6 Robot state estimation

According to different models, you only need to set the purchased model in [.bashrc], X1 (ordinary four-wheel drive) X3 (Mike wheel) X3plus (Mike wheel mechanical arm) R2 (Ackerman differential) and so on. Section takes X3 as an example

Open the [.bashrc] file

```
sudo vim .bashrc
```

Find the [ROBOT_TYPE] parameter and modify the corresponding model

```
export ROBOT_TYPE=X3    # ROBOT_TYPE: X1 X3 X3plus R2 X7
```

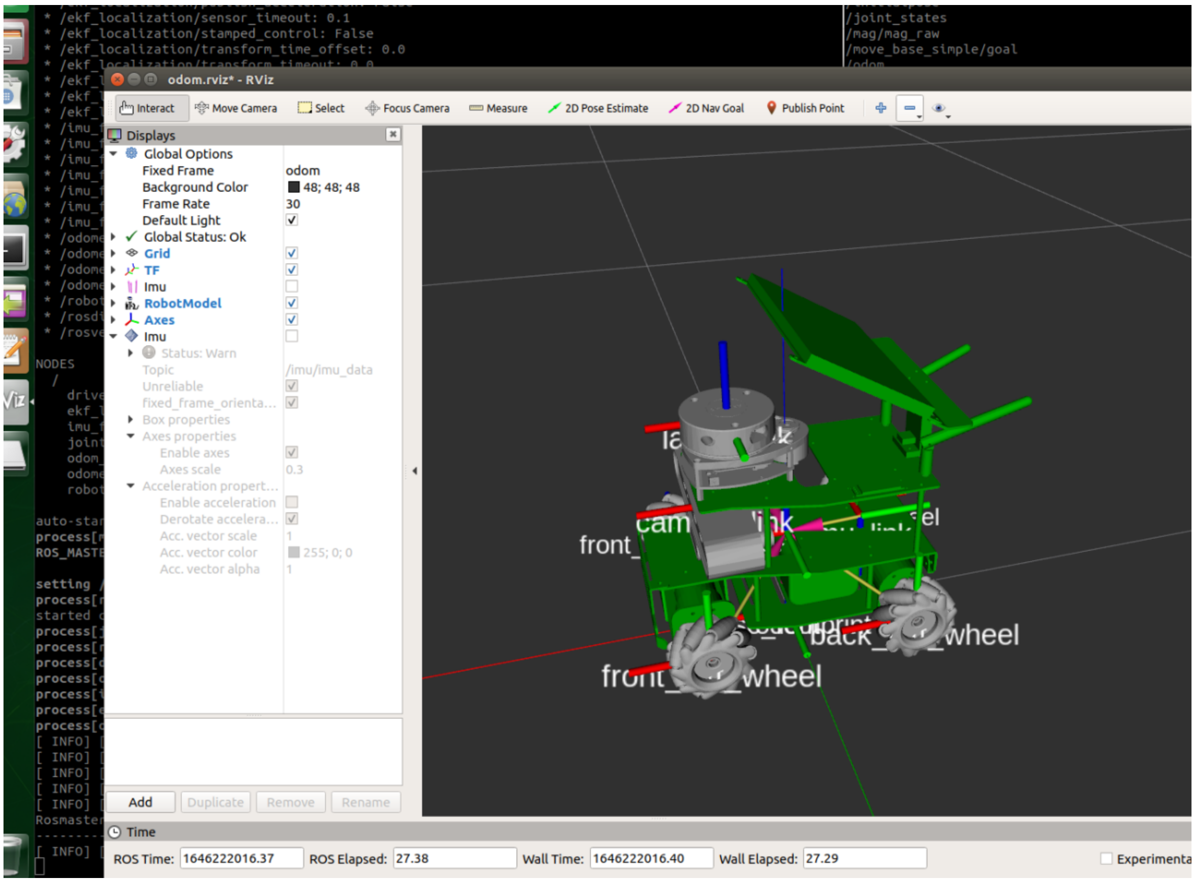
6.1 Start

6.1.1 Code reference path

```
~/yahboomcar_ws/src/yahboomcar_bringup/launch/bringup.launch
```

6.1.1 Start

```
roslaunch yahboomcar_bringup bringup.launch use_rviz:=true
```



```
 * /ekf_localization/sensor_timeout: 0.1
 * /ekf_localization/stamped_control: False
 * /ekf_localization/transform_time_offset: 0.0
```

```
/joint_states
/mag/mag_raw
/move_base_simple/goal
```

