# 16.485 - Lab 2

## Introduction to ROS

# Overview

- ROS architecture
- ROS master, nodes and topics
- Command Line Tools
- Transform (tf) package

# What is ROS?

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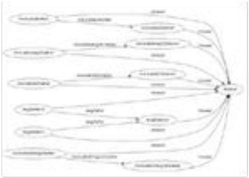

## Plumbing

- Process management
- Message passing
- Device drivers
- ...

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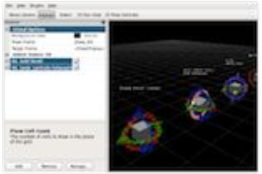

## Tools

- Simulation
- Visualization
- Debugging
- Data logging
- ...

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## Capabilities

- Control
- Planning
- Perception
- Manipulation
- ...

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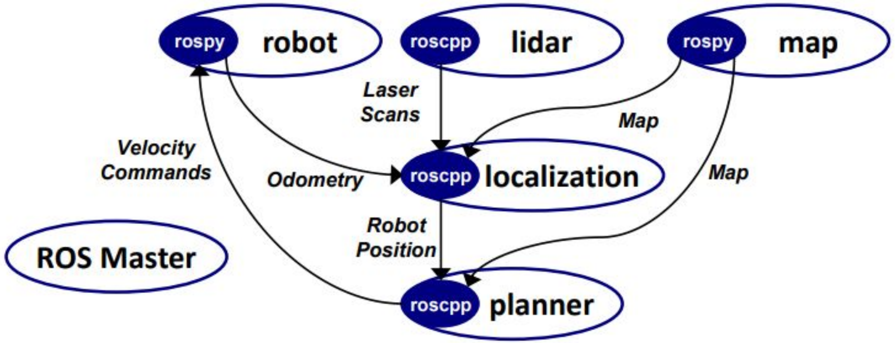
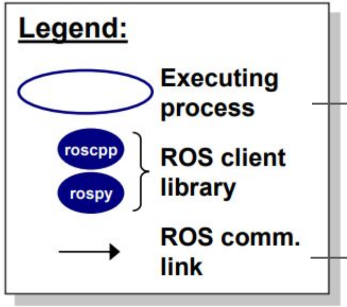
## Ecosystem

- Package organization
- Software distribution
- Documentation
- Tutorials
- ...

# ROS Computational Graph





**Legend:**

Executing process

ROS client library

ROS comm. link

**ROS jargon:**

**Node (vertex in the graph)**

**Topic (directed edge)**

**Subscription (incoming edge)**

**Publication (outgoing edge)**

**Message: the *type* of a topic**

# ROS Nodes

**Nodes**: processes performing computation in the ROS system

- Vertices in the ROS computational graph
- Created by including and initializing a ROS client library in the program's source code
- Each instance must have a unique name (text string)

# ROS topics and messages

**Topics**: named unidirectional communication links between ROS nodes – Form edges in the ROS computation graph

- Topics are named (text string)
- One or more nodes may publish messages to a topic
- One or more nodes may subscribe to messages on a topic
- Each topic is linked to a single message type
- Created dynamically at runtime by ROS nodes (using the ROS client library)

**Messages**: packets of data sent between ROS nodes

- Named data structure comprised of strictly typed fields, defined in .msg files • Somewhat similar to ‘C’ structs
- Converted to client language data structures during build / compile

