Robot Programming with Lisp

7. Coordinate Transformations, TF, ActionLib

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Outline

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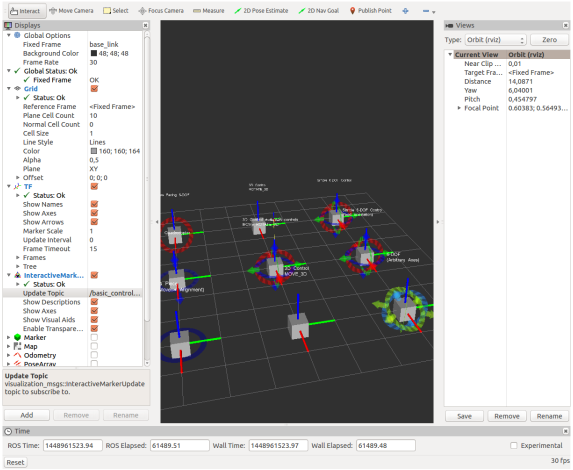
Poses in 3D Space

```
$ roscore
$ rosrun interactive_marker_tutorials basic_controls
$ rosrun rviz rviz
```



Global Options	
Fixed Frame	base_link
Background Color	■ 48; 48; 48
Frame Rate	30
✓ Global Status: Ok	
✓ Fixed Frame	OK
Grid	✓
✓ Status: Ok	
Reference Frame	<Fixed Frame>
Plane Cell Count	10
Normal Cell Count	0
Cell Size	1
Line Style	Lines
Color	■ 160; 160; 164
Alpha	0,5
Plane	XY
Offset	0; 0; 0
TF	✓
✓ Status: Ok	
Show Names	✓
Show Axes	✓
Show Arrows	✓
Marker Scale	1
Update Interval	0
Frame Timeout	15
Frames	
Tree	
InteractiveMark...	✓
✓ Status: Ok	
Update Topic	/basic_control...
Show Descriptions	✓
Show Axes	✓
Show Visual Aids	✓
Enable Transpare...	✓
Marker	☐
Map	☐
Odometry	☐
PoseArray	☐

Update Topic
visualization_msgs::InteractiveMarkerUpdate topic to subscribe to.

Add Remove Rename

Type: Orbit (rviz) Zero

Current View	Orbit (rviz)
Near Clip ...	0,01
Target Fra...	<Fixed Frame>
Distance	14,0871
Yaw	6,04001
Pitch	0,454797
Focal Point	0.60383; 0.56493...

Save Remove Rename

ROS Time: 1448961523.94 ROS Elapsed: 61489.51 Wall Time: 1448961523.97 Wall Elapsed: 61489.48 ☐ Experimental

Reset 30 fps

Representing Poses

Point in 3D: *{x, y, z}*

3D-Vector

```
CL-TRANSFORMS> (make-3d-vector 1 2 3)
#<3D-VECTOR (1.0d0 2.0d0 3.0d0)>
CL-TRANSFORMS> (describe *)
#<3D-VECTOR (1.0d0 2.0d0 3.0d0)>
  [standard-object]
Slots with :INSTANCE allocation:
  X   = 1.0d0
  Y   = 2.0d0
  Z   = 3.0d0
CL-TRANSFORMS> (y **)
2.0d0
```

Object in 3D: *{position, orientation}*

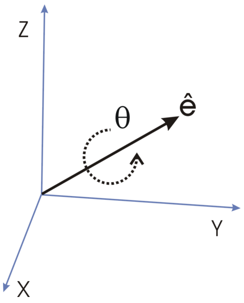
Position: *{x, y, z}*

Orientation: axis-angle / rotation matrix / quaternions / ...

Representing Rotations

Axis-Angle representation:

$$< axis, angle >= \left\langle \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}, \theta \right\rangle$$



Axis-Angle $\rightarrow$ Quaternion:

$$Q = \begin{pmatrix} q_x \\ q_y \\ q_z \\ q_w \end{pmatrix} = \begin{pmatrix} a_x \sin(\theta/2) \\ a_y \sin(\theta/2) \\ a_z \sin(\theta/2) \\ \cos(\theta/2) \end{pmatrix}$$

3D-Vector

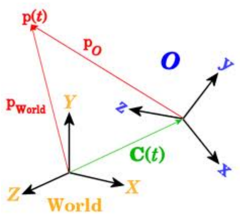
```
CL-TRANSFORMS> (make-quaternion 0 0 0 1)
CL-TRANSFORMS> (describe *)
#<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>
  [standard-object]
Slots with :INSTANCE allocation:
  X   = 0.0d0
  Y   = 0.0d0
  Z   = 0.0d0
  W   = 1.0d0
CL-TRANSFORMS> (axis-angle->quaternion
                 (make-3d-vector 0 0 1) pi)
```

