathbf{ixz} \\ ixy & \mathbf{iyy} & \mathbf{iyz} \\ ixz & izy & \mathbf{izz} \end{pmatrix}$$

Inertia Tensor



URDF modeling

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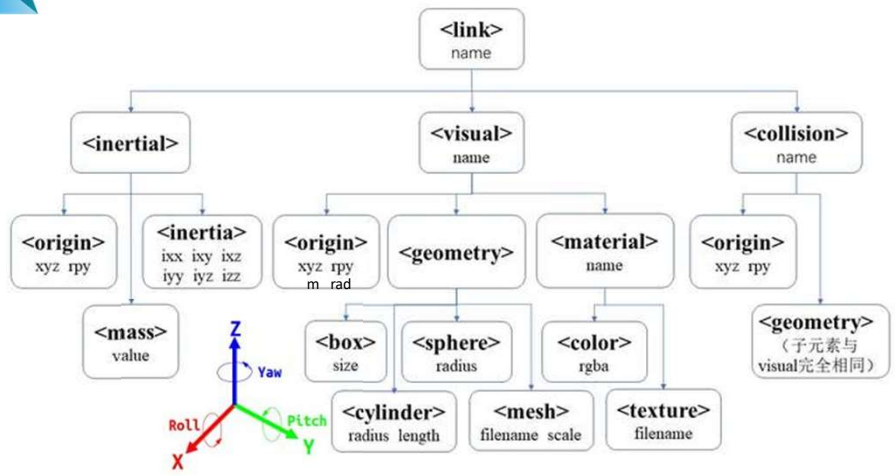

URDF modeling

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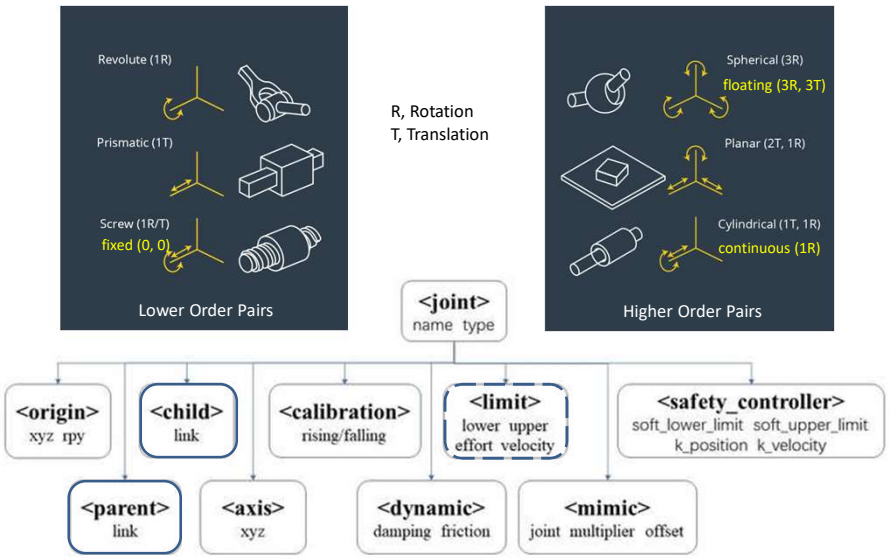

URDF modeling

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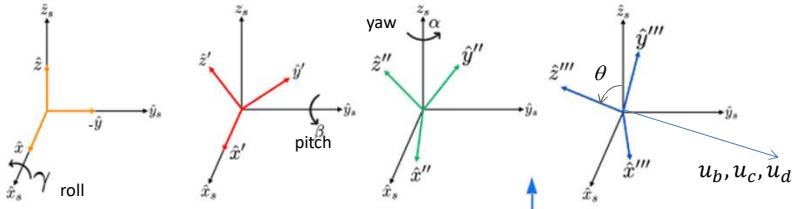
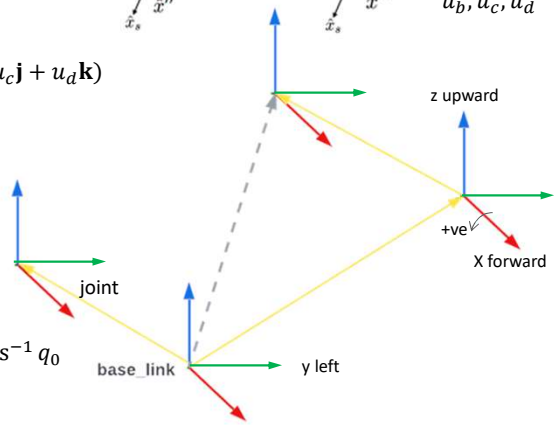


$$q = \cos\left(\frac{\theta}{2}\right) + \sin\left(\frac{\theta}{2}\right)(u_b\mathbf{i} + u_c\mathbf{j} + u_d\mathbf{k})$$

where θ is the angle of rotation and [u_b, u_c, and u_d] is the axis of rotation

$$\begin{pmatrix}\hat{x}\\ \hat{y}\\ \hat{z}\end{pmatrix} = \begin{pmatrix}\frac{q_1}{\sin\frac{\theta}{2}}\\ \frac{q_2}{\sin\frac{\theta}{2}}\\ \frac{q_3}{\sin\frac{\theta}{2}}\end{pmatrix}$$

$$\theta = 2\cos^{-1} q_0$$



ROS frame orientation - quaternion

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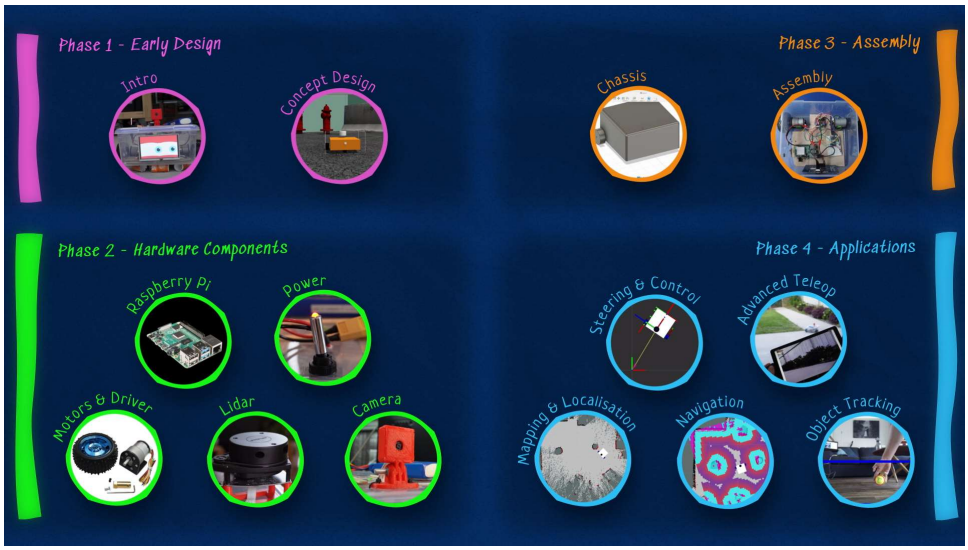
https://articulatedrobotics.xyz/category/concept-design



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- Most robotics work are in teams include one who develops a CAD model of robot.
- Instead of crafting an URDF by hand it is possible to export an URDF model.
- Below is a list of available URDF exporters for a variety of CAD and 3D modeling software systems.

CAD Exporters

- Fusion 360 URDF Exporter
- SolidWorkds URDF Exporter
- ROS Workbench for FreeCAD
- OnShape URDF Exporter
- CREO Parametric URDF Exporter

Other URDF Export Tools

- Copellia Sim URDF Exporter
- Isaac Sim URDF Exporter
- Blender URDF Exporter
- Gazebo SDFormat to URDF Parser
- SDF to URDF Converter in Python
- The Blender Robotics Tools includes a tool to export URDF files from Blender

URDF from CAD models

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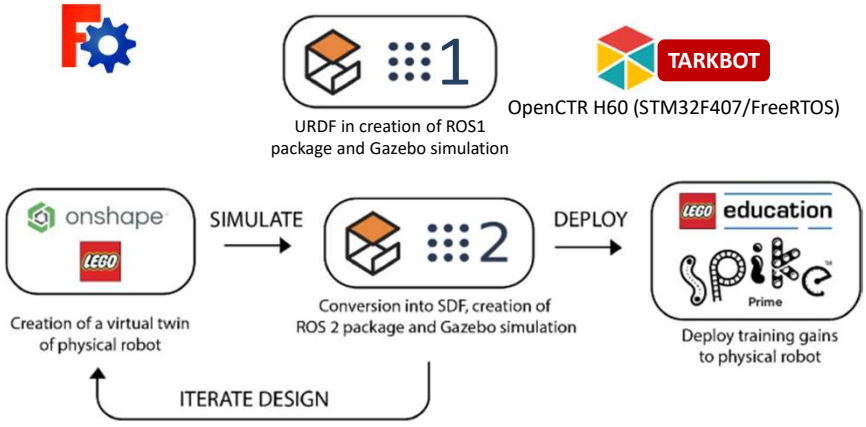
Common Software Common Hardware

https://download2.portableapps.com/portableapps/FreeCADPortable/FreeCADPortable_0.21.2.paf.exe