# ROS Master

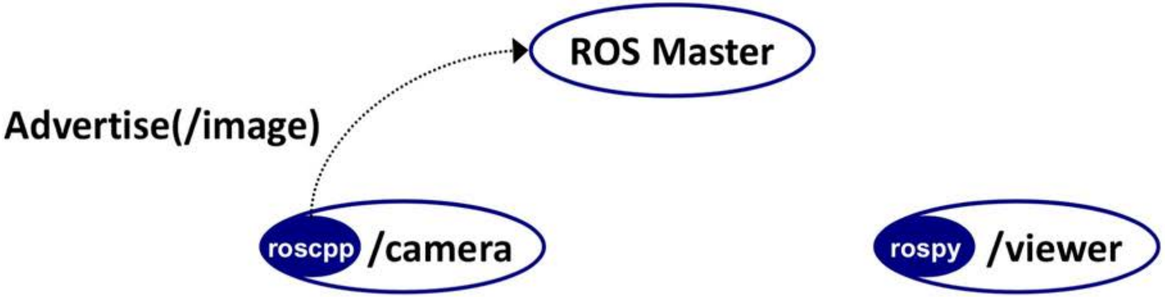
- Manages the communication between nodes
- Every node registers at startup with the master
- Behaves pretty much like a DNS

Start a master with

```
roscore
```

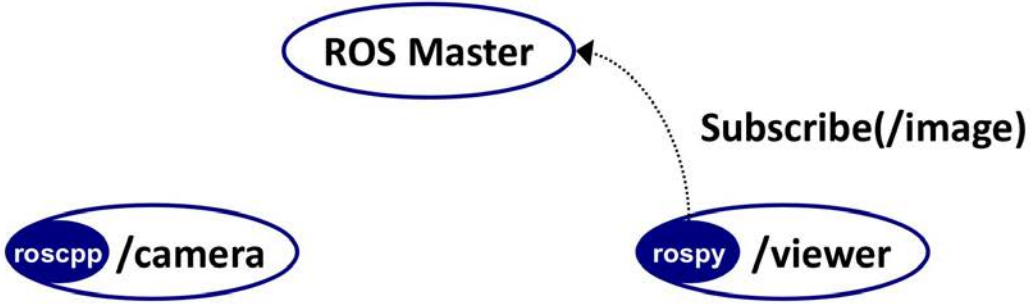
# ROS Master process

1 */camera* node announces intent to publish (advertises) on the */image* topic

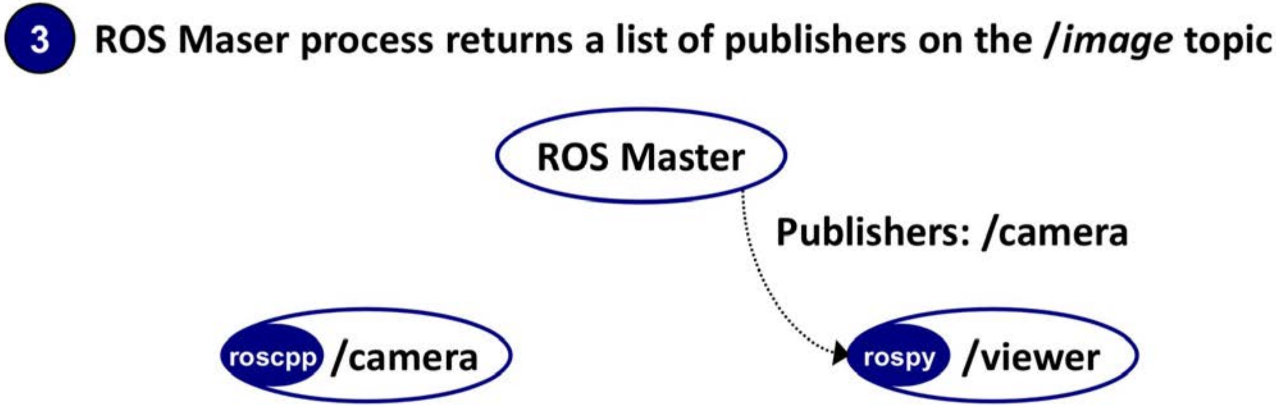


# ROS Master process

2 */viewer* node subscribes to the */image* topic, requesting a list of the publishers

