Robot Programming Transforms and Sensors in ROS

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Outline

- Robot Devices
  - Overview of Typical sensors and Actuators
  - Operating Devices in ROS
- Describing your Robot
  - Transform Tree
  - Transform Publisher
- Transforms and Time
  - Interpolating Transforms
  - TF library
  - Publishing and reading transforms
- Hands on a robot
- Displaying sensor data (rviz)
- Recording real data with a robot

How to access a Device in ROS?

- Each device is a node
- The input topics are the commands that the device can output
- The output topics are the feedback given by the device.

- In sensor_msgs/ many messages for the common sensors are defined.
- Use rosmsg show <message_name> to see the format of a message.

- To start a device it is sufficient to start the corresponding node and to give it the necessary configuration parameters. These include
  - Specific devices parameters (e.g. which serial port/usb device , the resolution of an image, and so on..)
  - The **name** of the **reference frame** in the sensor

Mobile Base in ROS

- Typical mobile bases are mapped as ROS nodes that
  - Publish messages of type
    - `nav_msgs/Odometry`

    These messages specify the odometry

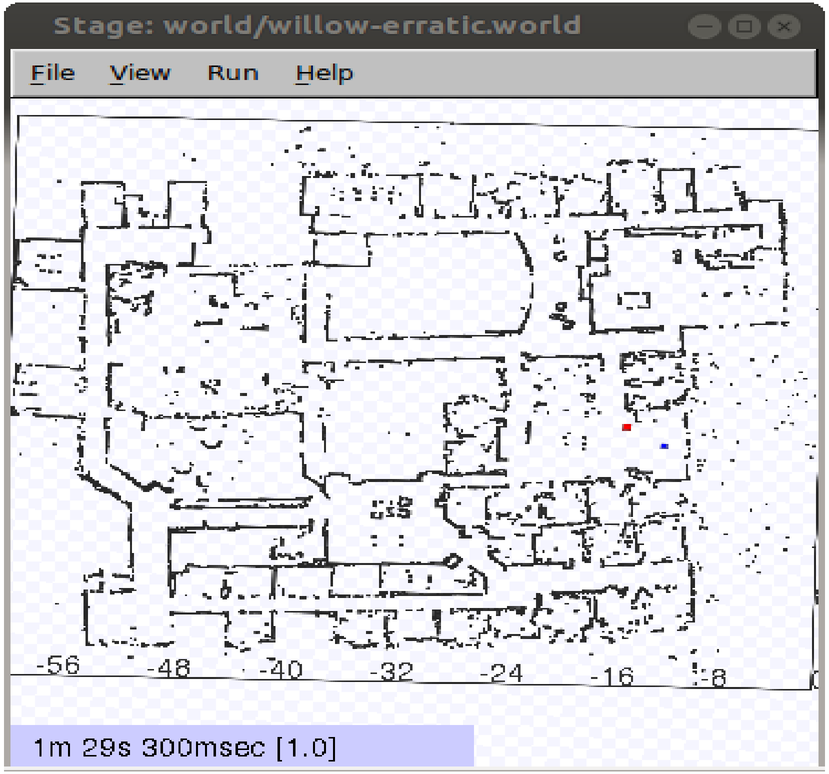
  - Subscribes to messages of type
    - `geometry_msgs/Twist`

      That specify the desired translational and rotational velocities

All this looks very similar to TurtleSim, but the transforms and the velocities are computed in 3D

Stage

- To launch stage
  - `$> roscore`
  - `$> roscd stage`
  - `$> rosrun stage stageros words/willow_erratic word`
- With rostopic you will see that there is a `/cmd_vel` argument. Publishing on this topic allows you to set the the robot speed
- The robot sends you the odometry feedback by the /odom topic, and potentially some additional state packet.