URDF from CAD models

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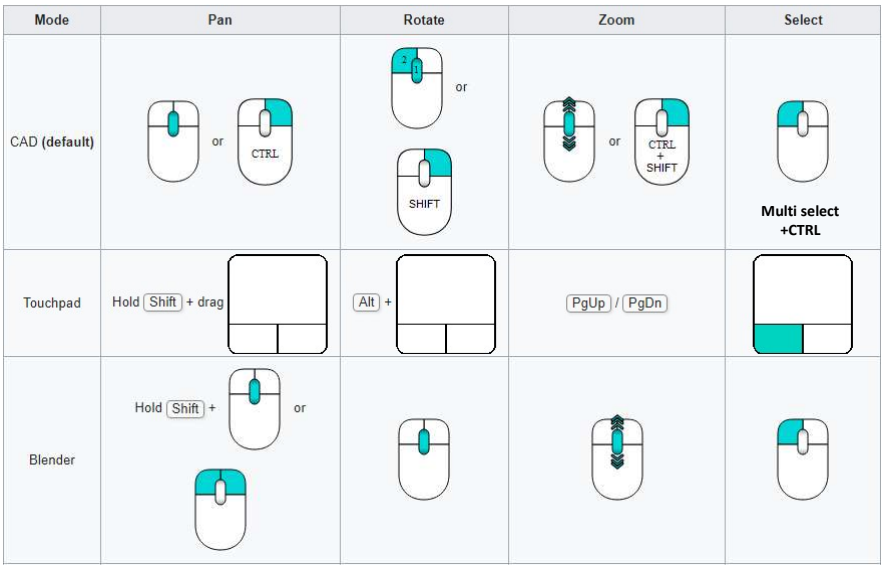

FreeCAD mouse navigation

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https://github.com/USeebi/Lesson0
https://github.com/drfenixion/freecad.overcross/wiki

- Ctrl + + and Ctrl + − to zoom in and out, respectively.
- The arrow keys, ◄ ► ▲ ▼, to shift the view left/right and up/down
- Shift + ◄ and Shift + ► to rotate the view by 90 degrees
- The numeric keys, 0 1 2 3 4 5 6, for the seven standard views:
  Isometric, Front, Top, Right, Rear, Bottom, and Left
- V O will set the camera in Orthographic view.
- While V P sets it in Perspective view.
- Ctrl will allow you to select more than one object or element

FreeCAD keyboard navigation

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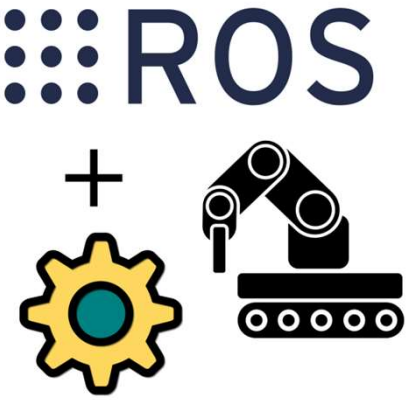
Design Workspace in Robotics



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Timeliness — be aware of the due dates and complete the tasks in accordance with the schedule stipulated by their teachers.

Good Planning — break an extended task into smaller sub-parts and complete them in stages.

Good Record Keeping — keep a complete record of their work, including drafts and backup copies of computer files.

Originality — ensure the work they submit is their own, record the sources of information used and acknowledge them properly in their work.

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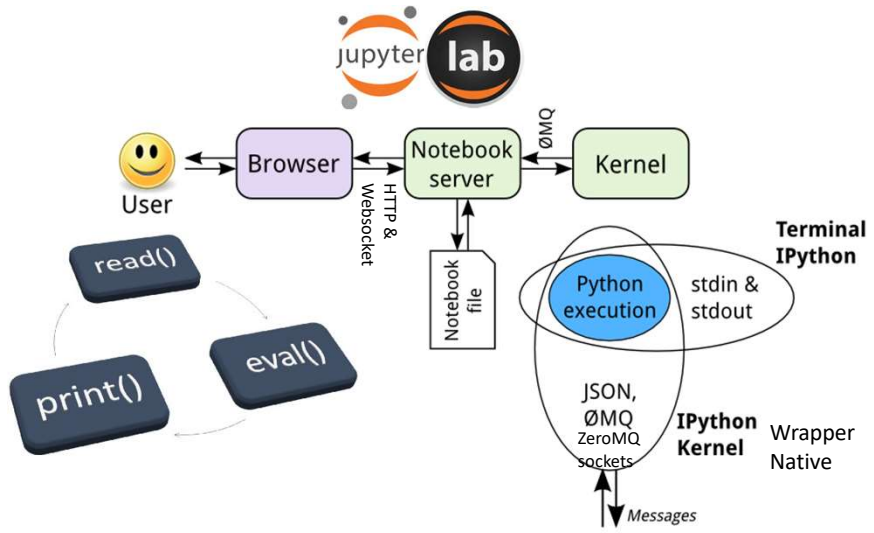

Proposed Python workspace

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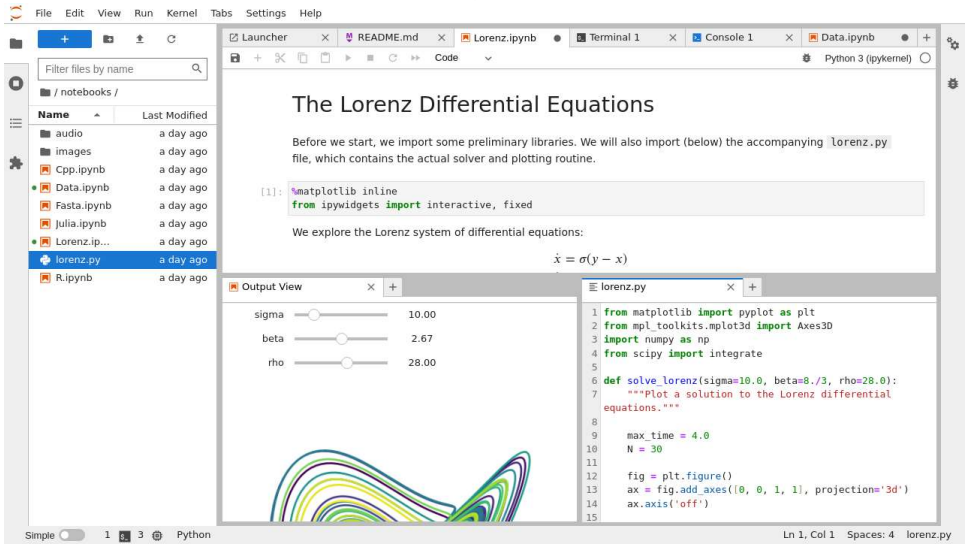
https://robostack.github.io/index.html



Proposed Python workspace

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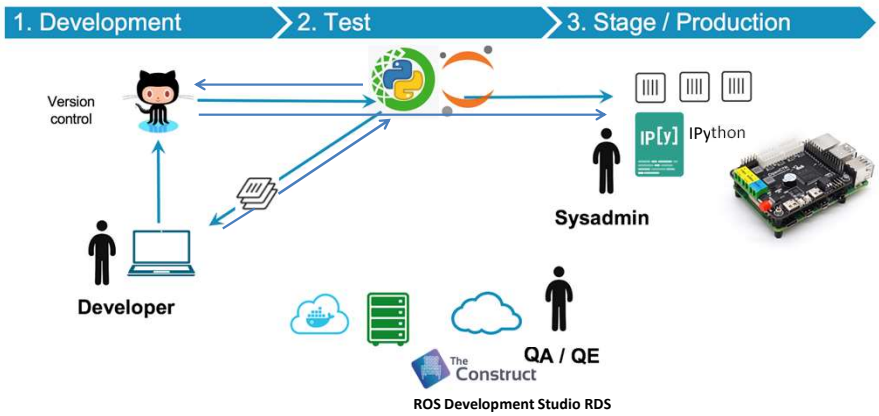

Proposed CI/CD workflow

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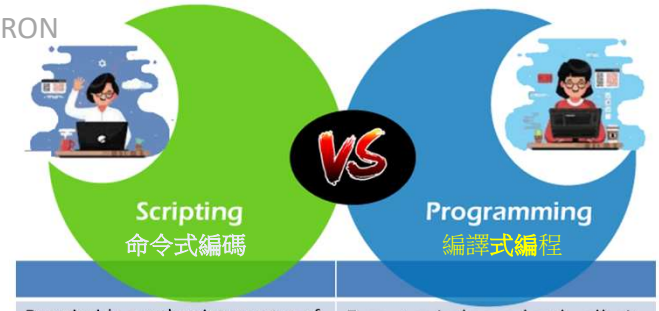

Runs inside another interpreter of a particular runtime environment	Executes independently albeit required runtime libraries
Do not create a ***.exe*** file	These generate ***.exe*** files
Glue languages for existing programs and libraries	High-speed languages to work with API
Useful in rapid prototyping	
Command statements (declarative language)	

