15.ROS-TF transformation

TF transformation is coordinate transformation, including transformation of position and attitude. It uses a tree data structure to buffer and maintain coordinate transformation relationships between multiple coordinate systems based on time, which can help developers complete coordinate transformations such as points and vectors at any time and between coordinate systems. This course explains what are the commonly used TF tools in the ros system and how to broadcast/monitor transformations.

15.1 TF common tools

When introducing the TF tool, first understand two important concepts: source_frame and target_frame, also called parent_frame and child_frame. They each represent a coordinate system. When we broadcast or monitor the TF transformation, we are actually broadcasting and monitoring the relative pose transformation of the two.

15.1.1 tf_monitor

Used to print the release status of all coordinate systems in the TF tree, terminal input,

```
rosrun tf tf_monitor
```

After running, all the publishing status will be printed out in the running terminal. Of course, the publishing status of the specified coordinates can also be printed. You need to add the name of the specified coordinate system at the end and enter it in the terminal.

```
rosrun tf tf_monitor source_frame target_frame
```

15.1.2 tf_echo

Used to view the transformation relationship between specified coordinate systems, terminal input,

```
rosrun tf tf_echo source_frame target_frame
```

15.1.3、static_transform_publisher

Used to publish static coordinate transformations between two coordinate systems that do not undergo relative position changes. This tool needs to set the offset parameters and rotation parameters of the coordinates, and the publishing frequency is in ms. Terminal input,

```
#Euler angle format display
#Euler angle yaw (yaw angle rotating around the z-axis) pitch (pitch angle
rotating around the y-axis) roll (roll angle rotating around the x-axis)
rosrun tf static_transform_publisher x y x yaw pitch roll frame_id child_frame_id
period_in_ms
#Quaternion format display
static_transform_publisher x y z  qx qy qz qw frame_id child_frame_id
period_in_ms
```

15.1.4 rqt_tf_tree

This is a real-time tool that observes the coordinate system tree published on ros and uses the refresh button to update the contents of the tree. Terminal input,

```
rosrun rqt_tf_tree rqt_tf_tree
```

15.2. TF transformation broadcast and monitoring programming implementation (C++)

Steps to create tf broadcaster:

- Define tf broadcaster (TransformBroadcaster);
- Initialize tf data and create coordinate transformation values;
- Publish coordinate transformation (sendTransform);

Steps to create tf listener:

- Define TF listener (TransformListener);
- Look up coordinate transformation (waitForTransform, lookupTransform)

First create a function package, the command is learn_tf, enter in the terminal,

```
cd ~/ros_ws/src
catkin_create_pkg learn_tf rospy roscpp turtlesim tf
```

After creation, return to the workspace and compile.

```
cd ~/ros_ws
catkin_make
```

15.2.1. Create TF broadcaster

In the src folder of the function package learn_tf, create a c++ file (the file suffix is .cpp), name it turtle_tf_broadcaster.cpp, and copy the following code into it,

```
#include <ros/ros.h>
#include <tf/transform_broadcaster.h>
#include <turtlesim/Pose.h>
std::string turtle_name;
void poseCallback(const turtlesim::PoseConstPtr& msg)
{
    static tf::TransformBroadcaster br;// Create a tf broadcaster
    // Initialize tf data
    tf::Transform transform;
    transform.setOrigin( tf::Vector3(msg->x, msg->y, 0.0) );//Set xyz
coordinates
    tf::Quaternion q;
    q.setRPY(0, 0, msg->theta);//Set Euler angles: Rotate with x-axis, y-axis,
z-axis
    transform.setRotation(q);
    br.sendTransform(tf::StampedTransform(transform, ros::Time::now(),
"world",turtle_name));// Broadcast tf data between world and turtle coordinate
systems
```

```
}
int main(int argc, char** argv)
{
    ros::init(argc, argv, "turtle_world_tf_broadcaster");// Initialize ROS node
    if (argc != 2)
    {
    ROS_ERROR("Missing a parameter as the name of the turtle!");
    return -1;
    }
    turtle_name = argv[1];// Enter the parameter as the name of the turtle
    // Subscribe to turtle position topics/pose
    ros::NodeHandle node;
    ros::Subscriber sub = node.subscribe(turtle_name+"/pose", 10,&poseCallback);
    // Loop waiting for callback function
    ros::spin();
    return 0;
};
```