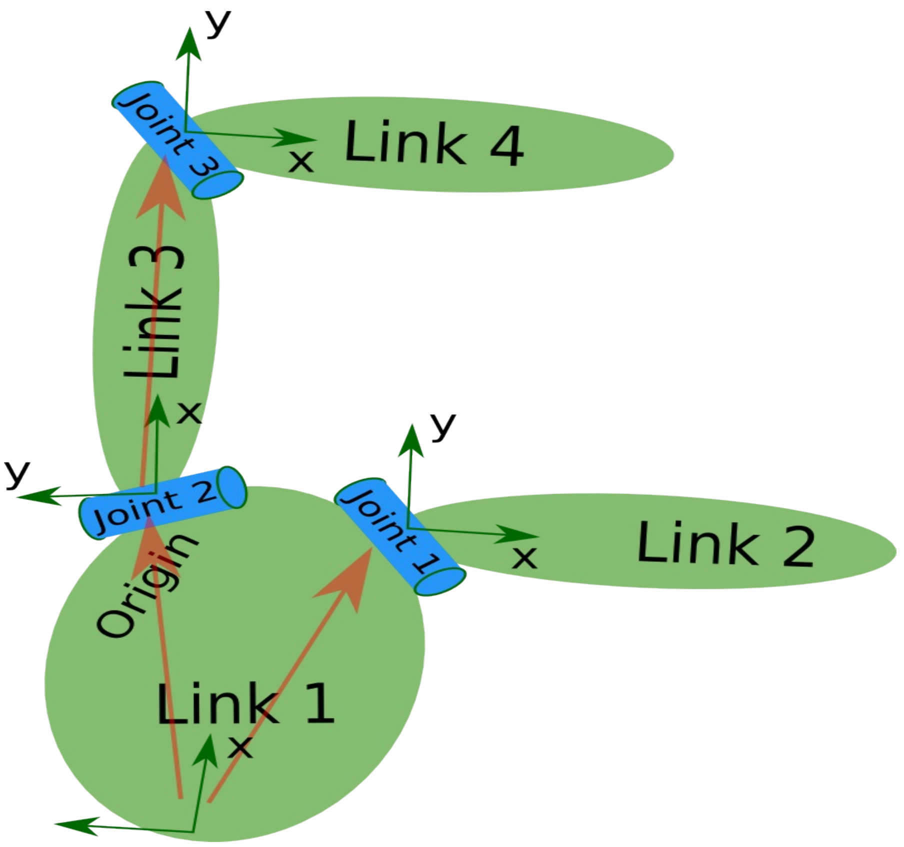


Specifying the Arrangement of Devices

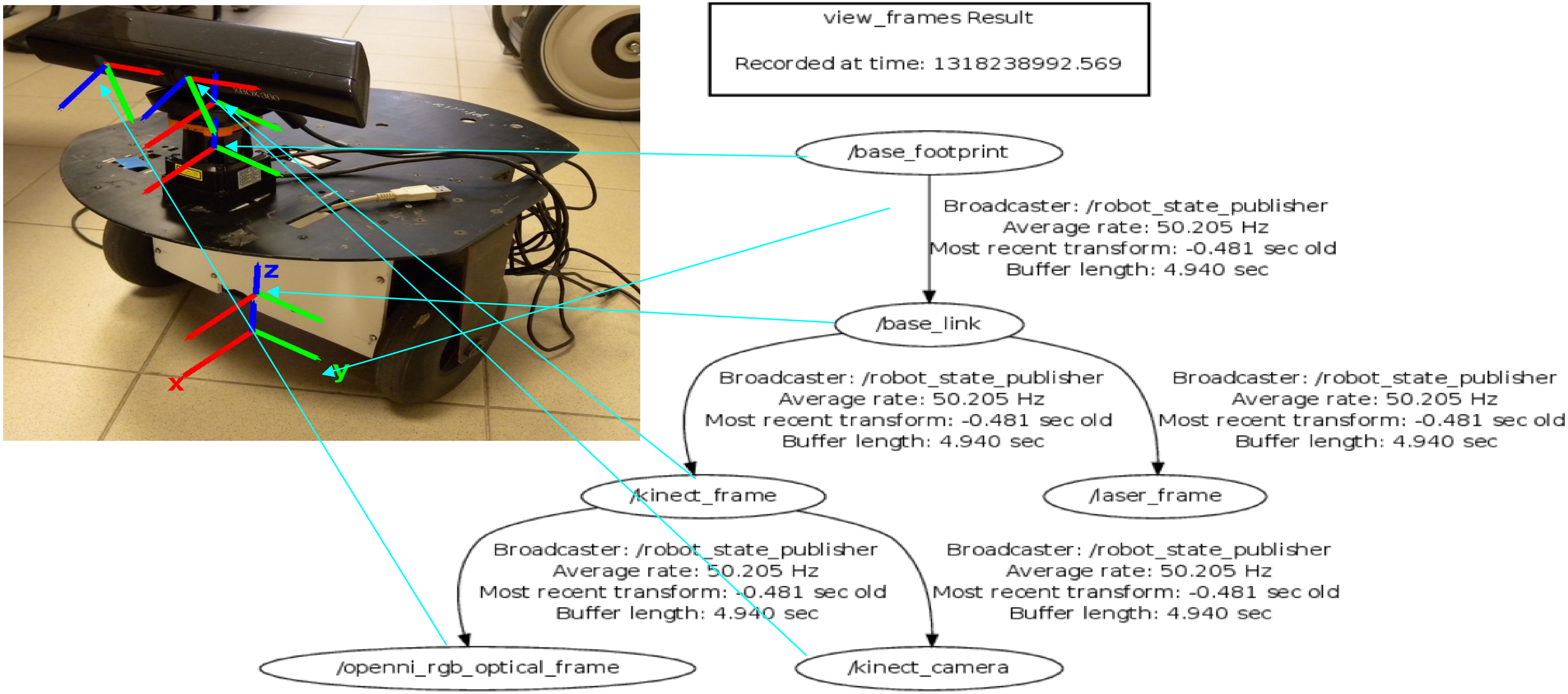
- All these devices are mounted on a robot in an articulated way.
- Some devices are mounted on other devices that can move.
- In order to use all the sensors/actuators together we need to describe this configuration.
  - For each “device” specify one or more frames of interest
  - Describe how these frames are located w.r.t each other

Defining the Structure

- You have to specify the kinematics of the robot.
- Each “Link” is a reference frame of a sensor
- Each “joint” defines the transformation that maps the child link in the parent link.
- ROS does not handle closed kinematic chains, thus only a “tree” structure is allowed
- The root of the tree is usually some convenient point on the mobile base (or on its footprint)



Practical Example



Transform Publishers

- **A transform can be published by any ros node**.
- The local configuration of a robot (e.g. the position of the sensors/actuators w.r.t a frame on the robot platform) is usually published by a convenience node: the **robot_state_publisher**.
- **The robot state publisher**:
  - takes a description of the robot (the kinematics), that specifies for each frame:
    - the parent frame
    - the type of joint
  - Listens the state of the joints
  - Computes the transforms for all the frames.
- If the robot has no movable devices (except the base) one can use the **static_transform_publisher**.
- The **static transform publisher** is a node that can be invoked like that

  $> `rosrun tf static_transform_publisher fromFrame toFrame x y z roll pitch yaw hz`

  e.g.

  $> `rosrun tf static_transform_publisher baseFrame cameraFrame 0 0 0.3 0 0 3.14 10`

  will start a node that publishes a transform between the baseFrame and the camera, telling that the camera is mounted at 30 cm above the mobile base and is looking backwards (yaw = M_PI).(*)

(*) check the online documentation for an updated command line

Visualizing The Data

- Once all sensors are started and the robot description is correctly done, we can visualize the data.
- To this end, we will use the RVIZ ros tool.
- I will give a practical example, you can look at the ros wiki, for rviz.