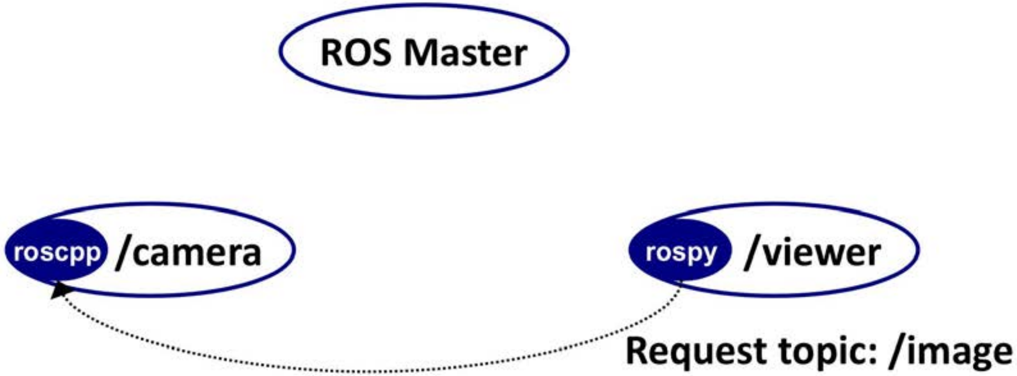


# ROS Master process

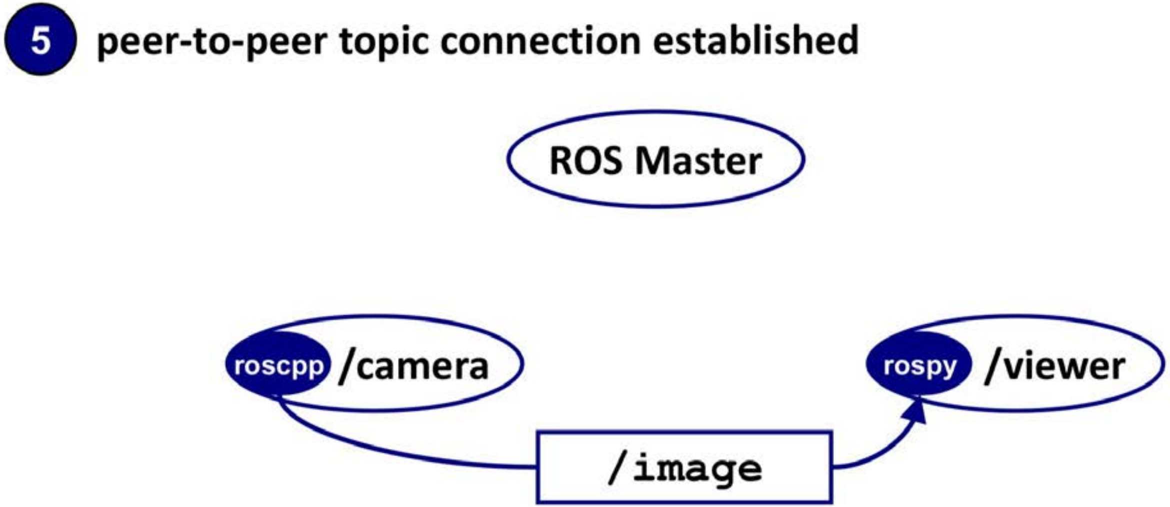

3 ROS Maser process returns a list of publishers on the */image* topic

# ROS Master process

4 */viewer* node contacts */camera* node to request a peer-to-peer connection



# ROS Master process



# ROS Runtime tools

Starting nodes individually is impractical for large runtime graphs – Technically, you could call each executable directly

ROS provides several utilities to start and stop ROS processes

- `rosrun` – execute individual nodes
- `roslaunch` – starts multiple nodes per a .launch file specification

Note: `roslaunch` starts the ROS master if it is not already running

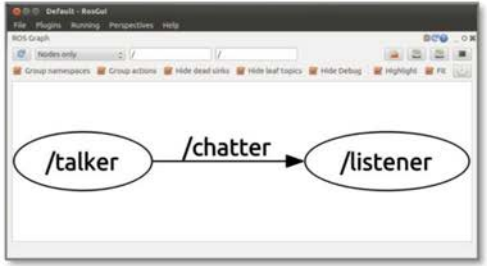
# Inspection tools

Your robot application might not work the first time you try it...

