ECE 495/595 Lecture Slides

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Summary and Quick Links

These slides contain the following concepts:

- What is URDF? (Slide 3)
- Basic components of a URDF file (Slide 4)
- Xacro macros (Slide 11)
- CAD mesh files (Slide 14)
- Loading URDF models (Slide 16)
- TF frames of a robot model (Slide 17)

What is URDF?

- URDF is a standard XML format for describing robot models.
- User defines the shape of the various links of a robot, the joints that connect them, and the behavior of the joints (revolute, prismatic, fixed).
- Collision and inertial properties of links can also be specified for simulation in Gazebo, but that will be discussed in another set of slides.
- It is recommended to go through the official tutorials on the ROS wiki: `http://wiki.ros.org/urdf/Tutorials`

Components of a URDF Model

- The two fundamental elements of a URDF model are **links** and **joints**.
- Any number of links and joints are specified in separate XML tags.
- Links specify the physical properties of each separate piece of the robot. Their names match the TF frames that will eventually be published.
- Joints specify the kinematic relationship between links, including the type and limits of the joint.

Components of a URDF Model

- Example XML tags for two simple links:

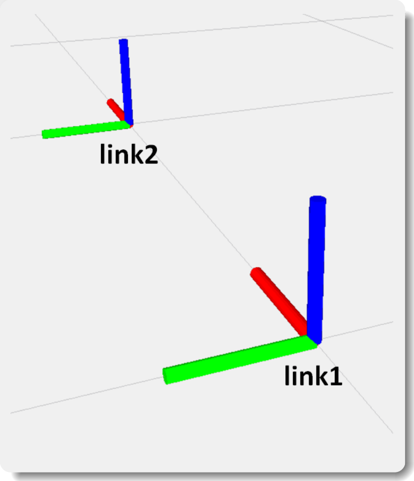
```xml
<link name="link1" >
  <visual>
    <geometry>
      <!-- Shape goes here -->
    </geometry>
    <material name="color_name" >
      <!-- Color goes here -->
    </material>
  </visual>
</link>

<link name="link2" >
  <visual>
    <geometry>
      <!-- Shape goes here -->
    </geometry>
    <material name="color_name" >
      <!-- Color goes here -->
    </material>
  </visual>
</link>
```

Components of a URDF Model

- Describe a fixed joint between these two links:

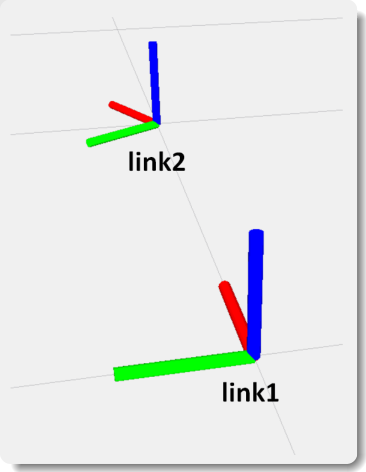
```
<joint name="joint1" type="fixed" >
  <parent link="link1" />
  <child link="link2" />
  <origin xyz="1 0 0" rpy="0 0 0" />
</joint>
```



Components of a URDF Model

▷ Describe a revolute joint between these two links:

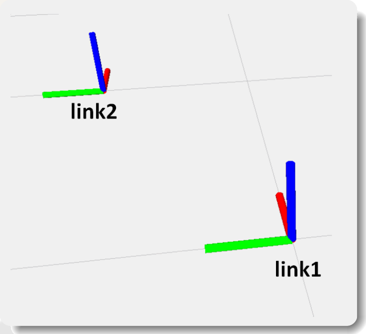
```xml
<joint name="joint1" type="revolute" >
  <parent link="link1" />
  <child link="link2" />
  <origin xyz="1 0 0" rpy="0 0 0" />
  <axis xyz="0 0 1" />
  <limit effort="1000.0" velocity="3.0" />
</joint>
```



Components of a URDF Model

- Describe a prismatic joint between these two links:

```
<joint name="joint1" type="prismatic" >
  <parent link="link1" />
  <child link="link2" />
  <origin xyz="1 0 0" rpy="0 0 0" />
  <axis xyz="0 1 0" />
  <limit effort="1000.0" velocity="3.0" />
</joint>
```



Components of a URDF Model

▷ Here is an example of a complete URDF model:

```xml
<robot name="example_robot" >

  <link name="link1" >
    <visual>
      <geometry>
        <box size="0.1 0.1 0.5" />
      </geometry>
      <material name="green" >
        <color rgba="0 1 0 1" />
      </material>
    </visual>
  </link>

  <link name="link2" >
    <visual>
      <geometry>
        <cylinder radius="0.2" length="1.0" />
      </geometry>
      <material name="red" >
        <color rgba="1 0 0 1" />
      </material>
    </visual>
  </link>
```

Components of a URDF Model

- Continued...

```
  <joint name="joint1" type="fixed" >
    <parent link="link1" />
    <child link="link2" />
    <origin xyz="1 0 0" rpy="0 0 0" />
  </joint>

</robot>
```

- Notice how everything is inside of a **<robot> </robot>** tag.

