pcg_gazebo_pkgs

A PYTHON LIBRARY FOR SCRIPTING AND RAPID-PROTOTYPING OF SIMULATED GAZEBO MODELS AND WORLDS

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ROSCon 2019 - Macau

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INTRODUCTION

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Procedural Generation for Gazebo
Motivation

- **Problems:**
  - How to do rapid-prototyping of simulations in Gazebo (specially for non-simulation experts)
  - How to quickly design and create new and/or multiple simulations with different
    - Physics engine parameters [1]
    - Robot components and structures [1]
    - Objects placements [1]

- **Idea:** *Procedural Generation for Gazebo*
  - Technique from gaming development

- **Approach**
  - Use scripting language
  - Create abstractions of Gazebo model, worlds and configuration data structures (e.g. physics engine configuration)
  - Use of SDF and URDF formats to import/export model and world descriptions
  - Algorithmically generate of scenes, models and parameter configuration sets for a simulation


[1]

[1] Source: https://www.iconfinder.com/iconsets/brainy-mixed
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Procedural Generation for Gazebo
Detailed goals

- Rapid-prototyping of simulation scenarios
  - Create abstractions to simulation entities (e.g. models, sensors, physics engine parameters) that can be easily manipulated
  - Allow scripting of Gazebo simulations (generation of models, setting/accessing parameters in runtime, interacting with simulation via script)
    - Easy factory functions to create simulation models to populate scenarios (e.g. geometric primitives, derived from meshes)
    - Also useful in e.g. machine learning algorithms, reinforcement learning, optimization
  - Integration of scripted simulations in automated simulation-based tests
    - Generation of simulation scenarios for testing of, for example, motion planners and SLAM algorithms

- More control over the robot descriptions
  - XML parsers for SDF and URDF
  - Extend templating options for robot descriptions
  - Improve conversion between URDF and SDF formats for better use of Gazebo's features

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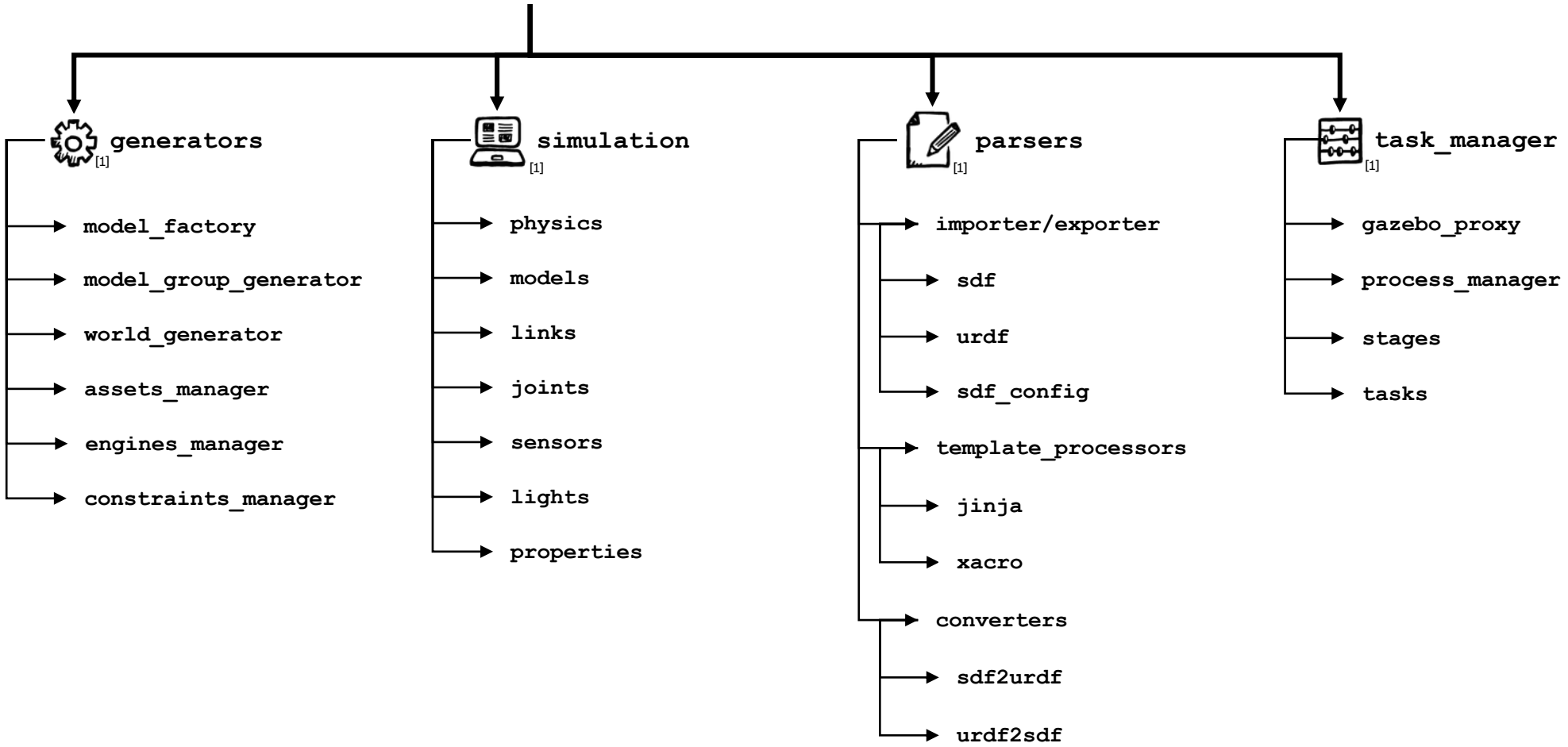