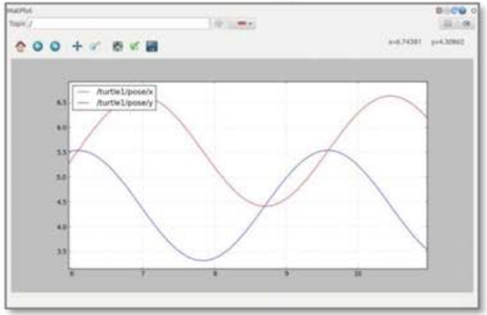
ROS **inspection tools** help debug the computational graph

- `rosnode` – information on ROS Nodes (publications, subscriptions)
- `rostopic` – information on ROS Topics (e.g. `rostopic list`)

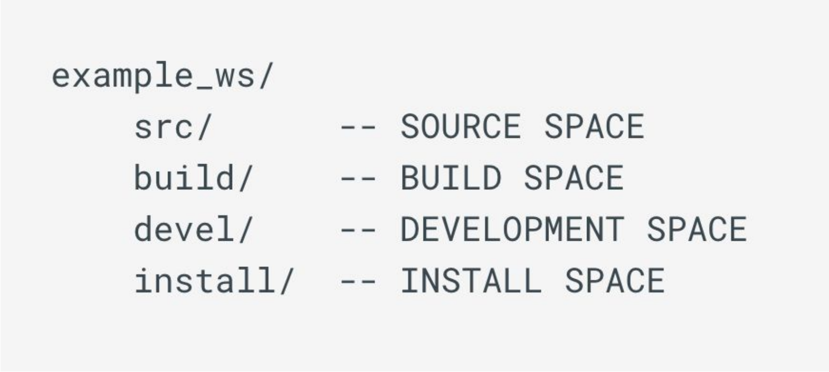
ROS Graph Plugin



Plot Plugin



# Workspace layout



```
example_ws/
    src/       -- SOURCE SPACE
    build/     -- BUILD SPACE
    devel/     -- DEVELOPMENT SPACE
    install/   -- INSTALL SPACE
```

- **Source**: Contains the source code for one or more packages.
- **Development**: Contains the built targets and the setup scripts.
- **Build**: Directory in which CMake builds the source files.
- **Install**: Directory for building the install target.

# Catkin

- official build system of ROS
- combines CMake macros and Python

Create a catkin workspace with

```
catkin init
```

Build with

```
catkin build
```

Do not forget to source the catking environment before running

```
source devel/setup.bash
```