Xacro Macros

- Even simple robots can require quite complicated URDF files.
- **xacro** macros help by allowing reusable modules and parameters, as well as mathematical expressions.
- In order to use the **xacro** capabilities, put the following in the **robot** tag:

```
xmlns:xacro="http://www.ros.org/wiki/xacro"
```

- Details about xacro are found here: http://wiki.ros.org/xacro

Xacro Macros

- **xacro:property** – Defines a particular value:

```
<xacro:property name="a_number" value="6" />
```

- **xacro:macro** – Defines a reusable module:

```
<xacro:macro name="a_macro" params="a_parameter" >
  <link name="link" >
    <visual>
      <box size="${a_parameter} ${a_number} 0" />
    </visual>
  </link>
</xacro:macro>
```

- Math expressions:

```
<xacro:property name="half_number" value="${a_number/2}" />
```

Xacro Macros

Example use of a macro

```
<robot name="urdf_example" xmlns:xacro="http://www.ros.org/wiki/xacro" >

  <xacro:macro name="link_macro" params="name y_scale" >
    <link name="${name}" >
      <visual>
        <geometry>
          <box size="1 ${y_scale} 1" />
        </geometry>
        <material name="blue" >
          <color rgba="0 0 1 1" />
        </material>
      </visual>
    </link>
  </xacro:macro>

  <xacro:link_macro name="link1" y_scale="1.0" />
  <xacro:link_macro name="link2" y_scale="0.5" />

  <joint name="joint1" type="continuous" >
    <parent link="link1" />
    <child link="link2" />
    <axis xyz="0 0 1" />
    <origin xyz="0 0 1.5" rpy="0 0 0" />
  </joint>
</robot>
```

CAD Mesh Files

- In a **<geometry>** tag, a mesh file exported from a CAD program can be specified in a **<mesh>** tag.
- Only **.stl** and **.dae** meshes are supported. Many CAD programs are capable of exporting in either of these formats, however.
- The imported mesh file is specified in the **filename** property of the **<mesh>** tag.
- A relative path to a ROS package is specified using **package://**

CAD Mesh Files

- Below is an example of a URDF link that uses a mesh file for visual geometry.

```
<link name="base_link" >
  <visual>
    <origin xyz="0 0 0" rpy="0 0 0" />
    <geometry>
<mesh filename="package://mantis_model/meshes/mantis_base.stl" scale="1 1 1" />
    </geometry>
    <material name="gray" />
  </visual>
</link>
```

- In this case, particular mesh file **mantis_base.stl** is in the **meshes** folder in the ROS package **mantis_model**

- The **scale** property is used to independently scale the x, y and z axes of the imported mesh.

Loading a URDF Model

- A URDF model is loaded as a ROS parameter. Anything that needs the model simply looks up this parameter.
- This parameter is usually called **/robot_description**, but is sometimes loaded into a namespace.
- The model is loaded as a parameter in a launch file like this:

```
<param name="robot_description" command="$(find xacro)/xacro.py
              '$(arg pkg_name)/urdf/robot.urdf.xacro' />
```

- **xacro.py** is a program that parses the URDF file.

TF Frame Management

- A node called **robot_state_publisher** publishes all the TF frames necessary for each link in the URDF file.
- For fixed joints, robot state publisher just publishes the offset and orientation as a static transform.
- For movable joints, the state publisher subscribes to a **sensor_msgs::JointState** message to receive what the current joint values are.
- This **JointState** message has to come from another node that is keeping track of the joint positions.

TF Frame Management

- ▷ **sensor_msgs::JointState** message structure:

```
micho@ubuntuvm: ~
micho@ubuntuvm:~$ rosmsg show JointState
[sensor_msgs/JointState]:
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
string[] name
float64[] position
float64[] velocity
float64[] effort

micho@ubuntuvm:~$
```

- ▷ The **name** vector corresponds to the joint names in the URDF file.

- ▷ The **position** vector controls the joint values.

TF Frame Management

- The **velocity** vector controls the velocity of the joints.
- The **effort** controls the force applied by the joint.
- A **JointState** message can be initialized like this:

```
sensor_msgs::JointState joints;
joints.name.resize(3);
joints.position.resize(3, 0);
joints.velocity.resize(3, 0);
joints.effort.resize(3, 0);

joints.header.frame_id = "base_footprint";
joints.name[0] = "joint1";
joints.name[1] = "joint2";
joints.name[2] = "joint3";
```

TF Frame Management

- To update the position of **joint1** to spin at a constant rate, for example, a timer could be used.
- If a timer is set up to run at 50 Hz, the callback would look something like this:

```
void timerCallback(const ros::TimerEvent& event)
{
        double constant_speed = 2.0; // rad/s
        joints.header.stamp = event.current_real;
        joints.velocity[0] = constant_speed;
        joints.position[0] += 0.02 * constant_speed;
        pub_joint_states.publish(joints);
}
```