Python scripting

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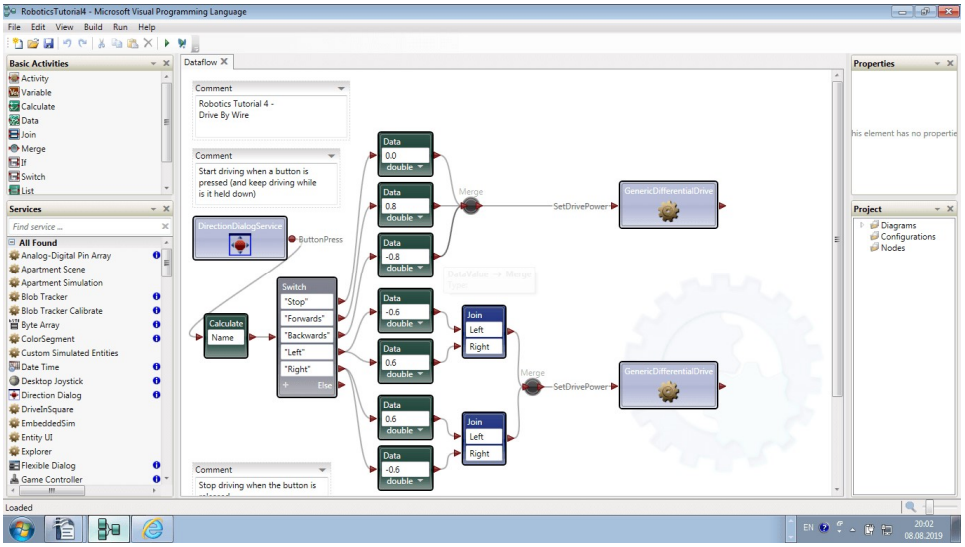

Visual scripting

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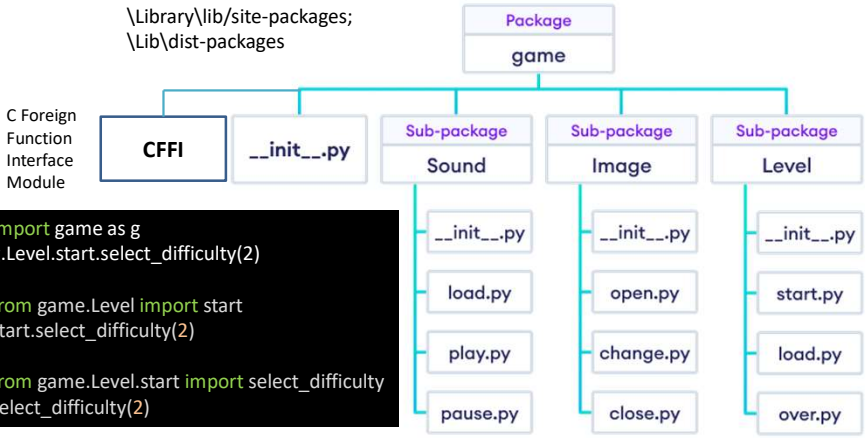
\Library\lib/site-packages;
\Lib\dist-packages




```
Import game as g
g.Level.start.select_difficulty(2)

from game.Level import start
start.select_difficulty(2)

from game.Level.start import select_difficulty
select_difficulty(2)
```

Packages are a way of structuring Python's module namespace by using "dotted module names".

Python packages

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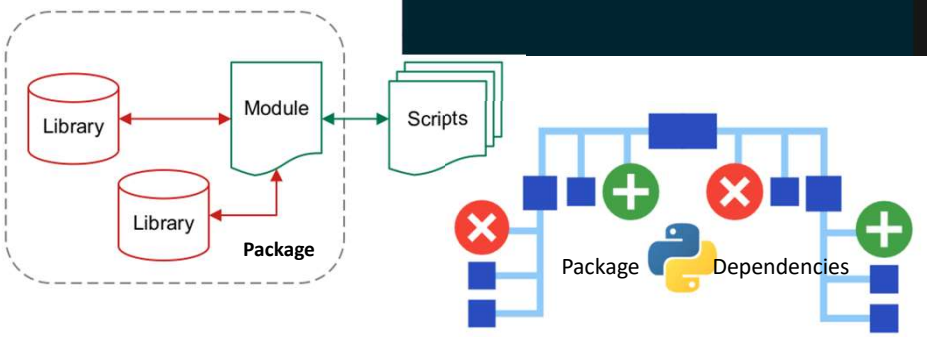
A module is a file containing Python definitions & statements and use them in a script or in an interactive instance of the interpreter. The file name is the module name with the suffix .py appended.

```
$ cat hello_world.py
#!/bin/env python
print("Hello world!")
$ chmod +x  hello_world.py
$ ./hello_world.py
Hello world!
$
$ python hello_world.py
Hello world!
$
```

shebang
Path to interpreter



Python packages

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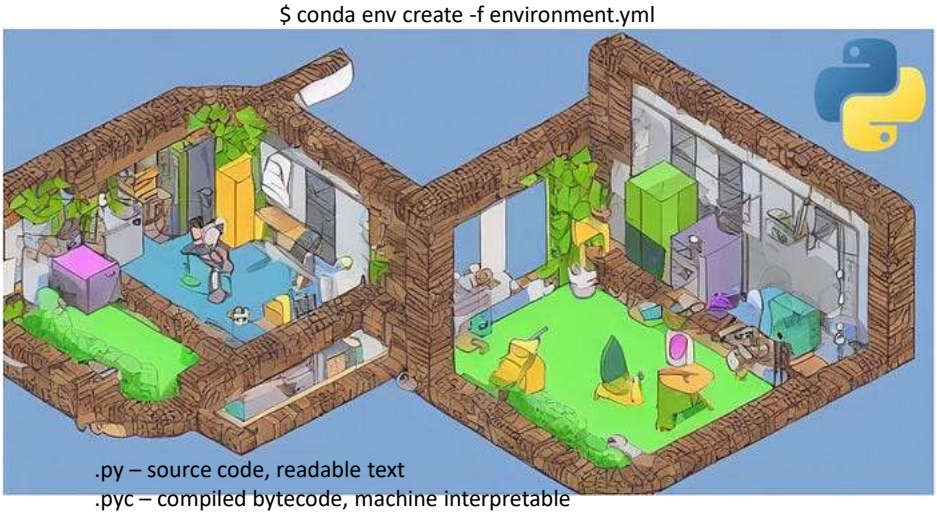
$ conda env export > environment.yml
$ conda env create -f environment.yml



.py – source code, readable text
.pyc – compiled bytecode, machine interpretable

Python virtual environment

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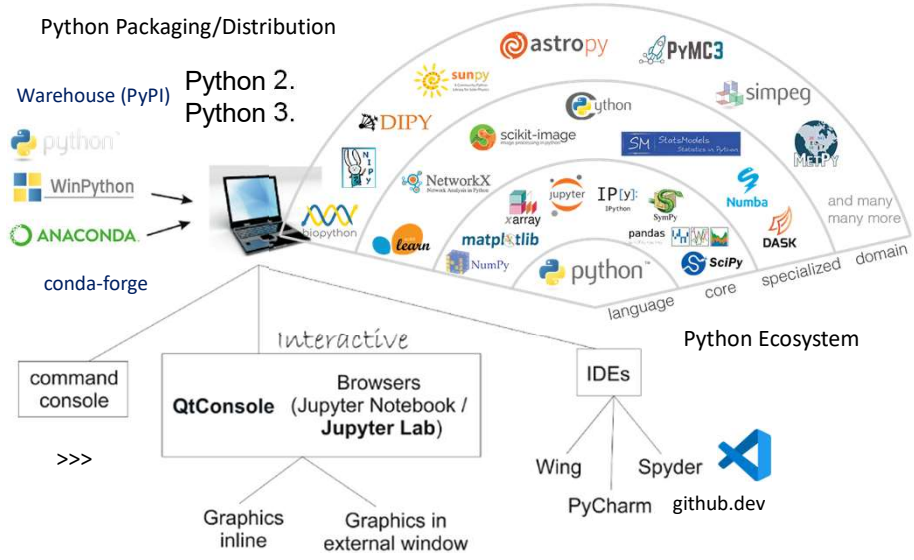

Python robotic development

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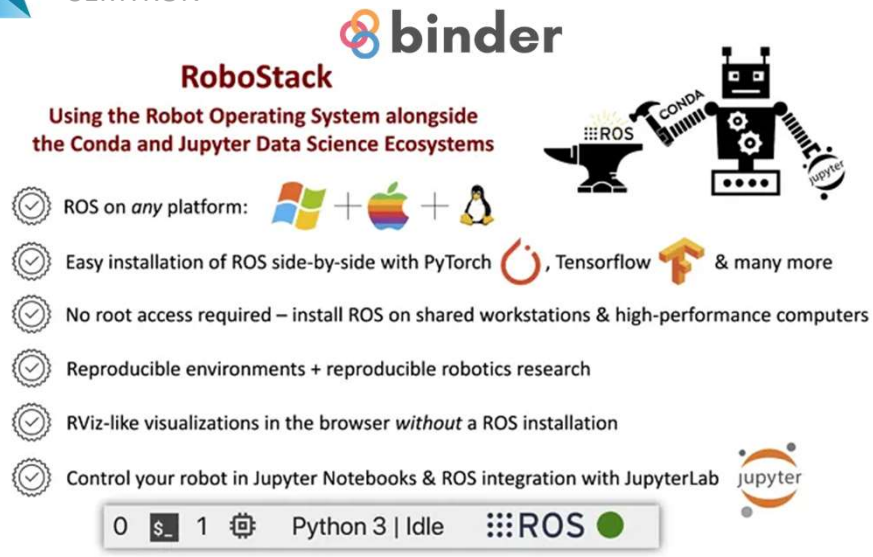