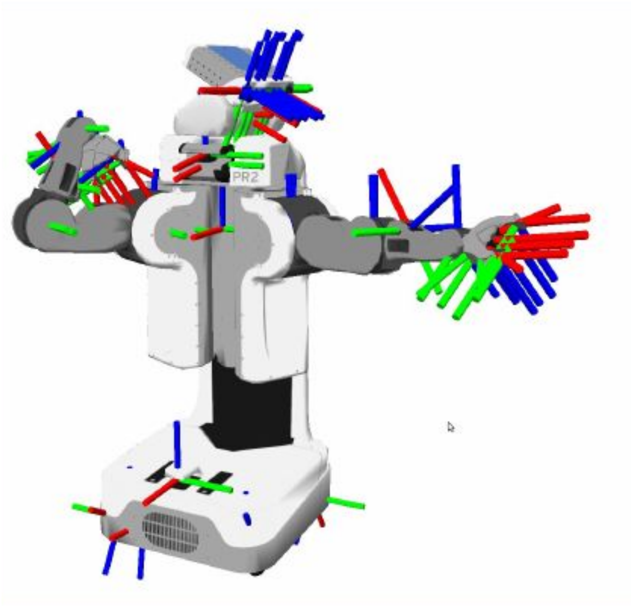
# ROS and Coordinate Transformations

Many frames in a robot

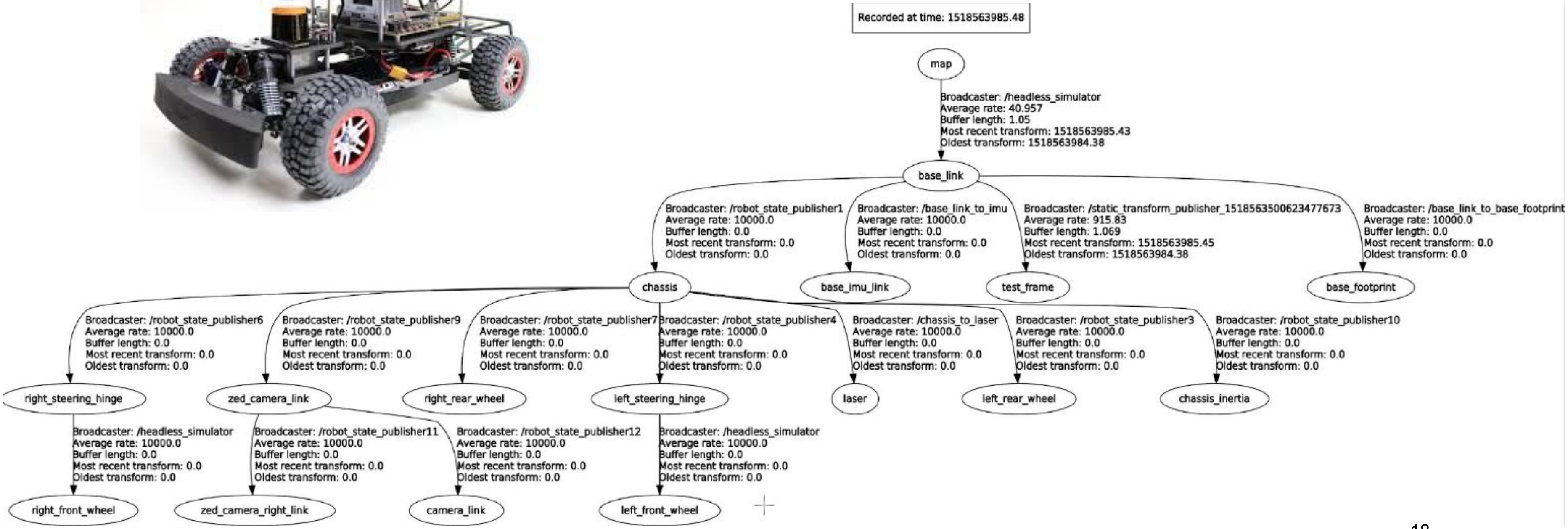
- Base frame
- Camera / LIDAR frames
- (maybe) Joints or end effectors...

Who keeps track of them in ROS?

TF



# Transformations organized in a tree!



Recorded at time: 1518563985.48

Broadcaster: /headless_simulator
Average rate: 40.957
Buffer length: 1.05
Most recent transform: 1518563985.43
Oldest transform: 1518563984.38