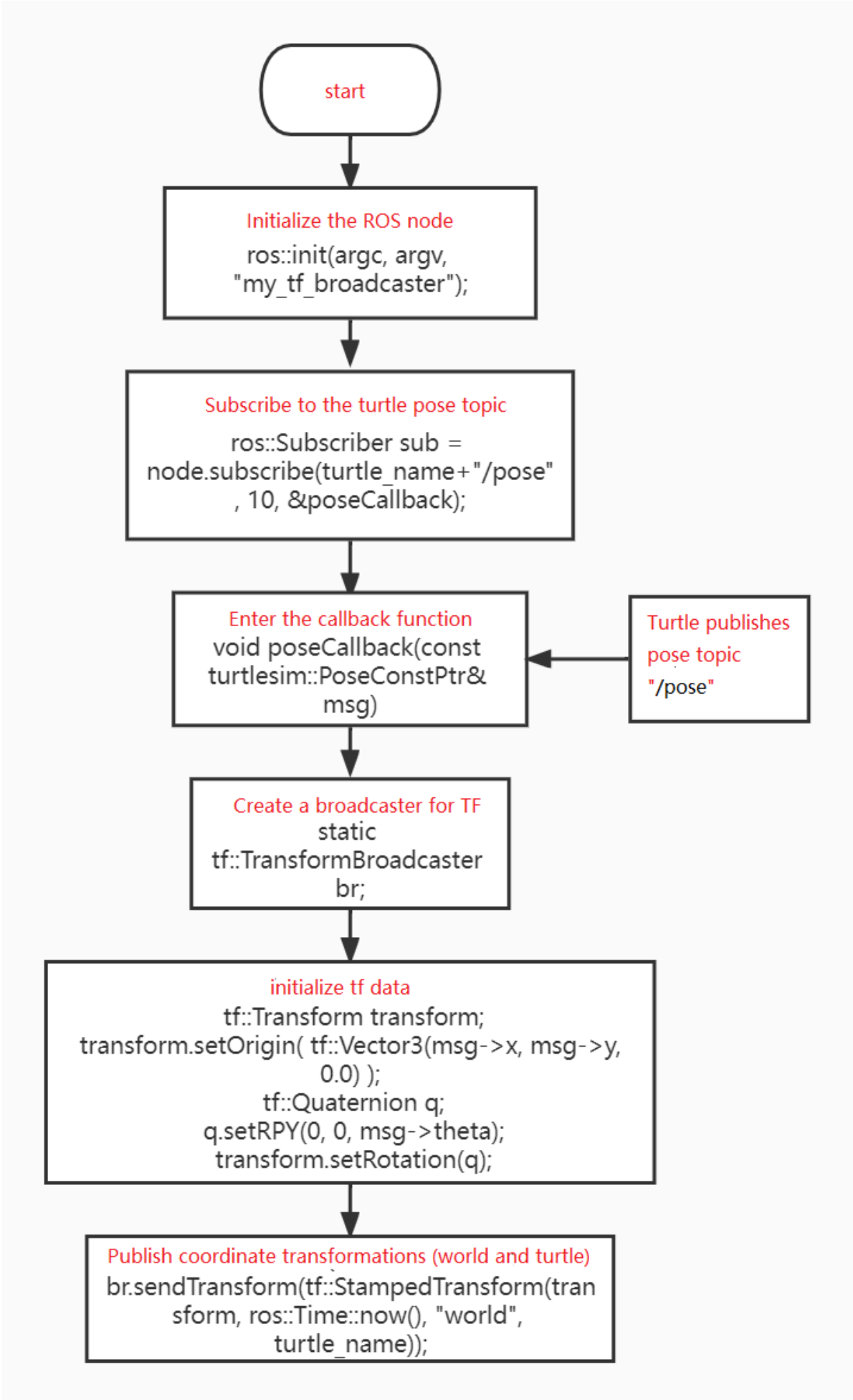
Modify the CMakeLists.txt file and add the following content,

```
add_executable(turtle_tf_broadcaster src/turtle_tf_broadcaster.cpp)
target_link_libraries(turtle_tf_broadcaster ${catkin_LIBRARIES})
```

Return to the workspace to compile,

```
cd ~/ros_ws
catkin_make
```

Program flow chart,



The code is analyzed as follows,

First, subscribe to the /pose topic of the little turtle. If the topic is published, then enter the callback function. In the callback function, first create the tf broadcaster, and then initialize the tf data. The value of the data is the data passed by the subscription/pose topic. Finally, the little turtle's transformation of the world coordinates is published through br.sendTransform. Here is the sendTransform function. There are 4 parameters. The first parameter represents the coordinate transformation of the tf::Transform type (that is, the previously initialized tf data).The second parameter is the timestamp, and the third and fourth are the source and target coordinate systems of the transformation.