Poses in Lisp

cl-transforms:pose

```
CL-TRANSFORMS> (setf p (make-pose
                         (make-3d-vector 1 2 0)
                         (make-quaternion 0 0 0 1)))
#<POSE
   #<3D-VECTOR (1.0d0 2.0d0 0.0d0)>
   #<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>>
CL-TRANSFORMS> (origin p)
#<3D-VECTOR (1.0d0 2.0d0 0.0d0)>
CL-TRANSFORMS> (orientation p)
#<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>
```

Coordinate Systems



Transformations

```
CL-TRANSFORMS> (setf W (make-identity-pose))
#<POSE
   #<3D-VECTOR (0.0d0 0.0d0 0.0d0)>
   #<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>>
CL-TRANSFORMS> (setf O (make-pose
                         (make-3d-vector 2 0 0)
                         (make-quaternion 0 0 0 1)))
#<POSE
   #<3D-VECTOR (2.0d0 0.0d0 0.0d0)>
   #<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>>
CL-TRANSFORMS> (transform
                (transform-inv (pose->transform O))
                p)
#<POSE
   #<3D-VECTOR (-1.0d0 2.0d0 0.0d0)>
   #<QUATERNION (0.0d0 0.0d0 0.0d0 1.0d0)>>
```

TurtleBot Coordinate Frames

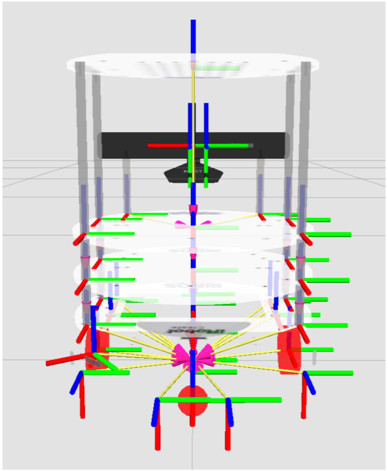
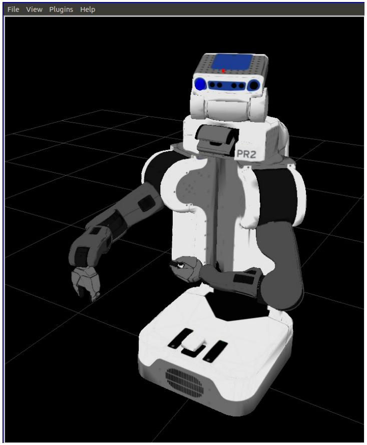


Image courtesy: Yujin Robot

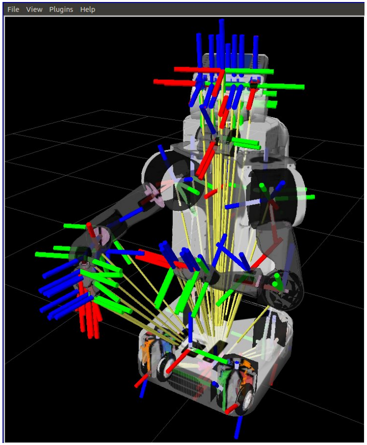
Outline

Motivation



- Robots consist of many *links*
- Every link describes its own *coordinate system*
- Sensor measurements are local to the corresponding link
- Links change their position over time (including the robot base)

Motivation



- Robots consist of many *links*
- Every link describes its own *coordinate system*
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Implementation

- Transforms are produced by different nodes:
  - Localization in map (AMCL, gmapping)
  - Odometry (base controller)
  - Joint positions (robot controllers and robot_state_publisher)
- Many publishers, many consumers
- Distributed system, redundancy issues, ...

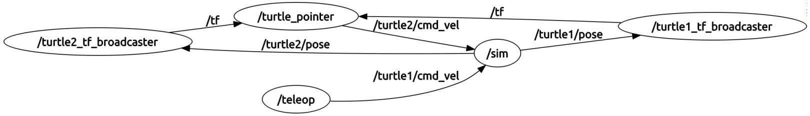
$$\downarrow$$

- **TF**: a coordinate frame tracking system
  - Publishing transforms to tf listeners
  - Looking up and calculating transforms by asking tf listeners
- Transformation data is cached over time
- All the transforms together build a TF tree

TurtleSim TF

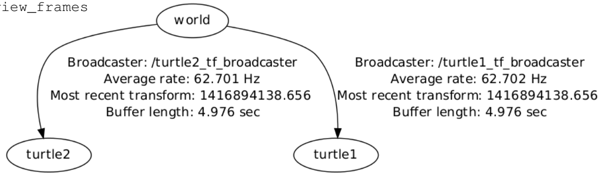
- Launch the turtlesim TF demo:

```
$ roslaunch turtle_tf turtle_tf_demo.launch
```



- Generate a TF tree graph:

```
$ rosrun tf view_frames
```


world
Broadcaster: /turtle2_tf_broadcaster
Average rate: 62.701 Hz
Most recent transform: 1416894138.656
Buffer length: 4.976 sec
Broadcaster: /turtle1_tf_broadcaster
Average rate: 62.702 Hz
Most recent transform: 1416894138.656
Buffer length: 4.976 sec
turtle2
turtle1