Broadcaster: /robot_state_publisher1
Average rate: 10000.0
Buffer length: 0.0
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Broadcaster: /base_link_to_imu
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Buffer length: 0.0
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Broadcaster: /static_transform_publisher_1518563500623477673
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Buffer length: 1.069
Most recent transform: 1518563985.45
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Broadcaster: /base_link_to_base_footprint
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Broadcaster: /robot_state_publisher6
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Broadcaster: /robot_state_publisher4
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Broadcaster: /chassis_to_laser
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Broadcaster: /robot_state_publisher3
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Broadcaster: /robot_state_publisher10
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Buffer length: 0.0
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Broadcaster: /headless_simulator
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Broadcaster: /robot_state_publisher11
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Broadcaster: /robot_state_publisher12
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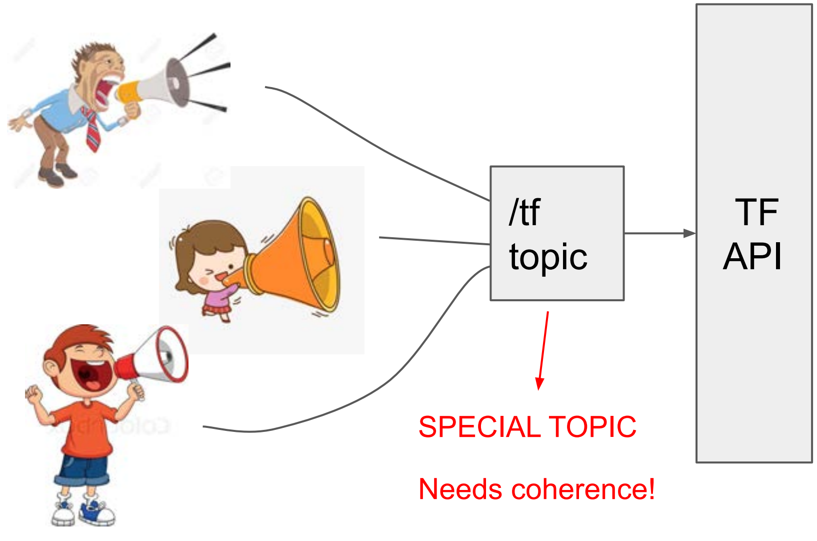
# Transformations organized in a tree!

WHY?

Nodes broadcast transforms to TF

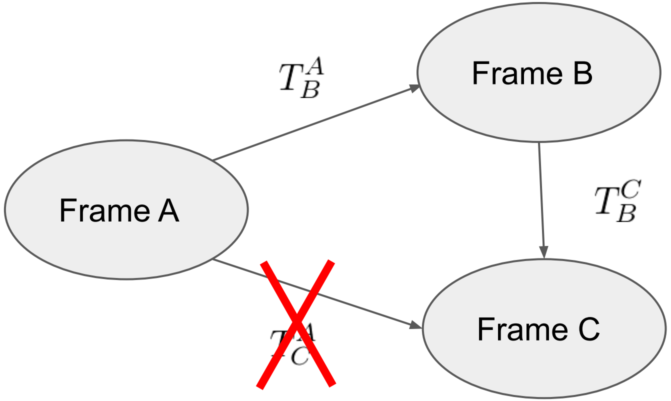


SPECIAL TOPIC

Needs coherence!

tf::TransformBroadcaster::sendTransform()

1. someone yells $T_B^A$
2. someone yells $T_C^A$
3. someone yells $T_B^C \neq T_B^A (T_C^A)^{-1}$



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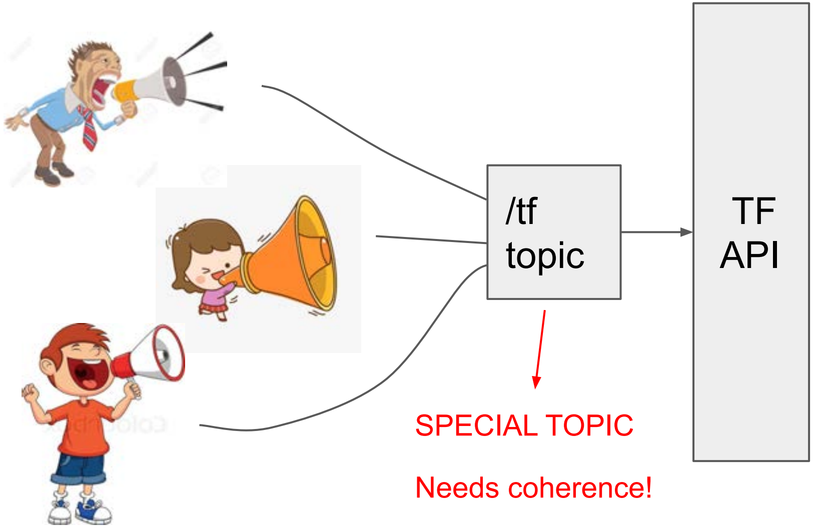