[1] Source: https://www.iconfinder.com/iconsets/brainy-mixed
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FEATURES

Inspection of Gazebo models
Visualizing models already in the database

- The library loads the paths of all static Gazebo models in the
  - current catkin workspace
  - **`$HOME/.gazebo/models`**
  - **`/usr/share/gazebo-$GAZEBO_VERSION/models`**
- They can be loaded using their tag into a **`SimulationModel`** object

```
In [1]: from pcg_gazebo.simulation import SimulationModel

In [2]: model = SimulationModel.from_gazebo_model('object_jansport_backpack_red')

In [3]: model.show()
```

/usr/local/bin/ipython

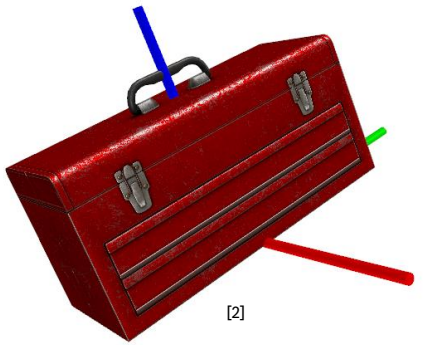
[1]

```
In [1]: from pcg_gazebo.simulation import SimulationModel

In [2]: model = SimulationModel.from_gazebo_model('object_toolbox')

In [3]: model.show()
```

/usr/local/bin/ipython



[2]

[1] Source: https://app.ignitionrobotics.org/chapulina/fuel/models/JanSport%20Backpack%20Red
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[2] Source: https://app.ignitionrobotics.org/openrobotics/fuel/models/Toolbox
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Inspection of Gazebo models

Inspecting SDF from a `SimulationModel` object

```
In [4]: sdf = model.to_sdf()

In [5]: print(sdf)
<model name="toolbox">
  <pose frame="">0 0 0.126548 0 -0 0</pose>
  <static>0</static>
  <self_collide>0</self_collide>
  <allow_auto_disable>0</allow_auto_disable>
  <link name="toolbox">
    <collision name="collision">
      <geometry>
        <mesh>
          <uri>model://object_toolbox/meshes/Toolbox.dae</uri>
          <scale>1 1 1</scale>
        </mesh>
      </geometry>
      <pose frame="">2.59092e-17 1.34051e-17 -0.126548 0 -0 0</pose>
      <max_contacts>10</max_contacts>
    </collision>
    <visual name="visual">
      <geometry>
        <mesh>
          <uri>model://object_toolbox/meshes/Toolbox.dae</uri>
          <scale>1 1 1</scale>
        </mesh>
      </geometry>
      <pose frame="">2.59092e-17 1.34051e-17 -0.126548 0 -0 0</pose>
      <cast_shadows>1</cast_shadows>
      <transparency>0.0</transparency>
    </visual>
    <inertial>
      <inertia>
        <ixx>0.08738482705732964</ixx>
        <iyy>0.034240830541697964</iyy>
        <izz>0.07690599862062936</izz>
        <ixy>0.0</ixy>
        <ixz>0.0</ixz>
        <iyz>0.0</iyz>
      </inertia>
      <pose frame="">0 0 0 0 -0 0</pose>
      <mass>3.0</mass>
    </inertial>
    <pose frame="">0 0 0 0 -0 0</pose>
  </link>
</model>
```