Python robotic development

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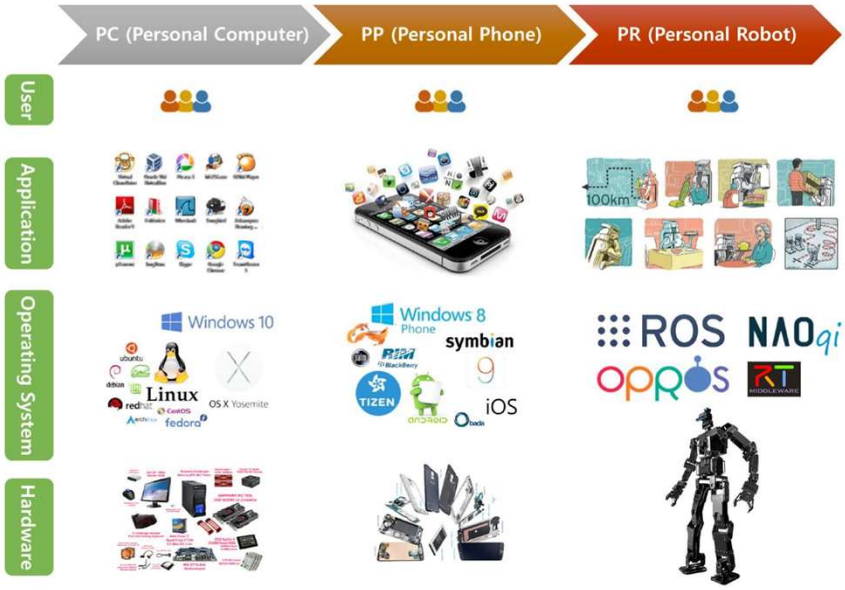

Operating System

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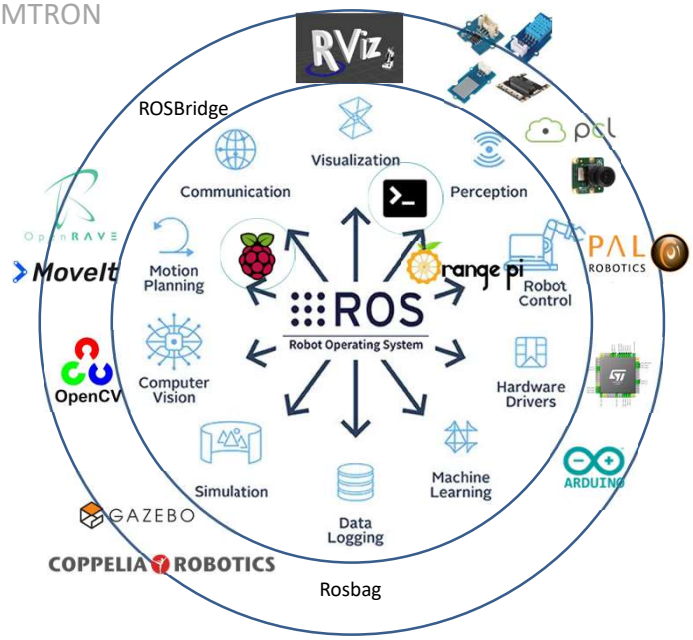

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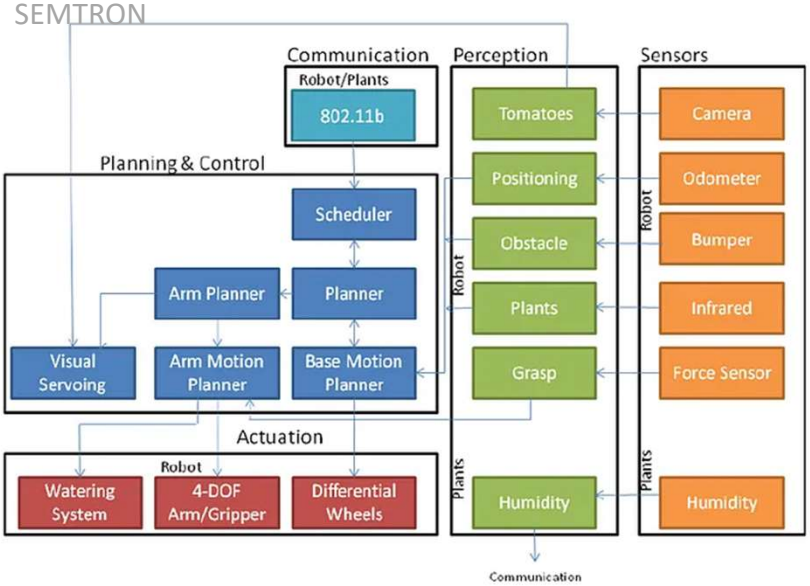
SEMTRON



Robot Operating System

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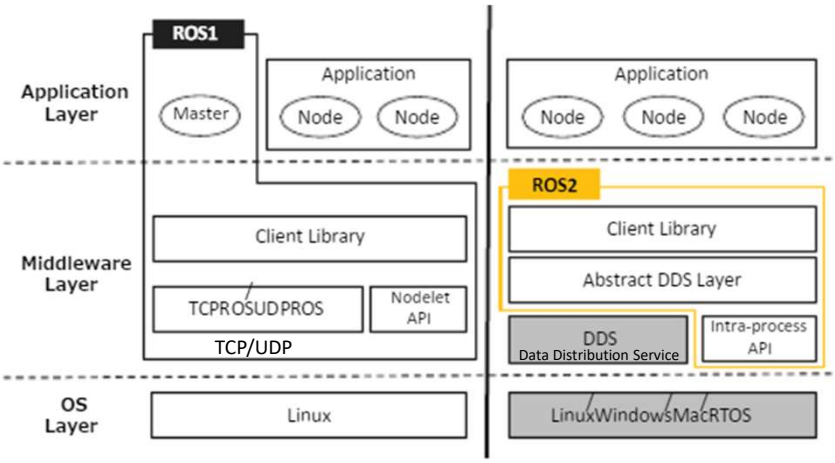

Robot Operating System

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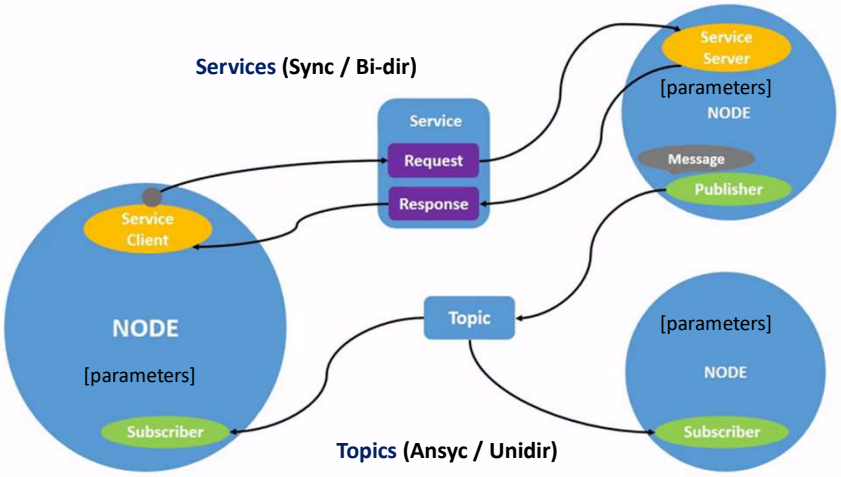
SEMTRON



Robot Operating System

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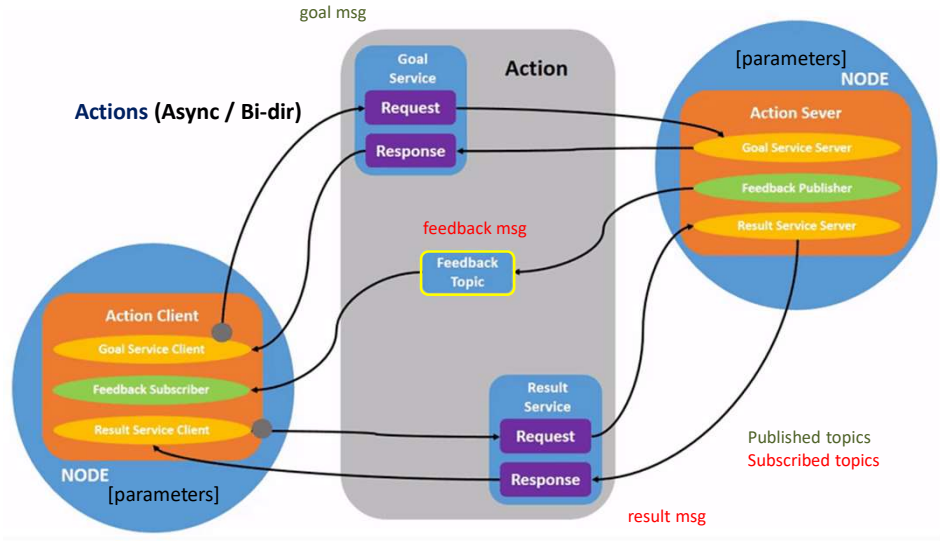