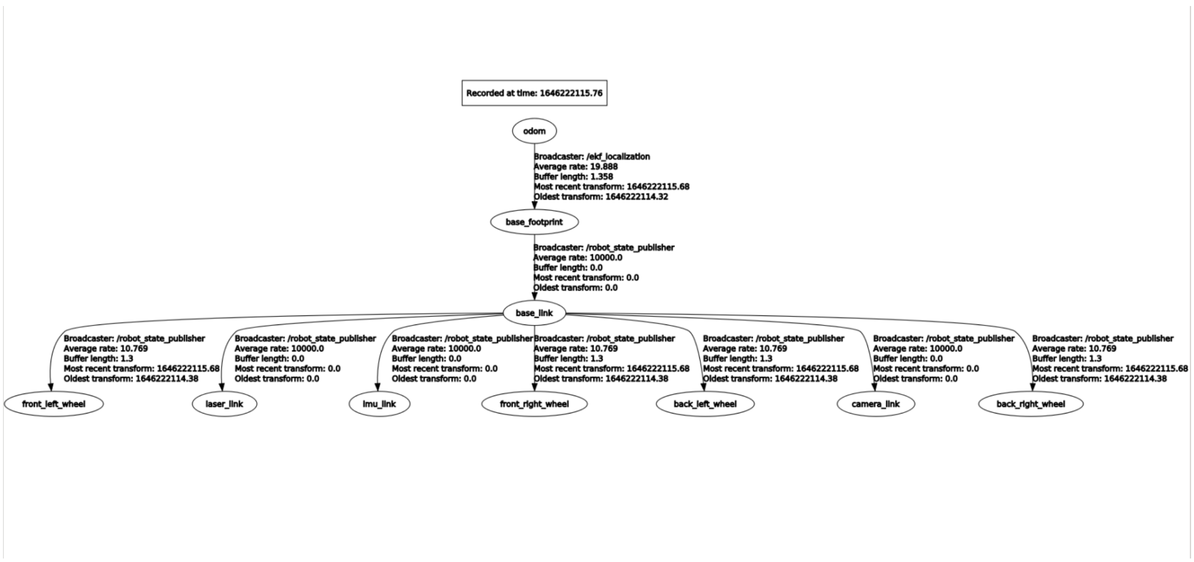
```
Displays
  Global Options
    Fixed Frame            odom
    Background Color       48; 48; 48
    Frame Rate             30
    Default Light          ✓
  Global Status: Ok
  Grid                     ✓
  TF                       ✓
  Imu
  RobotModel               ✓
  Axes                     ✓
  Imu
    Status: Warn
    Topic                  /imu/imu_data
    Unreliable             ✓
    fixed_frame_orienta... ✓
    Box properties
    Axes properties
      Enable axes          ✓
      Axes scale           0.3
    Acceleration propert...
      Enable acceleration
      Derotate accelera... ✓
      Acc. vector scale    1
      Acc. vector color    255; 0; 0
      Acc. vector alpha    1
```

ROS Time: 1646222016.37 ROS Elapsed: 27.38 Wall Time: 1646222016.40 Wall Elapsed: 27.29

6.1.1 View tf tree and node graph

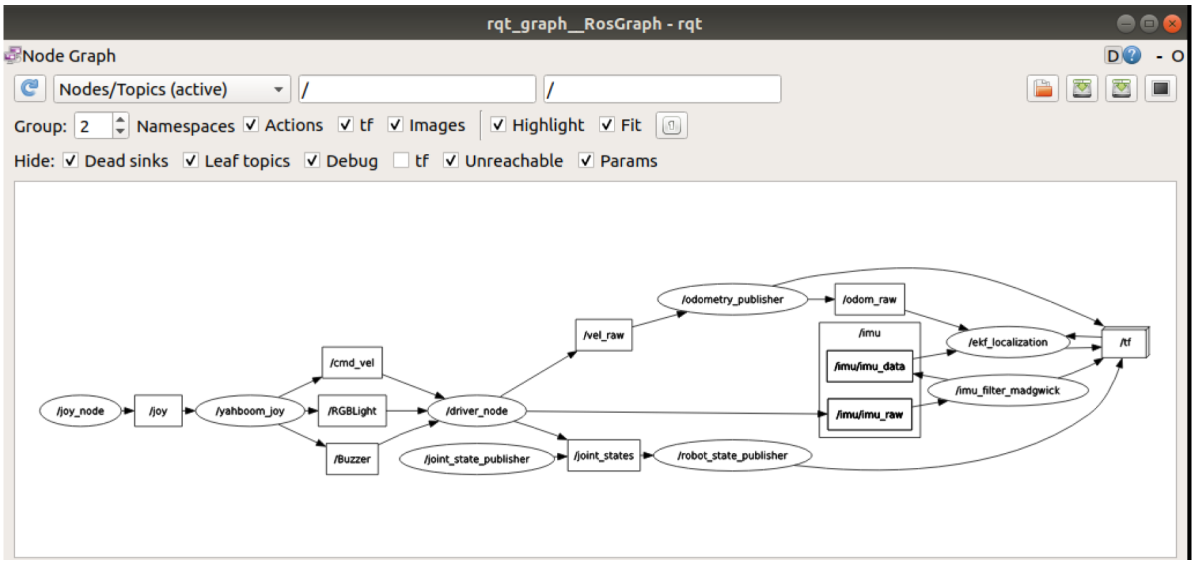
1. view the TF tree

```
rosrun rqt_tf_tree rqt_tf_tree
```