15.2.2 Create TF listener

In the src folder of the function package learn_tf, create a c++ file (the file suffix is .cpp), name it turtle_tf_listener.cpp, and copy the following code into it,

```
/**
* This routine monitors tf data, calculates and issues turtle2 speed
instructions
turtle2->turtle1 = world->turtle*world->turtle2
*/
#include <ros/ros.h>
#include <tf/transform_listener.h>
#include <geometry_msgs/Twist.h>
#include <turtlesim/Spawn.h>
int main(int argc, char** argv)
{
    ros::init(argc, argv, "turtle1_turtle2_listener");// Initialize ROS node
    ros::NodeHandle node; // Create node handle
    // Request service produces turtle2
    ros::service::waitForService("/spawn");
    ros::ServiceClient add_turtle = node.serviceClient<turtlesim::Spawn>
("/spawn");
    turtlesim::Spawn srv;
    add_turtle.call(srv);
    // Create a publisher that publishes turtle2 speed control instructions
    ros::Publisher vel = node.advertise<geometry_msgs::Twist>
    ("/turtle2/cmd_vel", 10);
    tf::TransformListener listener;// Create a tf listener
    ros::Rate rate(10.0);
    while (node.ok())
    {
        // Get the tf data between turtle1 and turtle2 coordinate systems
        tf::StampedTransform transform;
        try
        {
            listener.waitForTransform("/turtle2", "/turtle1",
ros::Time(0),ros::Duration(3.0));
            listener.lookupTransform("/turtle2", "/turtle1",
ros::Time(0),transform);
        }
         catch (tf::TransformException &ex)
        {
            ROS_ERROR("%s",ex.what());
            ros::Duration(1.0).sleep();
            continue;
```

```
        }
        // According to the positional relationship between turtle1 and turtle2
coordinate systems, the angular velocity and linear velocity are obtained through
mathematical calculation formulas, and the speed control instructions of turtle2
are issued.
        geometry_msgs::Twist turtle2_vel_msg;
        turtle2_vel_msg.angular.z = 6.0 *
atan2(transform.getOrigin().y(),transform.getOrigin().x());
        turtle2_vel_msg.linear.x = 0.8 * sqrt(pow(transform.getOrigin().x(),
2)+pow(transform.getOrigin().y(), 2));
        vel.publish(turtle2_vel_msg);
        rate.sleep();
    }
    return 0;
};
```