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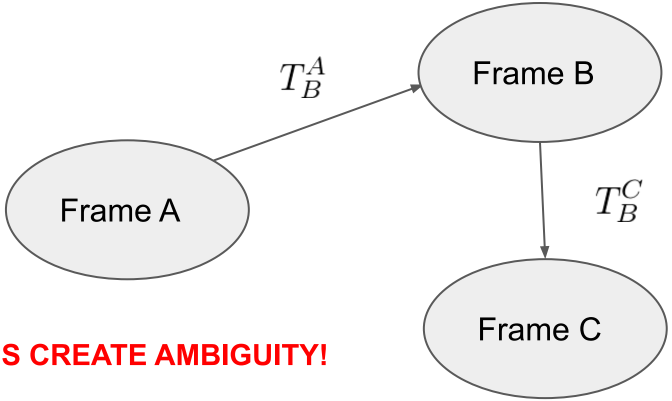
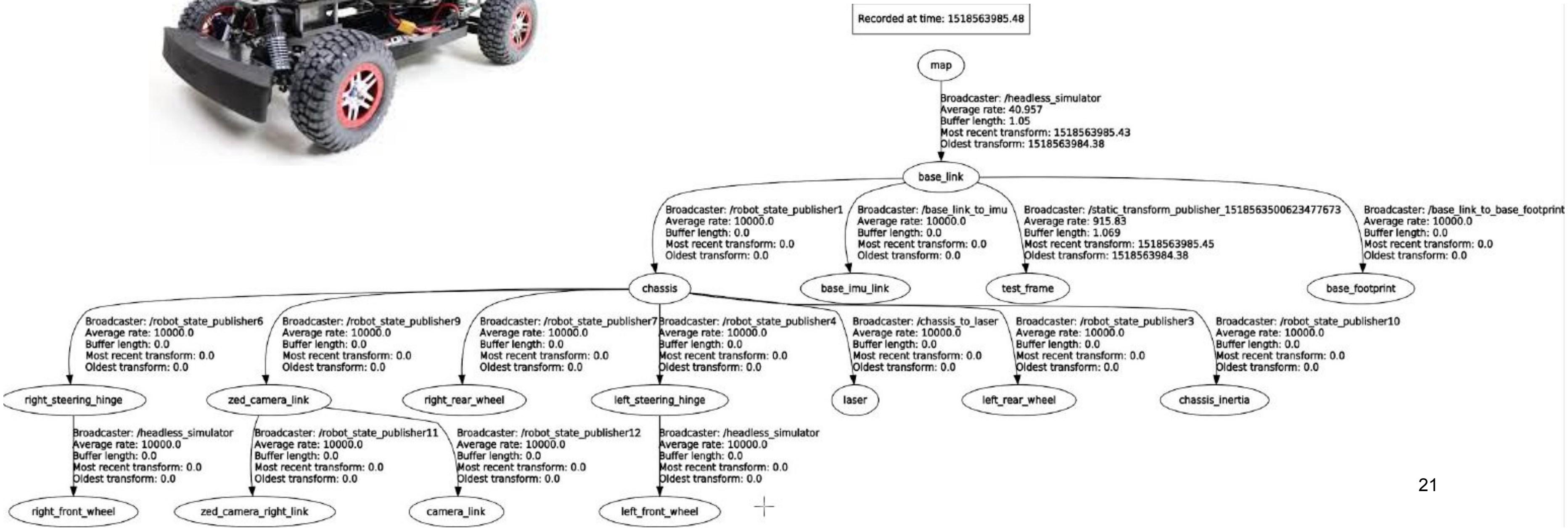


LOOPS CREATE AMBIGUITY!