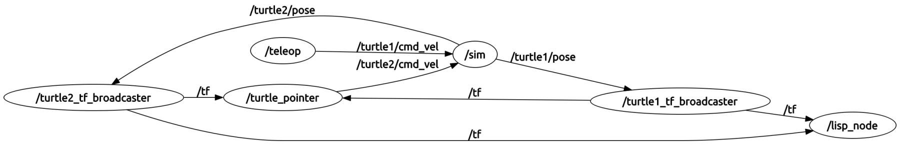
- Listen to transforms:

```
$ rosrun tf tf_echo turtle1 turtle2
```

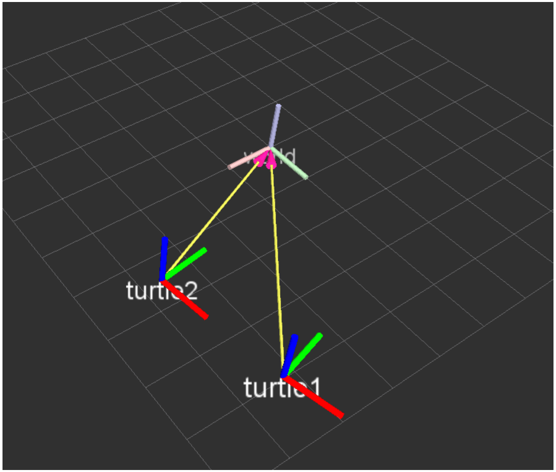
Lisp TF

cl_tf

```
TF> (roslisp:start-ros-node "lisp_node")
TF> (defparameter *transform-listener*
       (make-instance 'transform-listener))
TF> (lookup-transform *transform-listener* :source-frame "turtle1" :targe
#<STAMPED-TRANSFORM
   FRAME-ID: "turtle1", CHILD-FRAME-ID: "turtle2", STAMP: 1.4169d9
   #<3D-VECTOR (0.0d0 0.0d0 0.0d0)>
   #<QUATERNION (0.0d0 0.0d0 -0.5401331068059835d0 0.8415796022552d0)>>
```



$ rosrun rviz rviz



Outline

ROS Actions

Interface to define and execute goals:

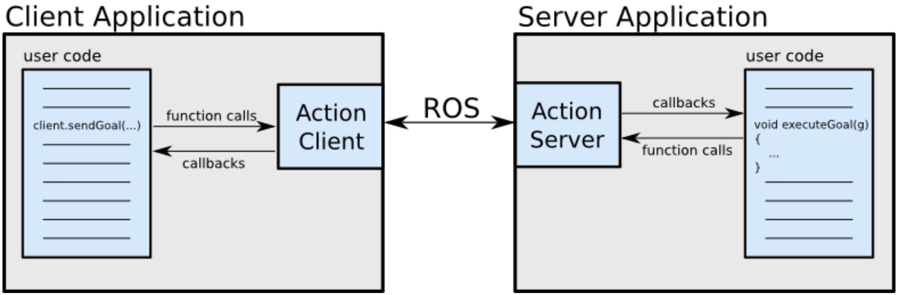


Illustration source: ROS actionlib wiki

Action Protocol

Relies on ROS topics to transport messages.

Action Interface

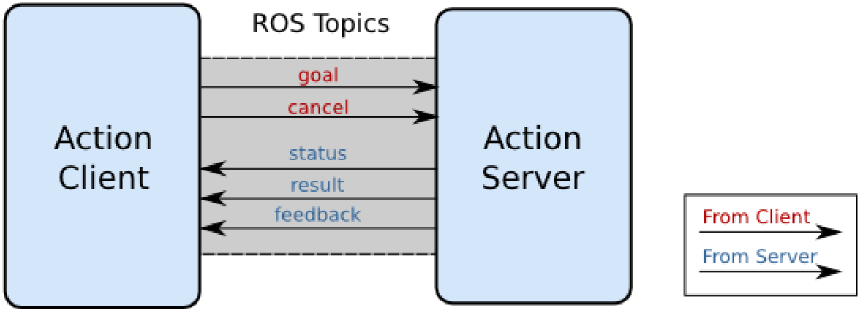


Illustration source: ROS actionlib wiki

Action Definitions

- Similar to messages and services.
- Definition: request + result + feedback
- Defined in *your_package/action/*.action*
- Example: *actionlib_tutorials/Fibonacci.action*

```
# goal definition
int32 order
---
# result definition
int32[] sequence
---
# feedback
int32[] sequence
```

Outline

Links

- Gazebo5 installation:
  `http://gazebosim.org/tutorials?cat=install&tut=install_ubuntu&ver=5.0`
- ActionLib Lisp tutorials:
  `http://wiki.ros.org/actionlib_lisp/Tutorials`

Info

- Assignment this week (5 out of 50 points)
- Assignment code: `REPO/assignment_7_README.txt`

Q & A

Thanks for your attention!