Robot Operating System

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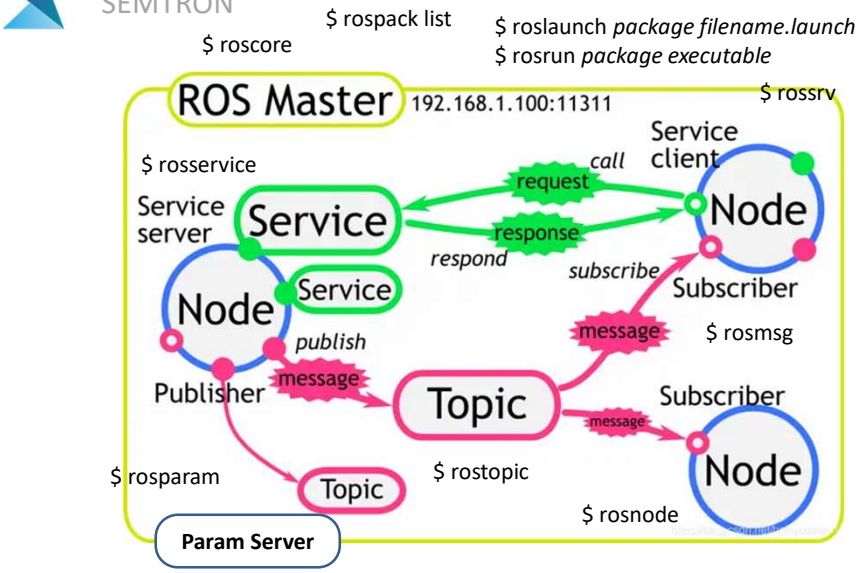

Robot Operating System

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```
### activate ros_noetic env
$ conda activate K:\Miniconda3\envs\ros_noetic
$ roscore

### launch ros1 cli
$ rostopic list

### launch rviz GUI
$ rosrun rviz rviz

### launch gazebo GUI
$ gazebo --verbose

### launch a demo node talker
$ roscd rospy_tutorials
$ 001_talker_listener/talker

### from another terminal activate the ros_noetic env and launch a demo listener
$ rosrun rospy_tutorials listener
```

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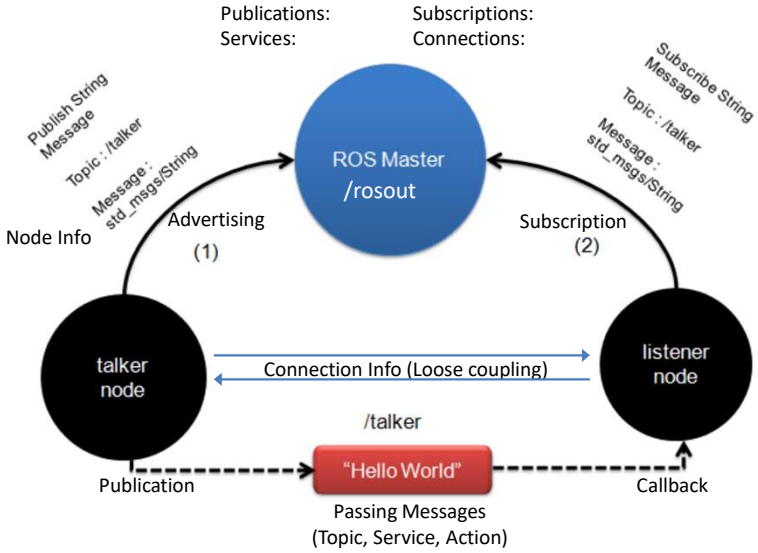

ROS nodes and messages

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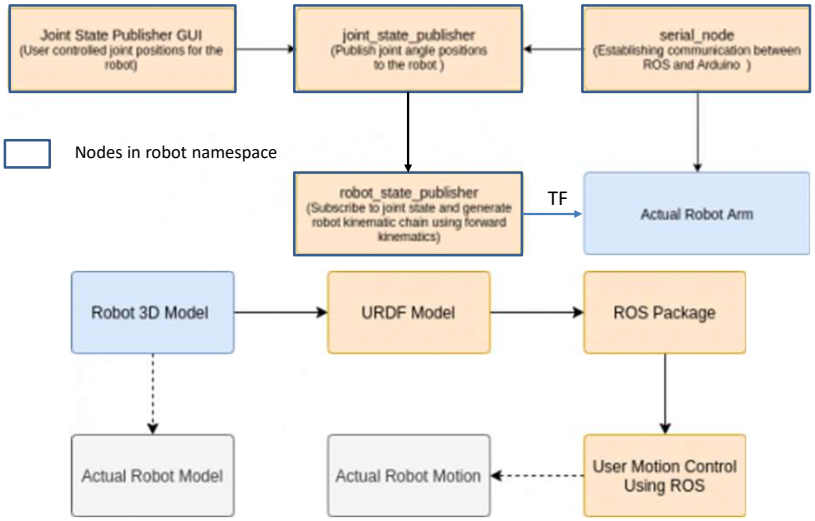

ROS URDF models

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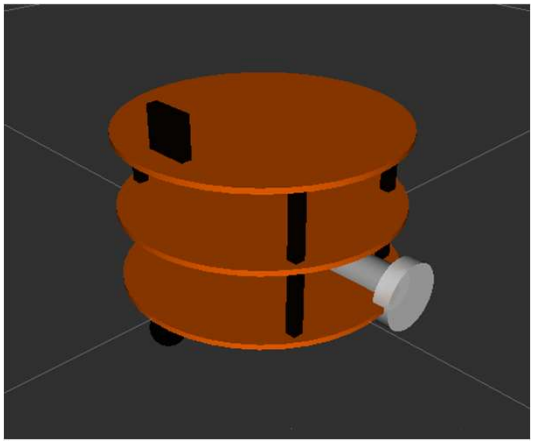
ROS机器人开发实践 -- 胡春旭
https://github.com/peijian1998/ros_exploring



ROS URDF models

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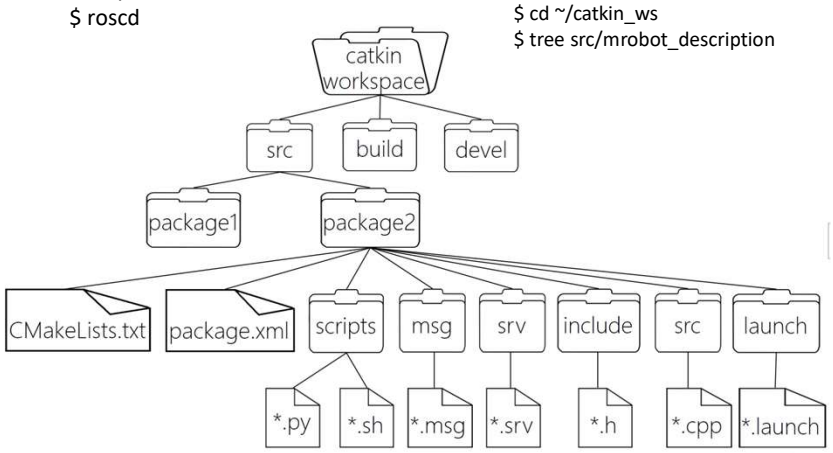
$ rospack
$ roscd

$ cd ~/catkin_ws
$ tree src/mrobot_description



ROS applications

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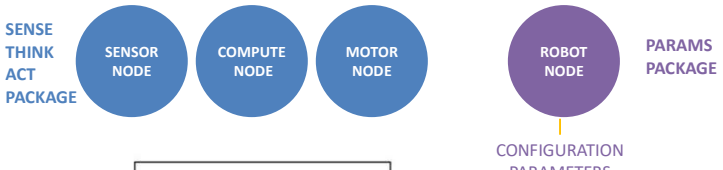

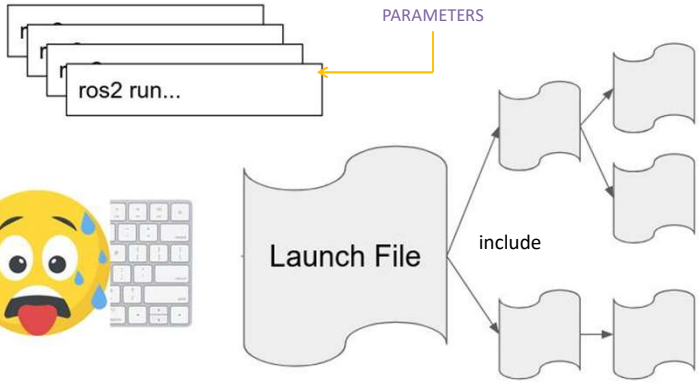

ROS applications

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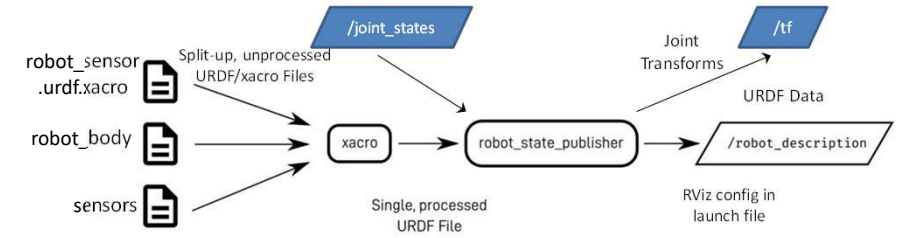
```
<xacro:include filename=".xacro" />
```