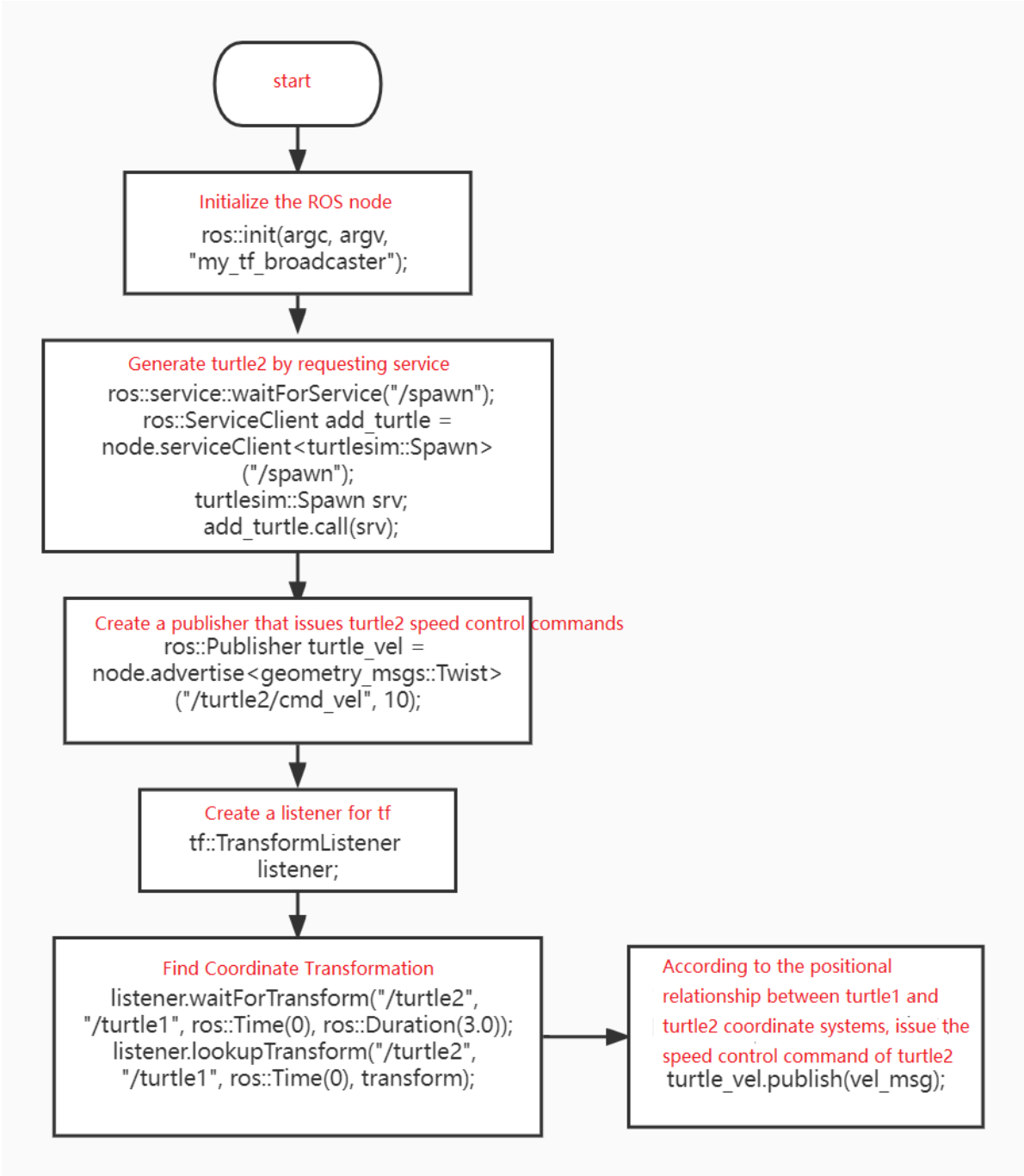
Modify the CMakeLists.txt file and add the following content,

```
add_executable(turtle_tf_listener src/turtle_tf_listener.cpp)
target_link_libraries(turtle_tf_listener ${catkin_LIBRARIES})
```

Return to the workspace to compile,

```
cd ~/ros_ws
catkin_make
```

Program flow chart,



The code is analyzed as follows,

First, another little turtle turtle2 is generated through service calls, and then a turtle2 speed control publisher is created; then a listener is created to monitor and find the left transformation of turtle1 and tuetle2. This involves two functions, waitForTransform and lookupTransform.

waitForTransform(target_frame,source_frame,time,timeout): The two frames represent the target coordinate system and the source coordinate system respectively.Time represents the time to wait for the transformation between the two coordinate systems. Because the coordinate transformation is a blocking program, timeout needs to be set to represent the timeout time.

lookupTransform(target_frame,source_frame,time,transform): Given the source coordinate system (source_frame) and the target coordinate system (target_frame), obtain the coordinate transformation (transform) at the specified time (time) between the two coordinate systems.

After lookupTransform, we get the result of coordinate transformation, transform, and then get the values of x and y through transform.getOrigin().y(), transform.getOrigin().x(),Then the angular velocity angular.z and linear velocity linear.x are obtained through mathematical operations, and finally published to let turtle2 move.

15.3. Run the program

After starting roscore, open the little turtle node. At this time, a little turtle will appear in the terminal; then we publish two tf transformations, turtle1->world, turtle2->world, because we want to know the changes between turtle2 and turtle1, You need to know the transformation between them and the world;Then, start the tf listening program. At this time, you will find that another small turtle turtle2 is generated in the terminal, and turtle2 will move towards turtle1;Then, we turn on the keyboard control and control the movement of turtle1 by pressing the direction keys, and then turtle2 will chase turtle1 to move.