Recorded at time: 1646222115.76
odom
Broadcaster: /ekf_localization
Average rate: 19.888
Buffer length: 1.358
Most recent transform: 1646222115.68
Oldest transform: 1646222114.32
base_footprint
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
base_link
Broadcaster: /robot_state_publisher
Average rate: 10.769
Buffer length: 1.3
Most recent transform: 1646222115.68
Oldest transform: 1646222114.38
front_left_wheel
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
laser_link
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
imu_link
Broadcaster: /robot_state_publisher
Average rate: 10.769
Buffer length: 1.3
Most recent transform: 1646222115.68
Oldest transform: 1646222114.38
front_right_wheel
Broadcaster: /robot_state_publisher
Average rate: 10.769
Buffer length: 1.3
Most recent transform: 1646222115.68
Oldest transform: 1646222114.38
back_left_wheel
Broadcaster: /robot_state_publisher
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
camera_link
Broadcaster: /robot_state_publisher
Average rate: 10.769
Buffer length: 1.3
Most recent transform: 1646222115.68
Oldest transform: 1646222114.38
back_right_wheel

2. view the node graph

```
rosrun rqt_graph rqt_graph
```



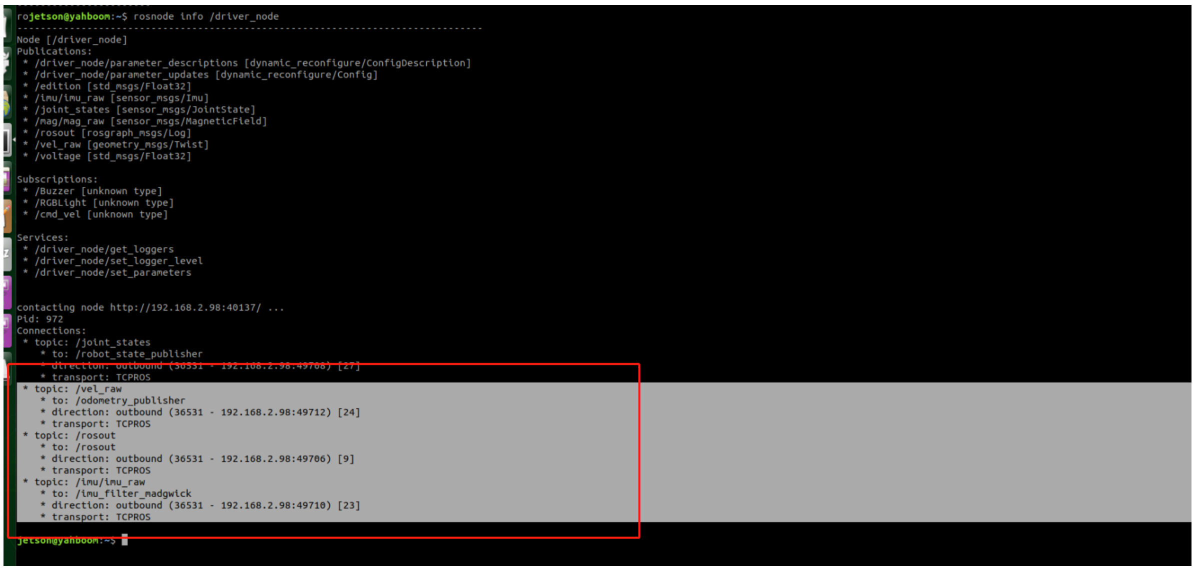
6.1.2 launch file analysis

In the bringup.launch file, there are several important nodes

1. /drive_node

This node mainly publishes /imu/imu_raw and /vel_raw data, terminal input

```
rosnode info /driver_node
```



```
rojetson@yahboom:~$ rosnode info /driver_node
--------------------------------------------------------------------------------