# Transformations organized in a tree!



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map

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base_link

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chassis

base_imu_link

test_frame

base_footprint

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right_steering_hinge

zed_camera_link

right_rear_wheel

left_steering_hinge

laser

left_rear_wheel

chassis_inertia

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right_front_wheel

zed_camera_right_link

camera_link

left_front_wheel

# Transformations organized in a tree!

**TF LOOKUP EXAMPLE:**

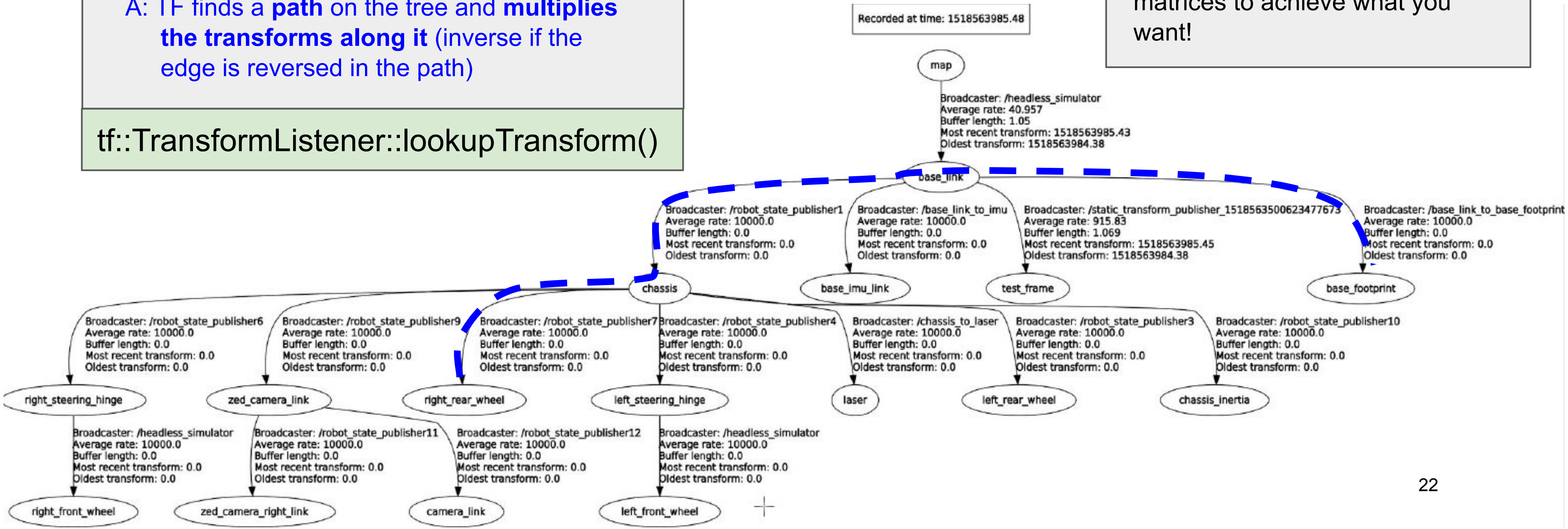
Q: what is **right_rear_wheel** to **base_footprint?**

A: TF finds a **path** on the tree and **multiplies the transforms along it** (inverse if the edge is reversed in the path)

tf::TransformListener::lookupTransform()

**RESULT:**
**you will never have to think...**

...about how to multiply matrices to achieve what you want!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