```
<?xml version="1.0"?>
<robot name="robot_name" xmlns:xacro="http://www.ros.org/wiki/xacro>"
```

```
<xacro:property name="M_PI" value="3.14159"/>
```

```
<xacro:property name="M_PI" value="3.14159"/>
```

```
<xacro:macro name="urdf_object"> params="A B C" </xacro:macro>
```

ROS URDF applications

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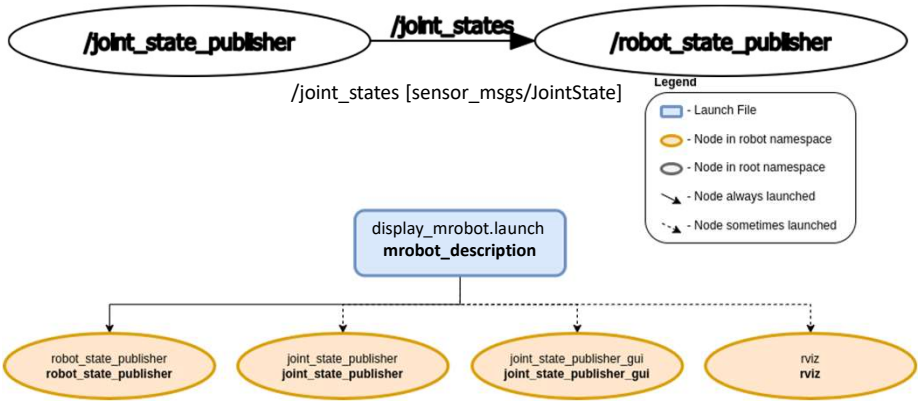
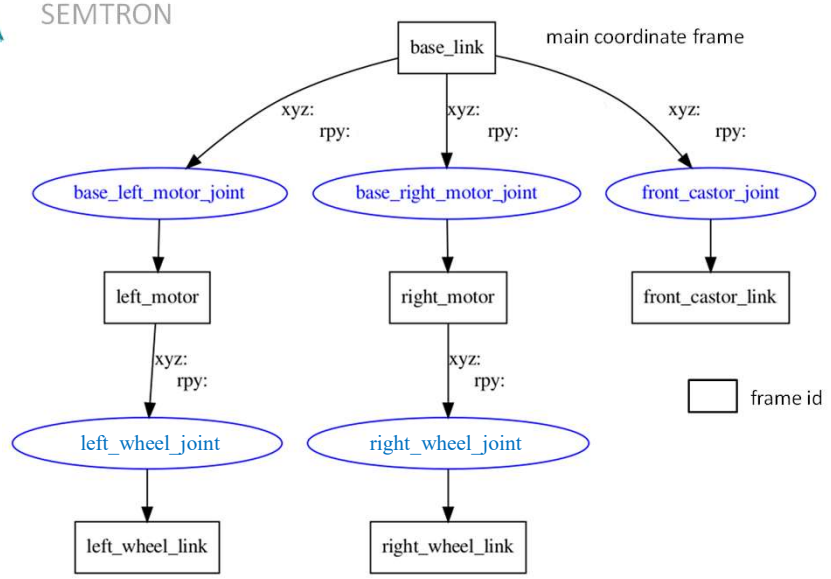
```
$ cd catkin_ws
$ source devel/setup.bash
$ rostopic echo /joint_states
$ rqt_graph
```

Node Graph



ROS visualizations

SEMTRON

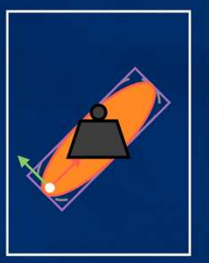


ROS URDF models


```
<link name="base_link">
    <visual>
        <origin xyz=" 0 0 0" rpy="0 0 0" />
        <geometry>
            <cylinder length="0.005" radius="0.13" />
        </geometry>
        <material name="yellow">
            <color rgba="1 0.4 0 1" />
        </material>
    </visual>
    <collision>
        <origin xyz=" 0 0 0" rpy="0 0 0" />
        <geometry>
            <cylinder length="0.005" radius="0.13" />
        </geometry>
    </collision>
    <inertial>
        <mass value="2" />
        <origin xyz="0 0 0" />
        <inertia ixx="0.01" ixy="0.0" ixz="0.0"
                 iyy="0.01" iyz="0.0" izz="0.5" />
    </inertial>

</link>
```

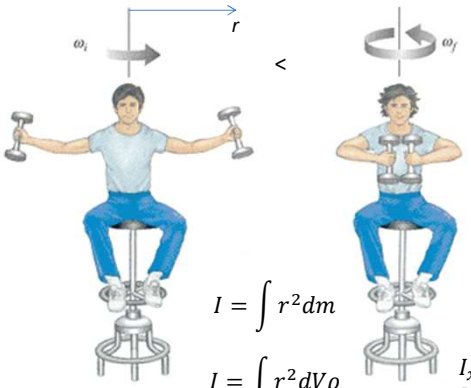
```
<link name="arm_link">
    <visual>
        <geometry>
        <origin>
        <material>
    </visual>
    <collision>
        <geometry>
        <origin>
    </collision>
    <inertial>
        <mass>
        <origin>
        <inertia>
    </inertial>
</link>
```



display_mrobot_chassis_withPhy_urdf.launch