Node [/driver_node]
Publications:
 * /driver_node/parameter_descriptions [dynamic_reconfigure/ConfigDescription]
 * /driver_node/parameter_updates [dynamic_reconfigure/Config]
 * /edition [std_msgs/Float32]
 * /imu/imu_raw [sensor_msgs/Imu]
 * /joint_states [sensor_msgs/JointState]
 * /mag/mag_raw [sensor_msgs/MagneticField]
 * /rosout [rosgraph_msgs/Log]
 * /vel_raw [geometry_msgs/Twist]
 * /voltage [std_msgs/Float32]

Subscriptions:
 * /Buzzer [unknown type]
 * /RGBLight [unknown type]
 * /cmd_vel [unknown type]

Services:
 * /driver_node/get_loggers
 * /driver_node/set_logger_level
 * /driver_node/set_parameters


contacting node http://192.168.2.98:40137/ ...
Pid: 972
Connections:
 * topic: /joint_states
    * to: /robot_state_publisher
    * direction: outbound (36531 - 192.168.2.98:49708) [27]
    * transport: TCPROS
 * topic: /vel_raw
    * to: /odometry_publisher
    * direction: outbound (36531 - 192.168.2.98:49712) [24]
    * transport: TCPROS
 * topic: /rosout
    * to: /rosout
    * direction: outbound (36531 - 192.168.2.98:49706) [9]
    * transport: TCPROS
 * topic: /imu/imu_raw
    * to: /imu_filter_madgwick
    * direction: outbound (36531 - 192.168.2.98:49710) [23]
    * transport: TCPROS

jetson@yahboom:~$
```

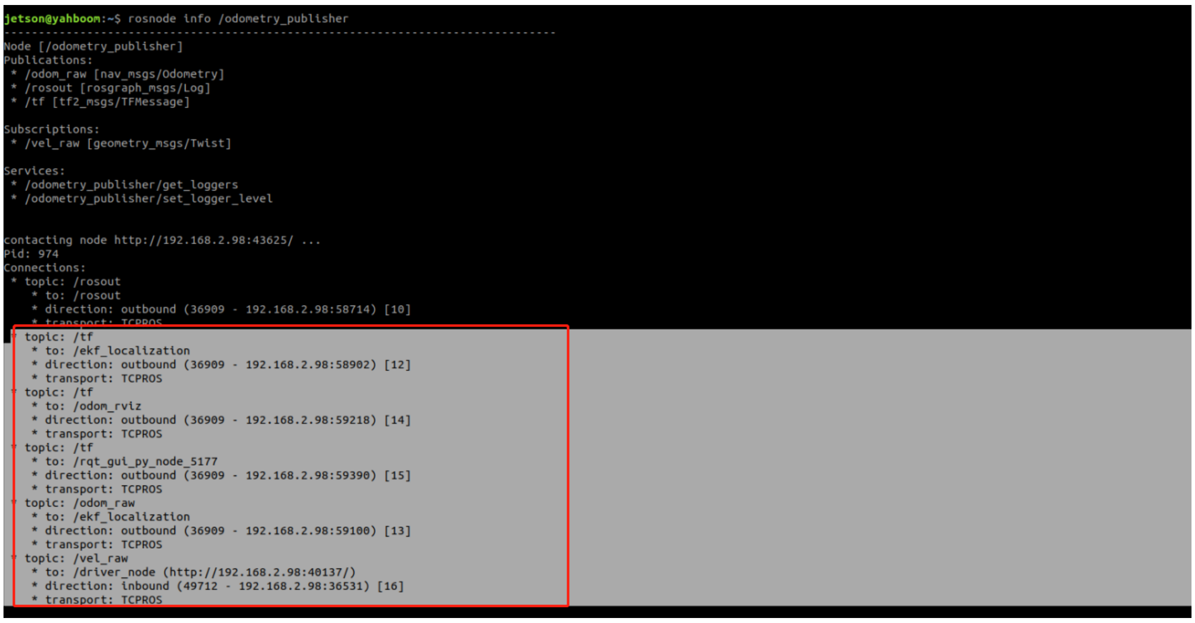
As can be seen,

- The /driver_node node publishes the /imu/imu_raw topic data to the /imu_filter_madgwick node, which filters and fuses the imu data;
- The /driver_node node publishes the /vel_raw topic data to the /odometry_publisher node. After the latter is integrated, the /odom_raw data is published;