First open roscore and enter in the terminal,

```
roscore
```

Run the little turtle node,

```
rosrun turtlesim turtlesim_node
```

Run the broadcast tf program and broadcast turtle1->world,

```
rosrun learn_tf turtle_tf_broadcaster __name:=turtle1_tf_broadcaster /turtle1
```

Run the broadcast tf program and broadcast turtle2->world,

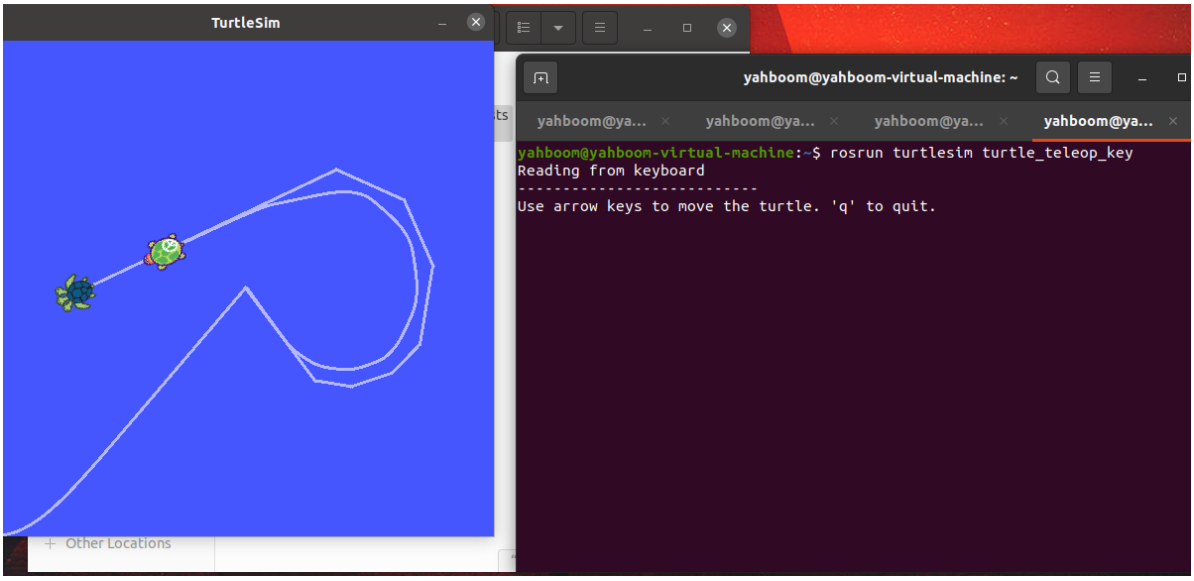
```
rosrun learn_tf turtle_tf_broadcaster __name:=turtle2_tf_broadcaster /turtle2
```

Run the listening tf program,

```
rosrun learn_tf turtle_tf_listener
```

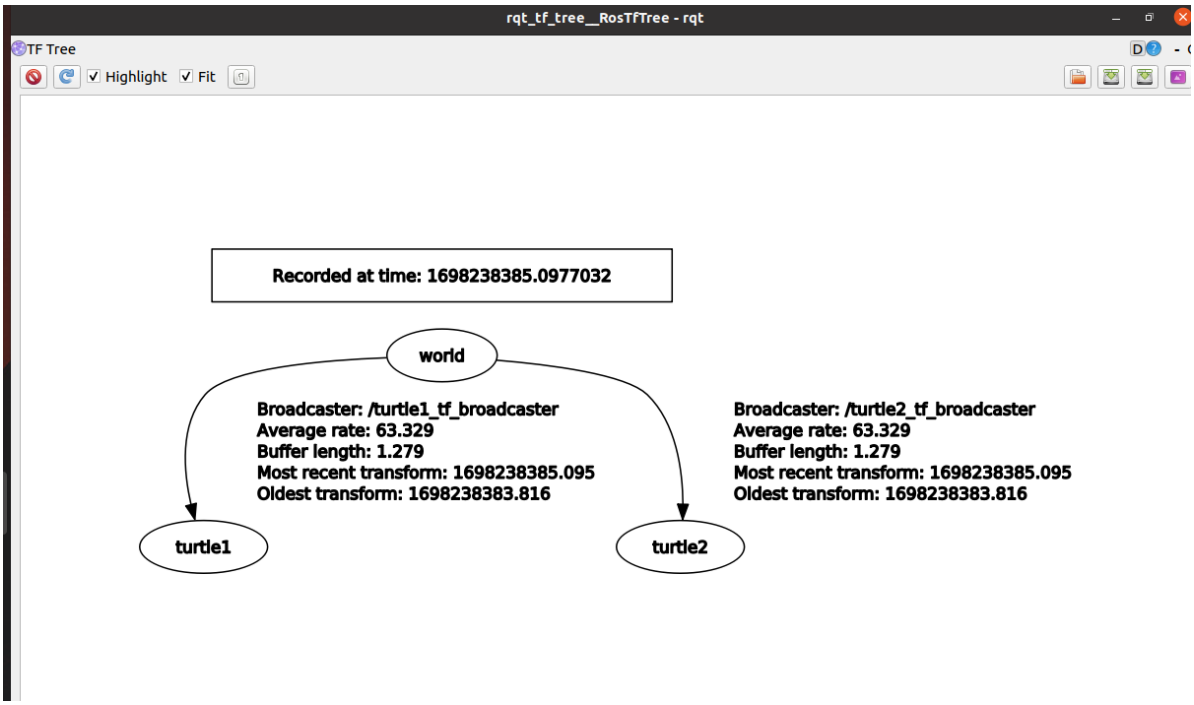
Run the keyboard to control the little turtle node,

```
rosrun turtlesim turtle_teleop_key
```