```
<launch>
    <param name="robot_description" textfile="$(find
mrobot_description)/urdf/mrobot_chassis_withPhy.urdf" />
```

SEMTRON



$$I = \int r^2 dm$$

$$I = \int r^2 dV\rho$$

$$I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

$$I_{xx} = \int \rho(\hat{y}^2 + \hat{z}^2) dV$$

$$I_{xy} = \int \rho(\hat{x}\hat{y}) dV$$

I_{xx} ***moment*** *of inertia* about the *x*-axis
I_{xy} ***product*** *of inertia* about a pair of given perpendicular axes

center of gravity $I \triangleq \iiint_V r^2 \rho(r) dV$

Physical properties in ROS URDF

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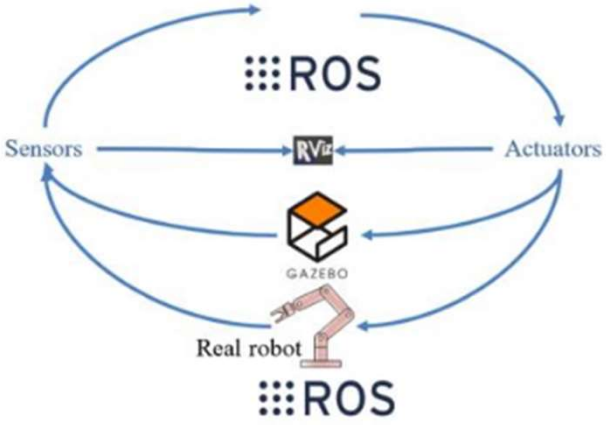
SEMTRON

Design Simulations in Robotics



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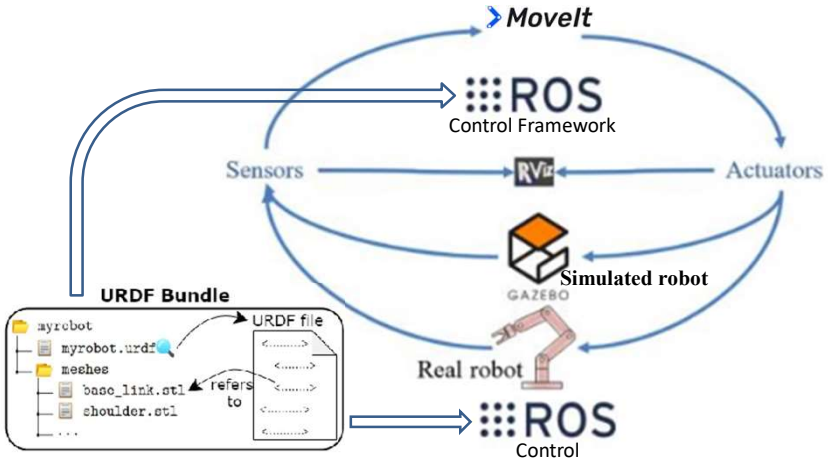
". . . RViz shows you what the robot thinks is happening, while Gazebo shows you what is really happening."



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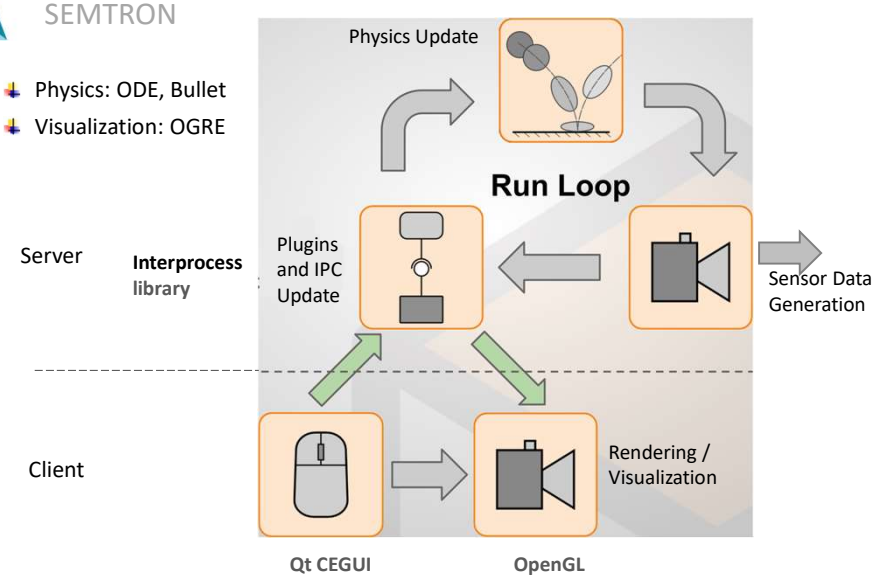
SEMTRON

- Physics: ODE, Bullet
- Visualization: OGRE



Gazebo Classic

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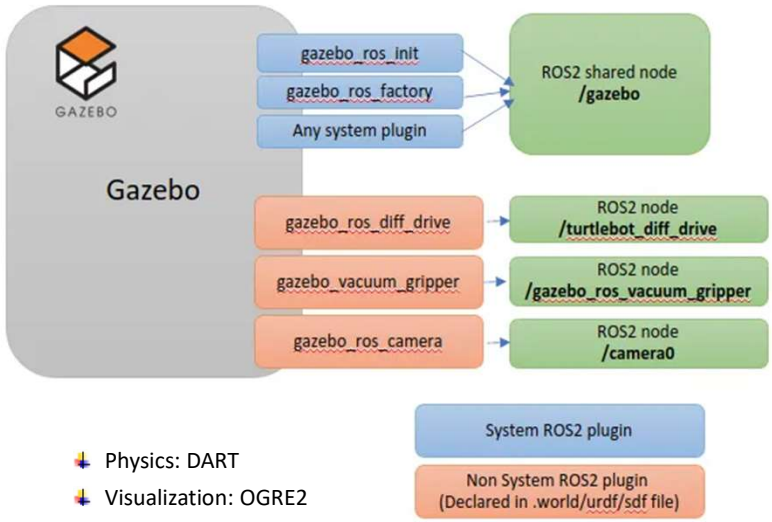
SEMTRON



- Physics: DART
- Visualization: OGRE2

Gazebo Ignition

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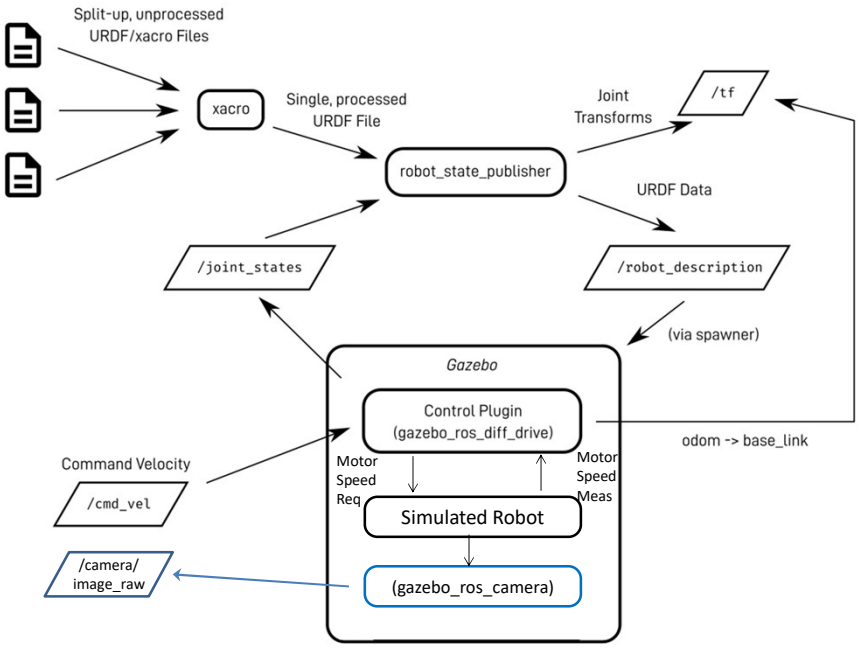

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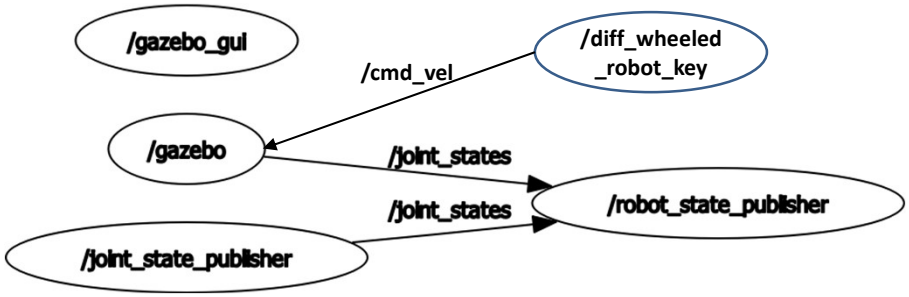
SEMTRON

```
$ roslaunch mrobot_gazebo view_mrobot_with_camera_gazebo.launch
$ roslaunch mrobot_teleop mrobot_teleop.launch
$ rostopic echo /cmd_vel
```



Node Graph

ROS simulation

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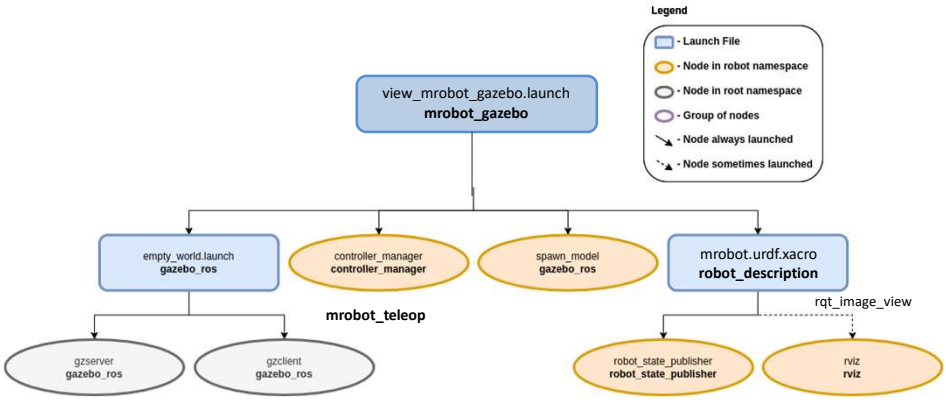
SEMTRON



ROS simulation

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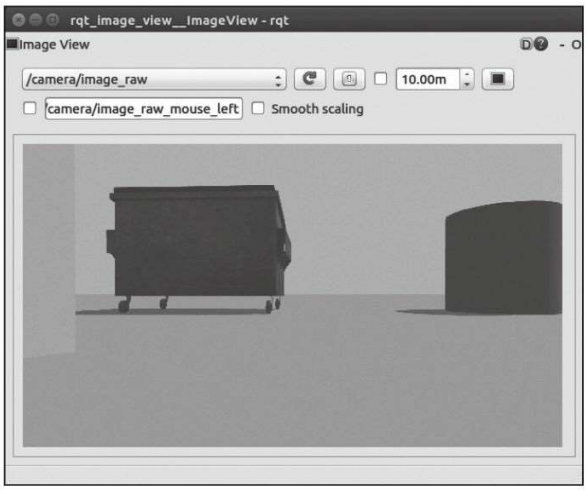
SEMTRON

view_mrobot_with_camera_gazebo.launch