Interpolation

- A robot is a complex system consisting in a potentially large set of devices
- These devices typically run in an asynchronous fashion. Each of them outputs the data when available.
- In many tasks, we are interested in knowing the position of the robot when a specific information is gathered by the sensor
- At this time, however there might not be a valid transformation, thus we have to determine the sensor position by interpolation.

Interpolation (II)

- To interpolate the position of a joint at time t we need to know
  - The position at time $t_m < t$
  - The position at time $t_M > t$
  - The velocities and
  - The kinematic constraints
- All these informations are available in the tf messages
- ROS provides a ***tf*** client library to interpolate and publish transforms.

TF Main Facts

- To perform interpolation it installs a set of transform buffers, one for each frame.
- It allows to send/receive transform messages
- One can obtain the interpolated position between any pair of frames.
- The ***tf*** package contains several useful programs to debug the system
  - **view_frames**: generates a pdf file by listening all transforms

    `$> rosrun tf view_frames`
  - **static_transform_publisher**: is a node that streams a specific transform given as argument.

Using TF

- TF has an own Listener that sets up the buffers
```
TransformListener(
ros::Duration max_cache_time=ros::Duration(DEFAULT_CACHE_TIME),
bool spin_thread=true)
```

- To see if you can compute the position of a frame w.r.t. another one you should first check that the buffers are consistend with the query
```
bool tf::TransformListener::canTransform (
const std::string &target_frame,
const std::string &source_frame,
const ros::Time &time,
std::string *error_msg=NULL) const
```

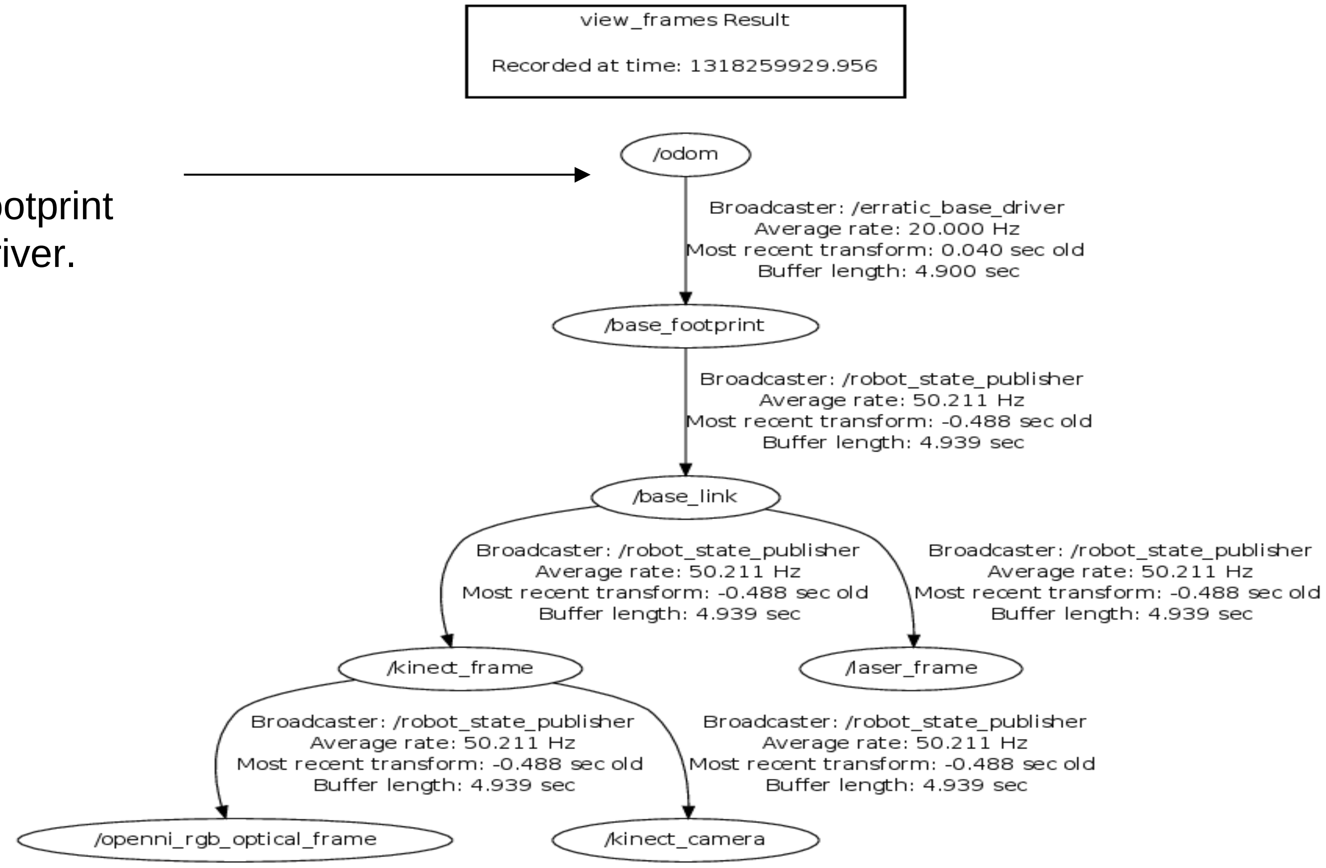
- To compute a transform between to frames use the following function
```
void tf::TransformListener::lookupTransform (
    const std::string &target_frame,
    const std::string &source_frame,
    const ros::Time &time,
    StampedTransform &transform) const
```