You can enter `rosrun rqt_tf_tree rqt_tf_tree` to view the TF tree and enter it in the terminal.

```
rosrun rqt_tf_tree rqt_tf_tree
```



As shown in the figure above, both turtle1 and turtle2 have a TF transformation relationship with the world. Therefore, when turtle1 undergoes relative coordinate transformation relative to the world, turtle2 knows where turtle1 is.Then calculate the relative posture of the two, adjust the linear velocity and angular velocity of turtle2, and move to the position of turtle1.

15.4 TF transformation broadcast and monitoring programming implementation (Python)

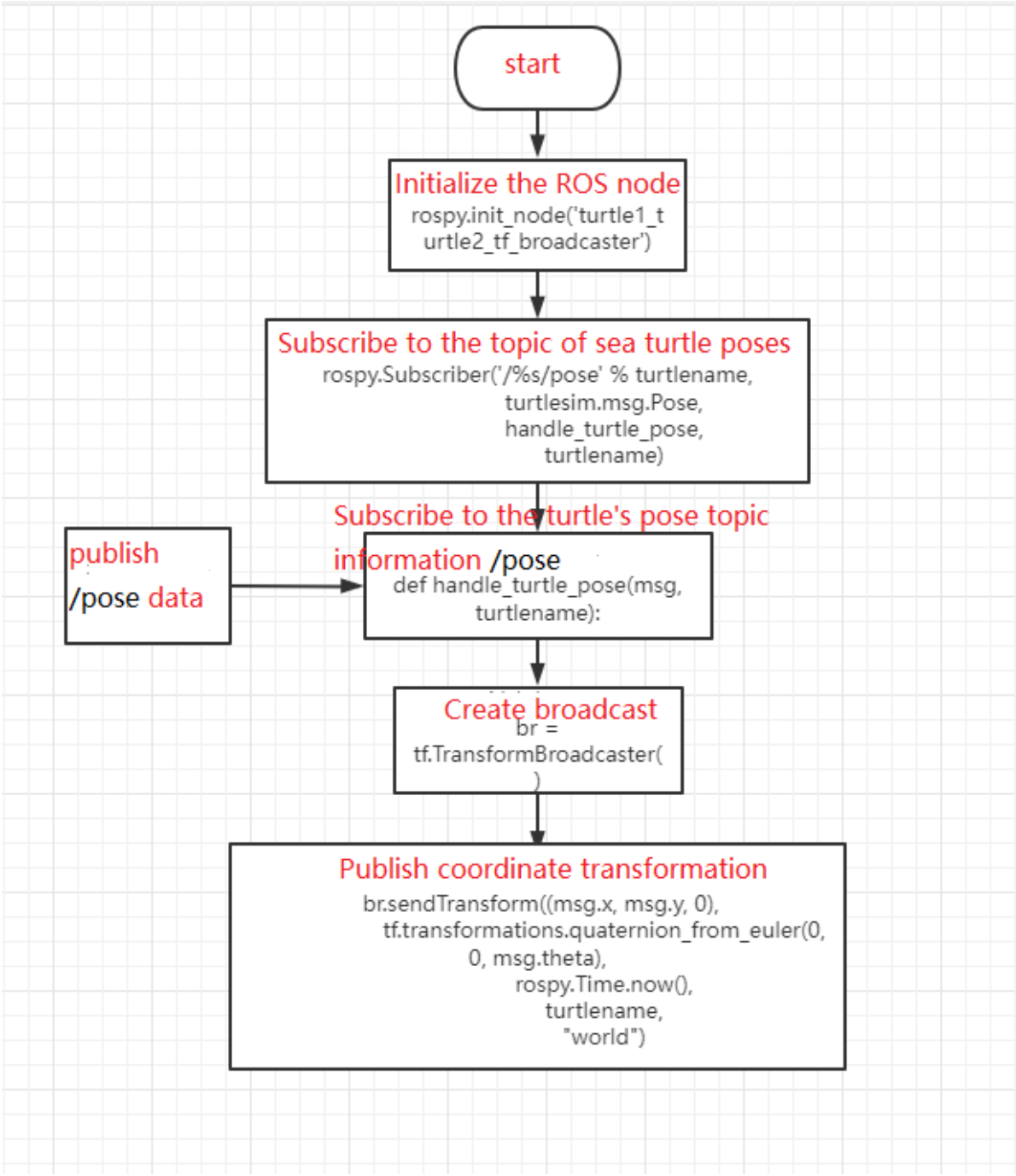
15.4.1 Create TF broadcaster

In the function package learn_tf, create a folder script, switch to the directory, create a new .py file, name it turtle_tf_broadcaster.py, copy and paste the following program code into the turtle_tf_broadcaster.py file,

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-
import roslib
roslib.load_manifest('learn_tf')
import rospy
import tf
import turtlesim.msg
def handle_turtle_pose(msg, turtlename):
    br = tf.TransformBroadcaster()#Define a tf broadcast
    #tf transformation between broadcast world and input named turtle
    br.sendTransform((msg.x, msg.y,
0),tf.transformations.quaternion_from_euler(0, 0,
msg.theta),rospy.Time.now(),turtlename,"world")
if __name__ == '__main__':
    rospy.init_node('turtle1_turtle2_tf_broadcaster')#Initialize ros node
    turtlename = rospy.get_param('~turtle',"turtle_name") #Get the turtle's name
from the parameter server
    #Subscribe/pose topic data, which is the turtle's pose information
```