2. /odometry_publisher

This node mainly receives the vel_raw topic data sent by the /driver_node node, publishes the /odom_raw topic data to /ekf_localization, and publishes the /tf topic data to other nodes, terminal input,

```
rosnode info /odometry_publisher
```

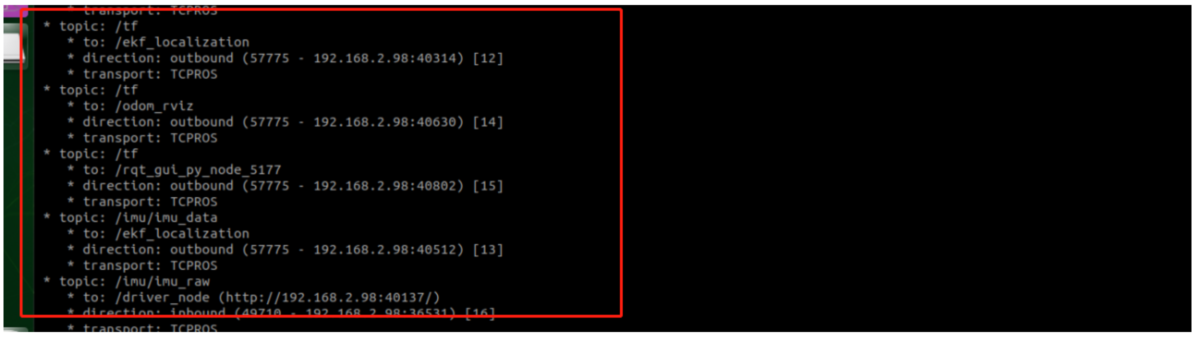


```
jetson@yahboom:~$ rosnode info /odometry_publisher
--------------------------------------------------------------------------------
Node [/odometry_publisher]
Publications:
 * /odom_raw [nav_msgs/Odometry]
 * /rosout [rosgraph_msgs/Log]
 * /tf [tf2_msgs/TFMessage]

Subscriptions:
 * /vel_raw [geometry_msgs/Twist]

Services:
 * /odometry_publisher/get_loggers
 * /odometry_publisher/set_logger_level


contacting node http://192.168.2.98:43625/ ...
Pid: 974
Connections:
 * topic: /rosout
    * to: /rosout
    * direction: outbound (36909 - 192.168.2.98:58714) [10]
    * transport: TCPROS
 * topic: /tf
    * to: /ekf_localization
    * direction: outbound (36909 - 192.168.2.98:58902) [12]
    * transport: TCPROS
 * topic: /tf
    * to: /odom_rviz
    * direction: outbound (36909 - 192.168.2.98:59218) [14]
    * transport: TCPROS
 * topic: /tf
    * to: /rqt_gui_py_node_5177
    * direction: outbound (36909 - 192.168.2.98:59390) [15]
    * transport: TCPROS
 * topic: /odom_raw
    * to: /ekf_localization
    * direction: outbound (36909 - 192.168.2.98:59100) [13]
    * transport: TCPROS
 * topic: /vel_raw
    * to: /driver_node (http://192.168.2.98:40137/)
    * direction: inbound (49712 - 192.168.2.98:36531) [16]
    * transport: TCPROS
```

3. /imu_filter_madgwick

This node mainly filters and fuses imu data, and then publishes the processed /imu/imu_data topic data to the /ekf_localization node to receive and publish /tf data to other nodes, terminal input,

```
rosnode info /imu_filter_madgwick
```