`SimulationModel` objects can be converted into a SDF object

```
In [10]: sdf.links
Out[10]: [<pcg_gazebo.parsers.sdf.link.Link at 0x7fb5cc080c18>]

In [11]: sdf.links[0].inertial.mass.value
Out[11]: 3.0

In [12]: sdf.links[0].visuals[0].geometry.mesh.uri.value
Out[12]: 'model://object_toolbox/meshes/Toolbox.dae'

In [13]: print(sdf.links[0].collisions[0])
<collision name="collision">
  <geometry>
    <mesh>
      <uri>model://object_toolbox/meshes/Toolbox.dae</uri>
      <scale>1 1 1</scale>
    </mesh>
  </geometry>
  <pose frame="">2.59092e-17 1.34051e-17 -0.126548 0 -0 0</pose>
  <max_contacts>10</max_contacts>
</collision>
```

The SDF elements can be accessed via their Python object abstraction

```
In [14]: sdf.links[0].inertial.mass.value = 1

In [15]: print(sdf.links[0].inertial)
<inertial>
  <inertia>
    <ixx>0.08738482705732964</ixx>
    <iyy>0.034240830541697964</iyy>
    <izz>0.07690599862062936</izz>
    <ixy>0.0</ixy>
    <ixz>0.0</ixz>
    <iyz>0.0</iyz>
  </inertia>
  <pose frame="">0 0 0 0 -0 0</pose>
  <mass>1.0</mass>
</inertial>


In [16]: sdf.export_xml('/tmp/new_toolbox.sdf')
```

The SDF elements also be altered and the object again exported into a XML file

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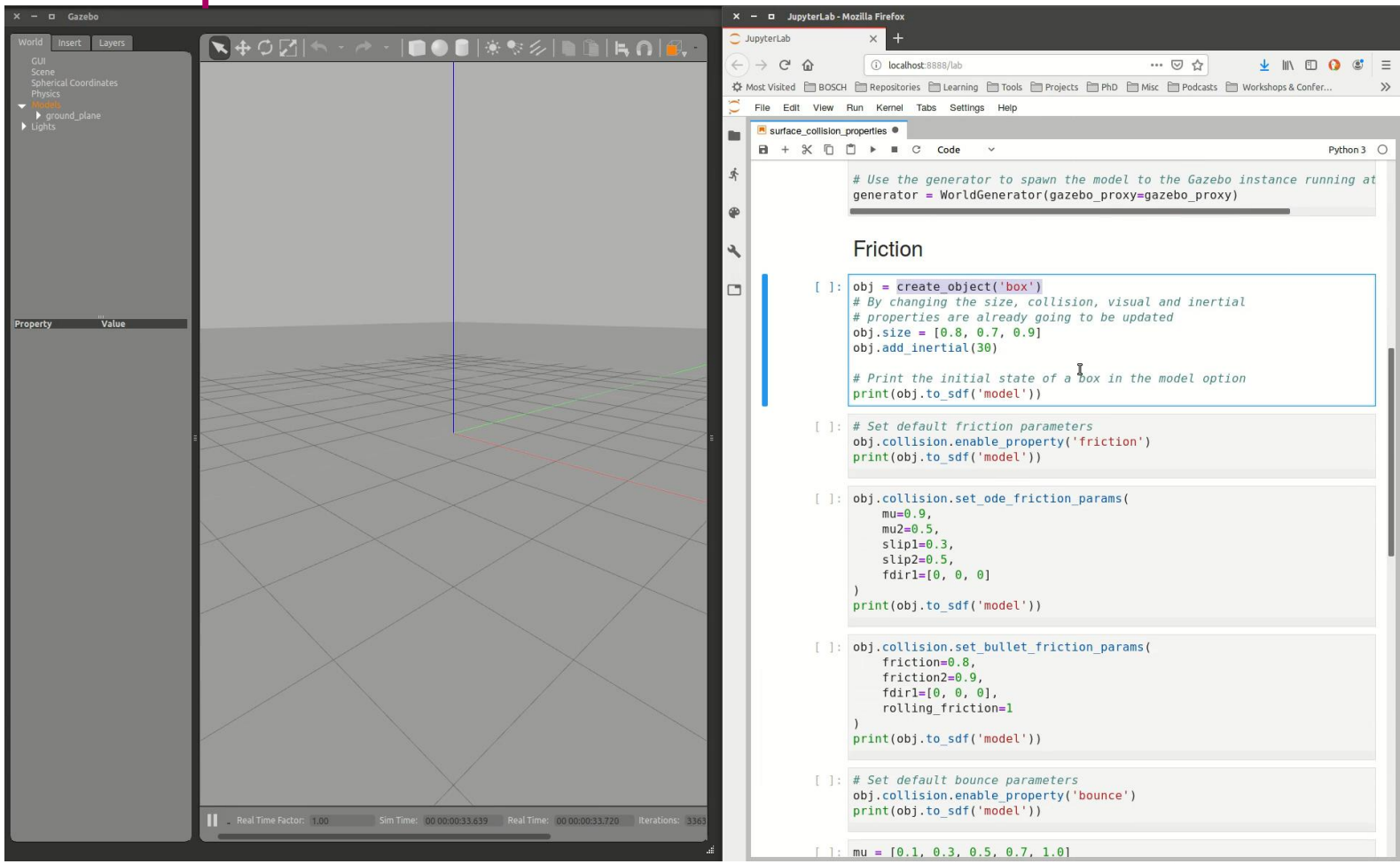
Creating models using Jupyter notebooks