```
    rospy.Subscriber('/%s/pose' %
turtlename,turtlesim.msg.Pose,handle_turtle_pose,turtlename)
    rospy.spin()
```

Program flow chart,



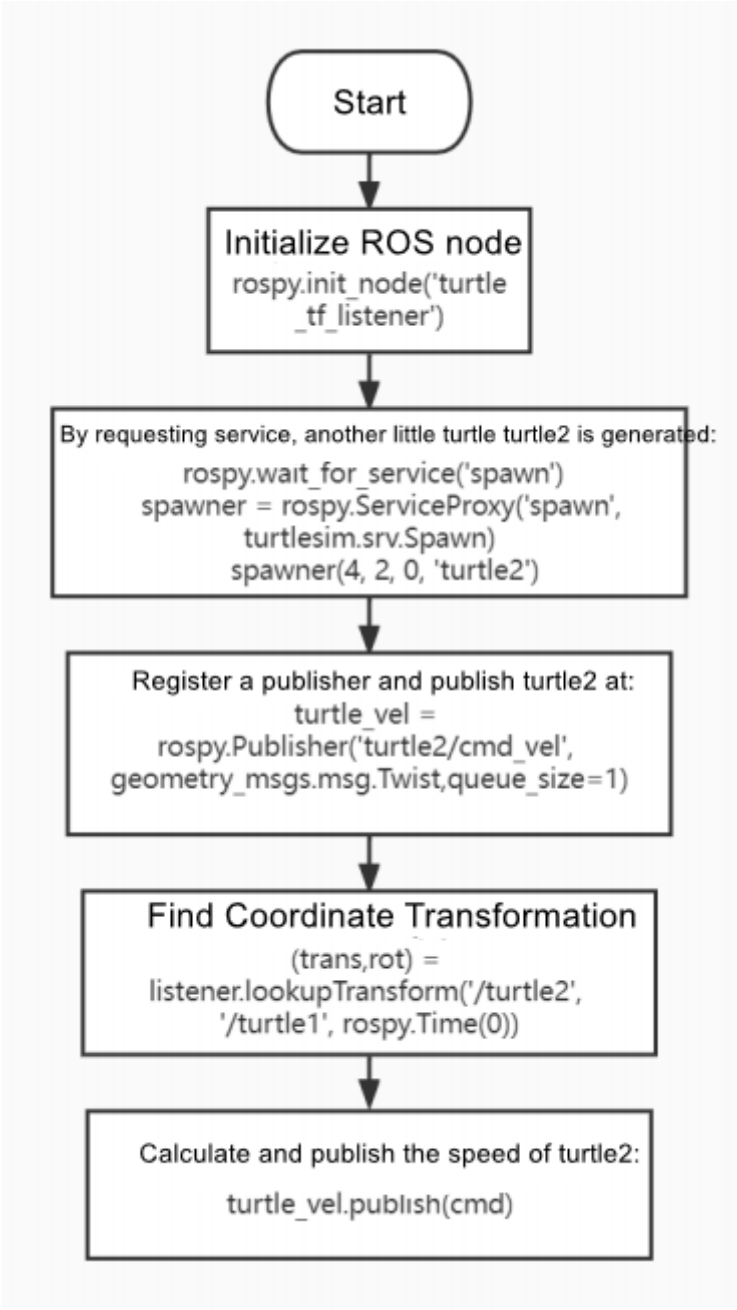
15.4.2 Create TF listener

In the function package learn_tf, create a folder script, switch to the directory, create a new .py file, name it turtle_tf_listener.py, copy and paste the following program code into the turtle_tf_listener.py file,

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-
import rospy
import math
import tf
import geometry_msgs.msg
```

```
import turtlesim.srv
if __name__ == '__main__':
    rospy.init_node('turtle_tf_listener')#Initialize ros node
    listener = tf.TransformListener()#Initialize a listener
    rospy.wait_for_service('spawn')
    #Call the service to spawn another turtle turtle2
    spawner = rospy.ServiceProxy('spawn', turtlesim.srv.Spawn)
    spawner(8, 6, 0, 'turtle2')
    #Declare a publisher to publish the speed of turtle2
    turtle_vel =
rospy.Publisher('turtle2/cmd_vel',geometry_msgs.msg.Twist,queue_size=1)
    rate = rospy.Rate(10.0)
    while not rospy.is_shutdown():
        try:
        #Find tf changes between turtle2 and turtle1
            (trans,rot) = listener.lookupTransform('/turtle2',
'/turtle1',rospy.Time(0))
        except (tf.LookupException,
tf.ConnectivityException,tf.ExtrapolationException):
            continue
    #Through mathematical calculations, calculate the linear velocity and angular
velocity, and then publish them
        angular = 6.0 * math.atan2(trans[1], trans[0])
        linear = 0.8 * math.sqrt(trans[0] ** 2 + trans[1] ** 2)
        cmd = geometry_msgs.msg.Twist()