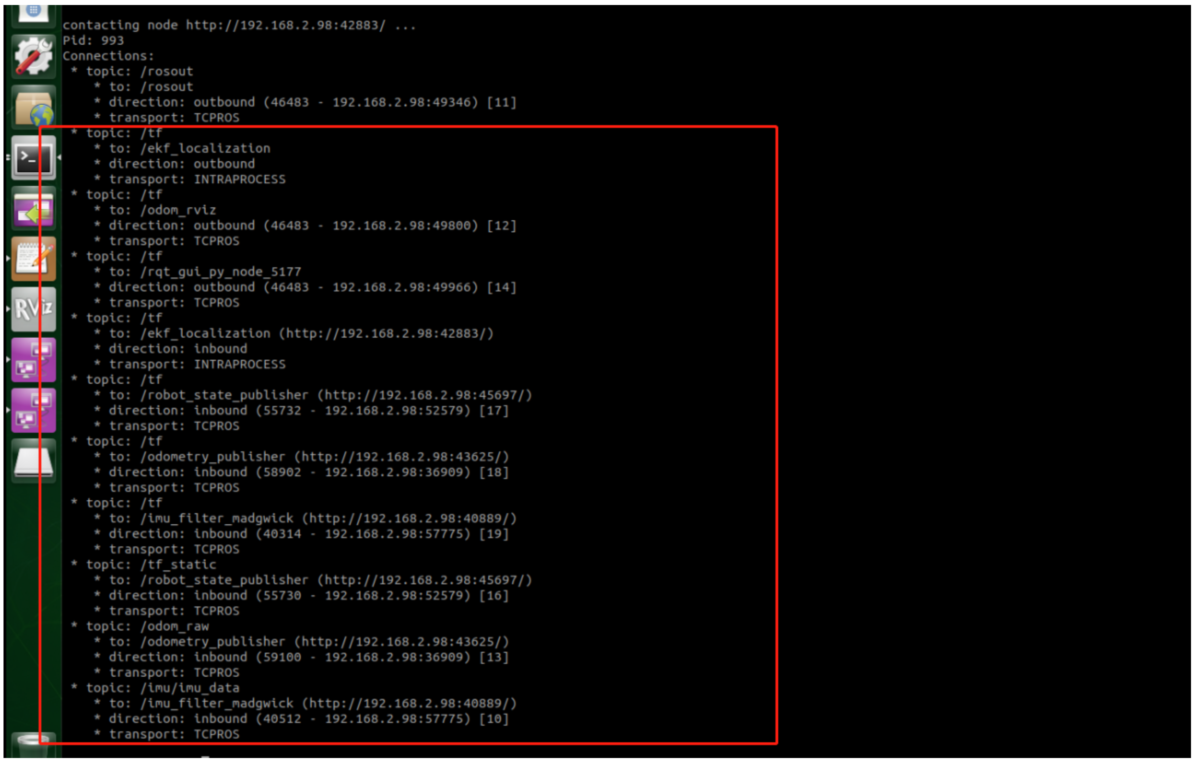


```
    * transport: TCPROS
 * topic: /tf
    * to: /ekf_localization
    * direction: outbound (57775 - 192.168.2.98:40314) [12]
    * transport: TCPROS
 * topic: /tf
    * to: /odom_rviz
    * direction: outbound (57775 - 192.168.2.98:40630) [14]
    * transport: TCPROS
 * topic: /tf
    * to: /rqt_gui_py_node_5177
    * direction: outbound (57775 - 192.168.2.98:40802) [15]
    * transport: TCPROS
 * topic: /imu/imu_data
    * to: /ekf_localization
    * direction: outbound (57775 - 192.168.2.98:40512) [13]
    * transport: TCPROS
 * topic: /imu/imu_raw
    * to: /driver_node (http://192.168.2.98:40137/)
    * direction: inbound (49710 - 192.168.2.98:36531) [16]
    * transport: TCPROS
```

4. /ekf_localization

This node mainly integrates imu data and odom data and publishes tf data, terminal input,

```
rosnode info /ekf_localization
```



```
contacting node http://192.168.2.98:42883/ ...
Pid: 993
Connections:
 * topic: /rosout
    * to: /rosout
    * direction: outbound (46483 - 192.168.2.98:49346) [11]
    * transport: TCPROS
 * topic: /tf
    * to: /ekf_localization
    * direction: outbound
    * transport: INTRAPROCESS
 * topic: /tf
    * to: /odom_rviz
    * direction: outbound (46483 - 192.168.2.98:49800) [12]
    * transport: TCPROS
 * topic: /tf
    * to: /rqt_gui_py_node_5177
    * direction: outbound (46483 - 192.168.2.98:49966) [14]
    * transport: TCPROS
 * topic: /tf
    * to: /ekf_localization (http://192.168.2.98:42883/)
    * direction: inbound
    * transport: INTRAPROCESS
 * topic: /tf
    * to: /robot_state_publisher (http://192.168.2.98:45697/)
    * direction: inbound (55732 - 192.168.2.98:52579) [17]
    * transport: TCPROS
 * topic: /tf
    * to: /odometry_publisher (http://192.168.2.98:43625/)
    * direction: inbound (58902 - 192.168.2.98:36909) [18]
    * transport: TCPROS
 * topic: /tf
    * to: /imu_filter_madgwick (http://192.168.2.98:40889/)
    * direction: inbound (40314 - 192.168.2.98:57775) [19]
    * transport: TCPROS
 * topic: /tf_static
    * to: /robot_state_publisher (http://192.168.2.98:45697/)
    * direction: inbound (55730 - 192.168.2.98:52579) [16]
    * transport: TCPROS
 * topic: /odom_raw
    * to: /odometry_publisher (http://192.168.2.98:43625/)
    * direction: inbound (59100 - 192.168.2.98:36909) [13]
    * transport: TCPROS
 * topic: /imu/imu_data
    * to: /imu_filter_madgwick (http://192.168.2.98:40889/)
    * direction: inbound (40512 - 192.168.2.98:57775) [10]
    * transport: TCPROS
```