```
<node name="rviz" pkg="rviz" type="rviz" args="-d $(find
mrobot_description)/config/mrobot.rviz" required="true" />
```



ROS simulation

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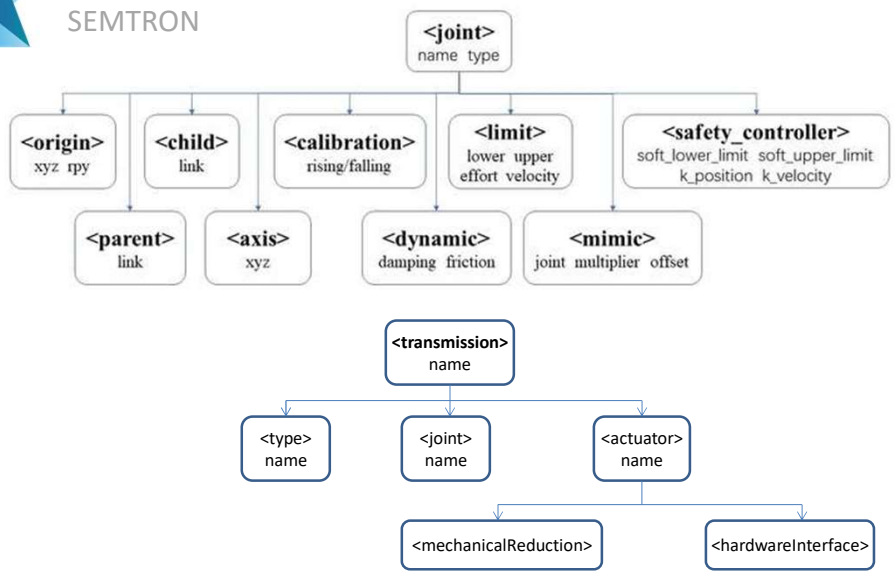
SEMTRON



Gazebo simulation

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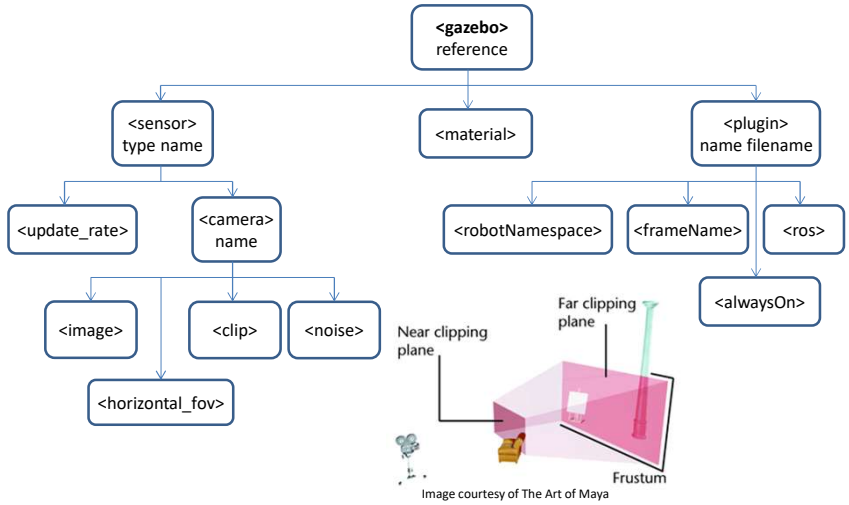
SEMTRON



Gazebo simulation

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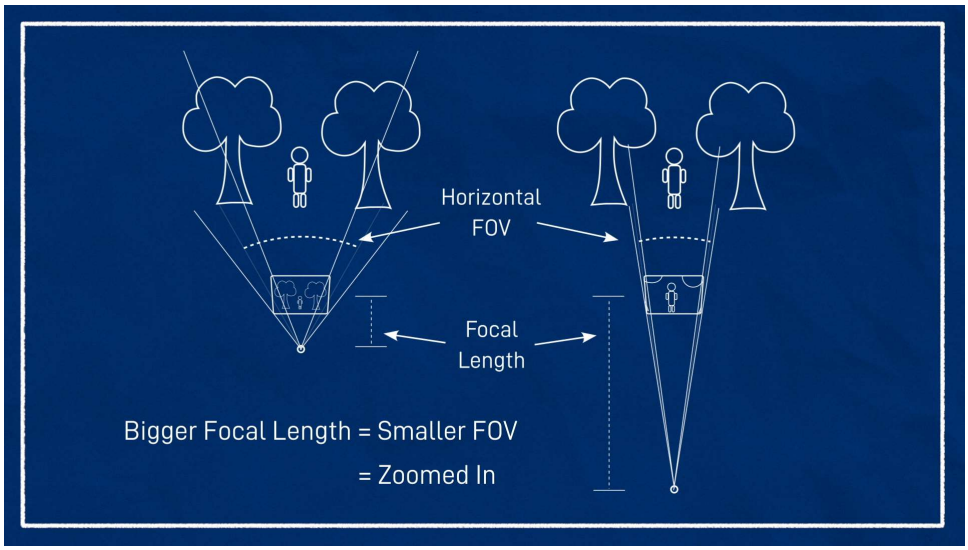
SEMTRON



Gazebo simulation

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Homework

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ROS Versions History

Jan 2010	Mar 2010	Aug 2010	Mar 2011	Aug 2011	Apr 2012	Dec 2012	Sep 2013	Jul 2014
ROS 1.0 Release!	Box Turtle	C Turtle	Diamondback	Electric Emys	Fuerte Turtle	Groovy Galapagos	Hydro Medusa	Indigo Igloo

May 2015	May 2016	May 2017	May 2018	2020	Dec 2017	Jul 2018	Dec 2018	Jun 2019
Jade Turtle	Kinetic Kame	Lunar Loggerhead	Melodic Morenia	Noetic Ninjemys	(ROS2) Ardent Apalone	(ROS2) Bouncy Bolson	(ROS2) Crystal Clemmys	(ROS2) Dashing Diademata

* Images sources: https://en.wikipedia.org/wiki/Robot_Operating_System
* Background picture by Negative Space

The Construct
Learn and develop for robots with ROS

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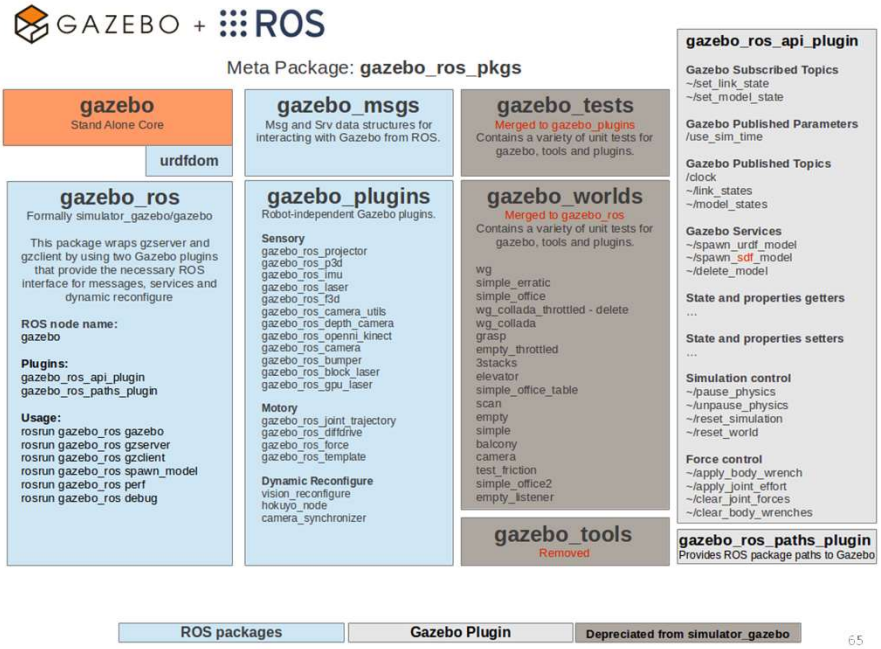

https://repo.anaconda.com/miniconda/Miniconda3-py311_24.5.0-0-Windows-x86_64.exe

```
>Downloads\Miniconda3-py311_24.5.0-0-Windows-x86_64.exe
  /InstallationType=JustMe /AddToPath=0 /RegisterPython=0 /NoRegistry=1 /S
  /D=K:\Miniconda3\py311
```

```
(base) ➢ conda install mamba -c conda-forge
(base) ➢ conda install git
(base) ➢ mamba create -p K:\Miniconda3\envs\ros_noetic python=3.11
(base) ➢ mamba activate K:\Miniconda3\envs\ros_noetic
(ros_noetic)
(ros_noetic) ➢ conda config --env --add channels conda-forge
(ros_noetic) ➢ conda config --env --add channels robostack-staging
(ros_noetic) ➢ conda config --env --remove channels defaults
(ros_noetic) ➢ mamba install ros-noetic-desktop ros-noetic-gazebo-ros
(ros_noetic) ➢ mamba install ros-noetic-gazebo-plugins ros-noetic-gazebo-ros-pkgs ros-noetic-
               gazebo-ros-control  ros-noetic-rqt-controller-manager ros-noetic-xacro ros-
               noetic-move-base
(ros_noetic) ➢ mamba deactivate

(base) ➢ mamba activate K:\Miniconda3\envs\ros_noetic
```

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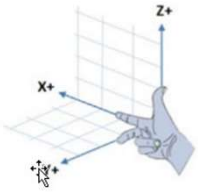
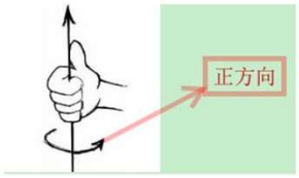
$ rosrun teleop_twist_keyboard teleop_twist_keyboard.py





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