        cmd.linear.x = linear
        cmd.angular.z = angular
        turtle_vel.publish(cmd)
        rate.sleep()
```

Program flow chart,



15.4.3. Write launch file to start

After the two python files are written, you need to give execution permission and enter in the terminal.

```
cd ~/ros_ws/src/learn_tf/scripts
sudo chmod a+x turtle_tf_listener.py
sudo chmod a+x turtle_tf_broadcaster.py
```

In the function package directory, create a new folder launch, switch to launch, create a new launch file, name it start_tf_demo_py.launch, and copy the following content into it,

```
<launch>
        <!-- Turtle Node-->
    <node pkg="turtlesim" type="turtlesim_node" name="sim"/>
        <!--broadcast turtle1->world-->
    <node name="turtle1_tf_broadcaster" pkg="learn_tf"
type="turtle_tf_broadcaster.py" respawn="false" output="screen" >
        <param name="turtle" type="string" value="turtle1" />
```

```
    </node>
        <!--broadcast turtle2->world-->
    <node name="turtle2_tf_broadcaster" pkg="learn_tf"
type="turtle_tf_broadcaster.py" respawn="false" output="screen" >
        <param name="turtle" type="string" value="turtle2" />
    </node>
        <!--listener-->
    <node pkg="learn_tf" type="turtle_tf_listener.py" name="listener" />
        <!--Turtle keyboard control node-->
    <node pkg="turtlesim" type="turtle_teleop_key" name="teleop"
output="screen"/>
</launch>
```

15.5 Startup

Terminal starts,

```
roslaunch learn_tf start_tf_demo_py.launch
```

After the program is running, click the mouse on the window running launch and press the arrow keys. Turtle2 will move with turtle1.