Recording a Dataset

- With **rosbag** you can record in a bag all the messages about a specific topic
- We will now record a bag of a moving robot
- This bag will be made available to you

Transform Tree in the Bag

New base frame.
Transform from odom to base_footprint
Is published by the base robot driver.



Launch Files

- A system running on ROS may consist in a large number of nodes, each with its parameters
- To start these nodes, one might use the .launch files (See roslaunch).
- Launch files are xml scripts used to start and configure a large number of nodes
- They need to reside in the /launch directory of a package
- They can be started with

  roslaunch <package_name> <launch_file>

```
<launch>

        <node name="map_server" pkg="map_server" type="map_server" args="$
        (find dis_navigation)/maps/dis-B1-2011-09-27.yaml"/>

           <group ns="erratic1">
                   <param name="tf_prefix" value="erratic1" />

                  <include file="$(find
        dis_robots)/launch/erratic_hokuyo.launch" />
                  <param name="hokuyo/frame_id" type="str"
        value="/erratic1/laser_frame"/>

                   <include file="$(find
        dis_navigation)/config/localization/glocalizer_node.xml" />
                   <include file="$(find dis_navigation)/config/navigation/
        move_base.xml" />
                   <node pkg="tf" type="static_transform_publisher"
        name="link_broadcaster_0" args="0 0 0 0 0 0 /map /erratic1/map 100"
        />
           </group>


          <group ns="erratic1">
                   <param name="glocalizer/initial_pose_x" value="0" />
                   <param name="glocalizer/initial_pose_y" value="1.8" />
                   <param name="glocalizer/initial_pose_a" value="0" />
           </group>


</launch>
```

Exercise 1

- Write a ros node that writes in a text format the 2D location of the laser (x,y,theta) when laser messages arrive, and the timestamp
- FORMAT:
  - One line per message
  - **`LASER <timestamp.sec>.<timestamp.usec> <laser pose w.r.t. odom frame (x,y,theta)>`**

Exercise Hints

- 1. create a transform listener
- 2. create a laser callback
  - In the laser callback query if you can obtain a transform from /odom to the laser frame specified in the laser message header (use canTransform)
  - If this is true, retrieve the transform (use lookup_transform)
  - Extract x,y,and yaw from the pair <translation, quaternion> stored in the transform filled by lookup_transform.
  - Append it to a file.

Exercise 2

- Extend the previous exercise to generate a file containing the laser endpoints in the /odom referece frame, at robot pose, and dumping them on a file.
- One point per line <x> <y>