Next, we describe these nodes in detail.

6.1.3 imu_filter_madgwick

1 Introduction

IMU refers to a six-axis sensor that includes a gyroscope and an accelerometer. MARG refers to a nine-axis sensor that adds a magnetometer to the IMU.

```
IMU  =  gyroscope  +  accelerometer
MARG (Magnetic, Angular  Rate, and  Gravity)  =  gyroscope  +  accelerometer  +
magnetometer
```

Madgwick is an Orientation Filter that filters and fuses raw data from IMU devices. It fuses angular velocity, acceleration, and (optional) magnetometer readings from generic IMU devices into orientation quaternions, and publishes the fused data on the IMU topic, regardless of the overall IMU integration process.

2. topic

/	topic name	type	Parse
Subscribed	/imu/data_raw	sensor_msgs/Imu	Messages of calibrated IMU data, including angular velocity and linear acceleration
Subscribed	/imu/mag	sensor_msgs/MagneticField	[Optional] Magnetometer, will be affected by magnetic fields
Published	/imu/data	sensor_msgs/Imu	Fused Imu information.

3. parameters

parameter name	type	Defaults	Parse
~gain	double	0.1	The gain of the filter. Higher values result in faster convergence but more noise. The lower the value, the slower the convergence, but the smoother the signal. Range: 0.0 to 1.0
~zeta	double	0.0	Gyro drift gain (about rad/s). Range: -1.0 to 1.0
~ mag_bias_x	double	0.0	Magnetometer bias (hard iron corrected) x-component. Range: -10.0 to 10.0
~mag_bias_y	double	0.0	Magnetometer bias (hard iron correction) y component. Range: -10.0 to 10.0
~ mag_bias_z	double	0.0	Magnetometer bias (hard iron correction) z component. Range: -10.0 to 10.0
~orientation_stddev	double	0.0	The standard deviation of the orientation estimate. Range: 0.0 to 1.0
~world_frame	string	"nwu"	World frame indicating direction (see REP-145). The old default was "nwu" (northwest up). New deployments should use "enu". Valid values: "nwu", "enu", "ned".
~ use_mag	bool	true	Whether to use magnetic field data in data fusion.
~use_magnetic_field_msg	bool	false	If set to true, Then subscribe /imu and /mag topics as sensor_msgs/MagneticField; If set to false (deprecated) Then use geometry_msgs/Vector3Stamped
~fixed_frame	string	odom	Parent coordinate system to use in publishing
~publish_tf	bool	false	Whether to publish the TF transform representing the direction of the IMU as the pose of the IMU; Use a fixed coordinate system as the parent coordinate system, The input imu information is used as the sub-coordinate system

parameter name	type	Defaults	Parse
~reverse_tf	bool	false	If set to true, the transformation from the imu coordinate system to the fixed coordinate system is published, not the other way around.
~constant_dt	double	0.0	The dt to use; if 0.0 (default) the dt dynamic value is calculated from the message start position.
~publish_debug_topics	bool	false	If set to true, two debug topics are published.
~stateless	bool	false	If set to true, the filtered orientation is not published. Instead, a stateless estimate of orientation is published based only on the latest accelerometer (and optional magnetometer) readings. for debugging.
~remove_gravity_vector	bool	false	If set to true, the gravity vector is subtracted from the acceleration field in the published IMU message.

6.1.4 robot_localization

1 Introduction

`robot_localization` is a collection of state estimation nodes, each of which is an implementation of a nonlinear state estimator for a robot moving in 3D space. It includes two state estimation nodes `ekf_localization_node` and `ukf_localization_node`. in addition, `robot_localization` supply `navsat_transform_node`, it helps to integrate GPS data.

`ekf_localization_node` is Extended Kalman Filter . It uses an omnidirectional motion model to predict states in time and uses sensed sensor data to correct the predicted estimates.

`ukf_localization_node` is unscented Kalman filter . It uses a carefully chosen set of sigma points to project the state through the same motion model used in the EKF, and then uses these projected sigma points to recover the state estimate and covariance. This eliminates the use of the Jacobian matrix and makes the filter more stable. However, with `ekf_localization_node` It is also more computationally heavy in comparison.

2. topic

/	topic name	type	Parse
Subscribed	/imu/data	sensor_msgs/Imu	Filtered imu information
Subscribed	/odom_raw	nav_msgs/Odometry	Odometer Information
Published	/odom	nav_msgs/Odometry	Fusion odometer information
Published	/tf	tf2_msgs/TFMessage	Coordinate system information

3. parameters

- frequency: The true frequency (in Hz) at which the filter produces state estimates. **Note: The filter does not start computing until it has received at least one message from one of the inputs.**
- [sensor] : For each sensor, the user needs to define this parameter according to the message type. Each parameter name is indexed from 0 (e.g. odom0, odom1, etc.) and must be defined in order (e.g. don't use pose0 and pose2 if pose1 is not already defined). The value of each parameter is the topic name for that sensor.

  ```
  odom0: /odom_raw
  ```

  ```
  imu0:/imu/data
  ```

- [sensor]_differential: For each sensor message defined above that contains pose information, the user can specify whether the pose variables should be integrated differentially. If the given value is set to true, then for the measurement taken at time t from the relevant sensor, we will first subtract the measurement at time t-1 and then convert the resulting value to velocity.

  ```
  ~odomN_differential
  ```

  ```
  ~imuN_differential
  ```

  ```
  ~poseN_differential
  ```

- [sensor]_relative: If this parameter is set to true, any measurements from this sensor will be fused relative to the first measurement received from this sensor. This is useful, for example, if you want the state estimate to always start at (0,0,0) and the roll, pitch and yaw angle values to be (0,0,0).

  ```
  ~odomN_relative
  ```

  ```
  ~imuN_relative
  ```

  ```
  ~poseN_relative
  ```

- two_d_mode: Set this to true if your robot operates in a flat environment and can ignore small changes in the ground (as reported by the IMU). It fuses all 3D variables (Z, roll, pitch and their respective velocity and acceleration) into a value of 0. This ensures that the covariances of these values don't explode, while ensuring that your robot's state estimate remains fixed on the XY plane.
- odom0_config ： [false, false, false, false, false, false, true, true, false, false, false, true, false, false, false]

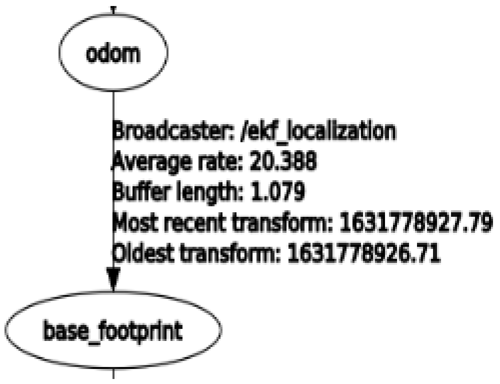
  The order of Boolean values is: [[X],[Y],[Z],[roll],[pitch],[yaw],[X '],[Y '],[Z '],[roll '],[pitch '],[yaw '],[X ''],[Y ''],[Z '']]. The user must specify which variables of these messages should be fused into the final state estimate.

4. the published transformation

If the user's `world_frame` parameter is set to `odom_frame` value, the conversion from `odom_frame` The coordinate system given by the parameter is published to `base_link_frame` The coordinate system given by the parameter. If the user's `world_frame` parameter is set to `map_frame` value, the conversion from `map_frame` The coordinate system given by the parameter is published to `odom_frame` The coordinate system given by the parameter.

For example, we set to publish the transformation from the coordinate system given by the [odom_frame] parameter to the coordinate system given by the [base_link_frame] parameter.

```
odom_frame: odom
base_link_frame: base_footprint
world_frame: odom
```


odom
Broadcaster: /ekf_localization
Average rate: 20.388
Buffer length: 1.079
Most recent transform: 1631778927.79
Oldest transform: 1631778926.71
base_footprint