Experimenting with friction parameters

- Create instances of the same **box** model with different friction coefficients
- Inspect the resulting SDF file
- Spawn to Gazebo
- Apply wrench to each model



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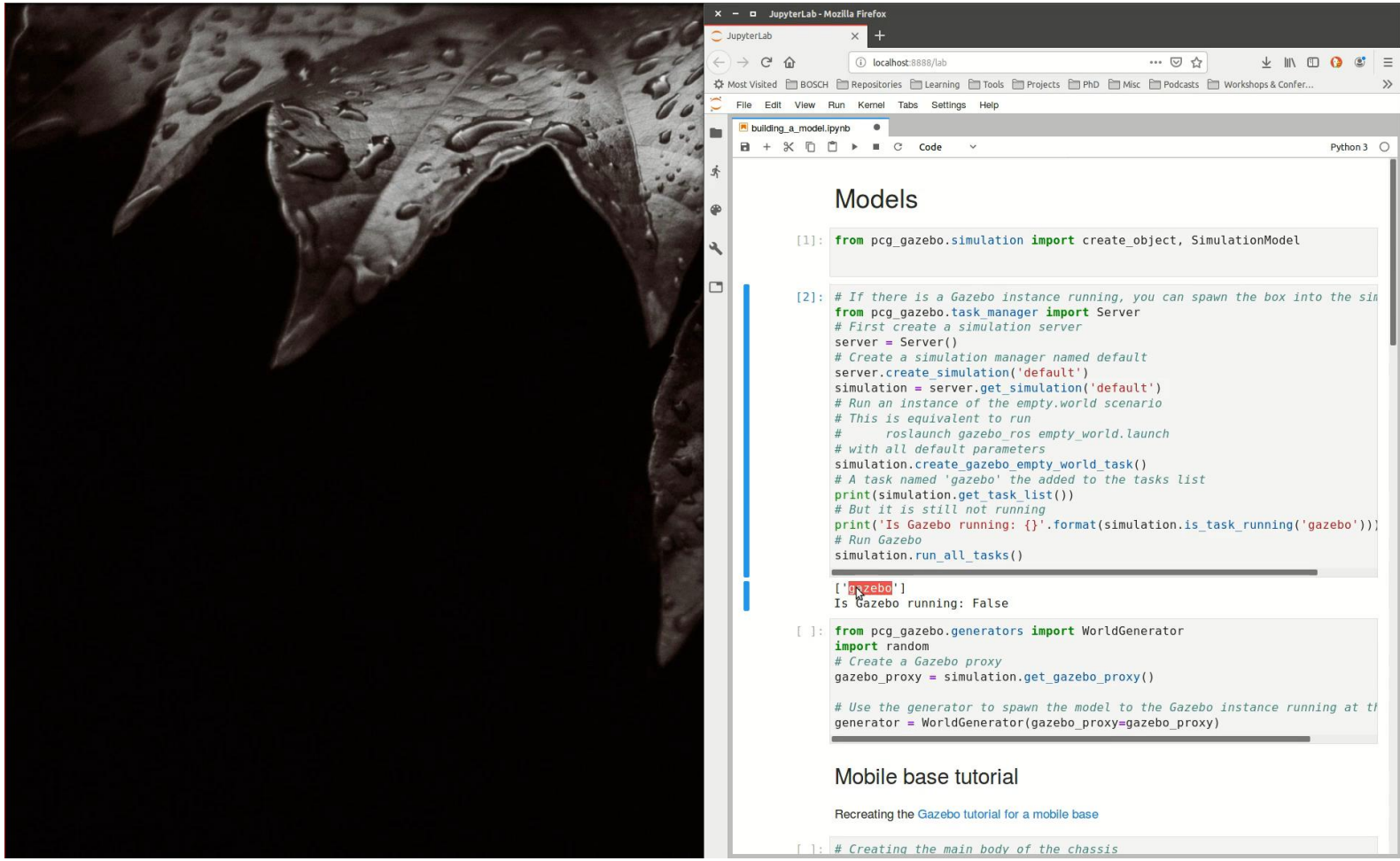
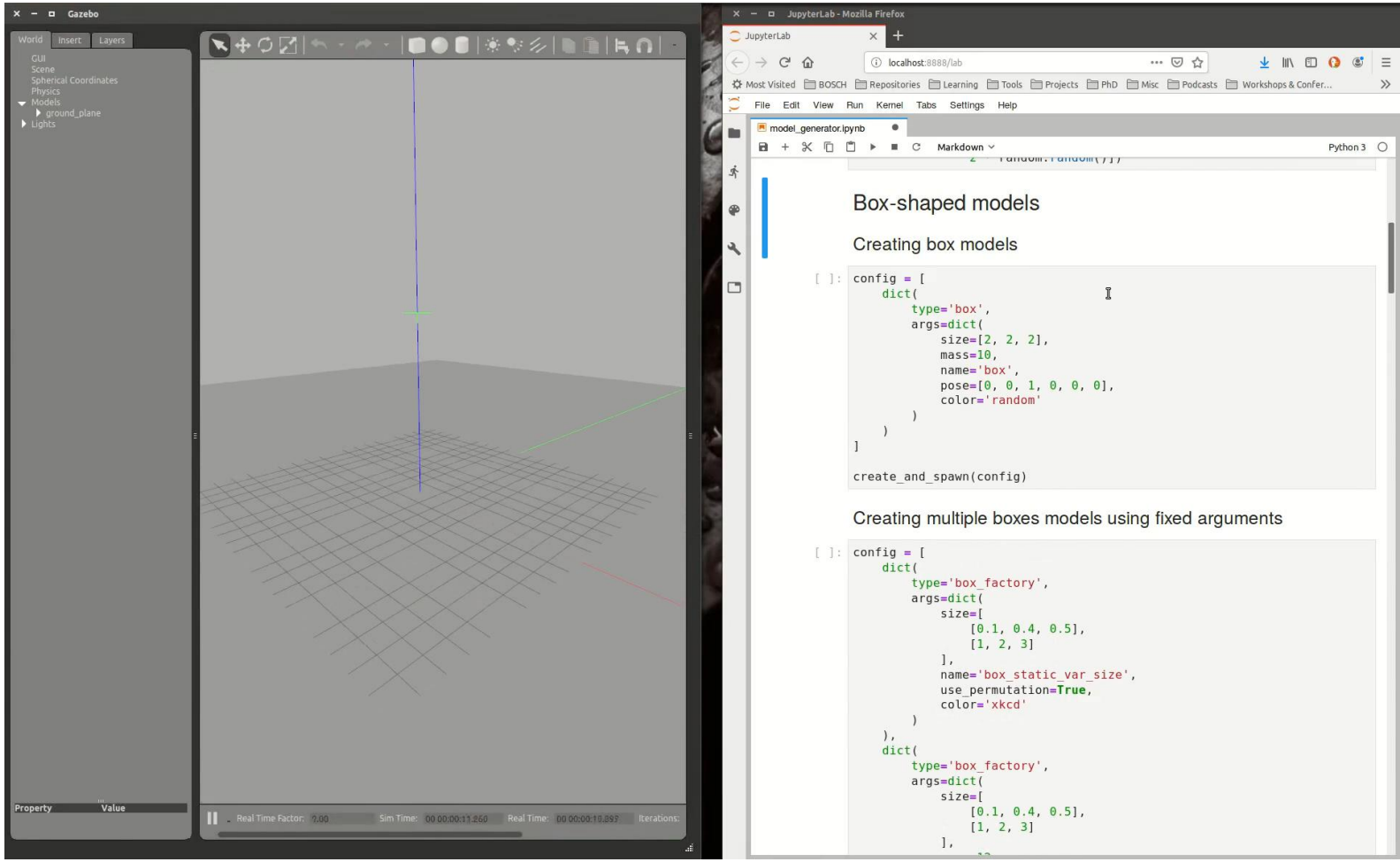
Creating models using Jupyter notebooks
Mobile base tutorial

- Start a Gazebo
- Create mobile base links
  - Chassis
  - Wheels
  - Caster wheel
- Set friction coefficients for caster wheels to zero for both **`bullet`** and **`ode`**
- For links from geometry primitives, the inertial tensors will be computed using the dimensions of the geometry
- Create joints
- Spawn to Gazebo

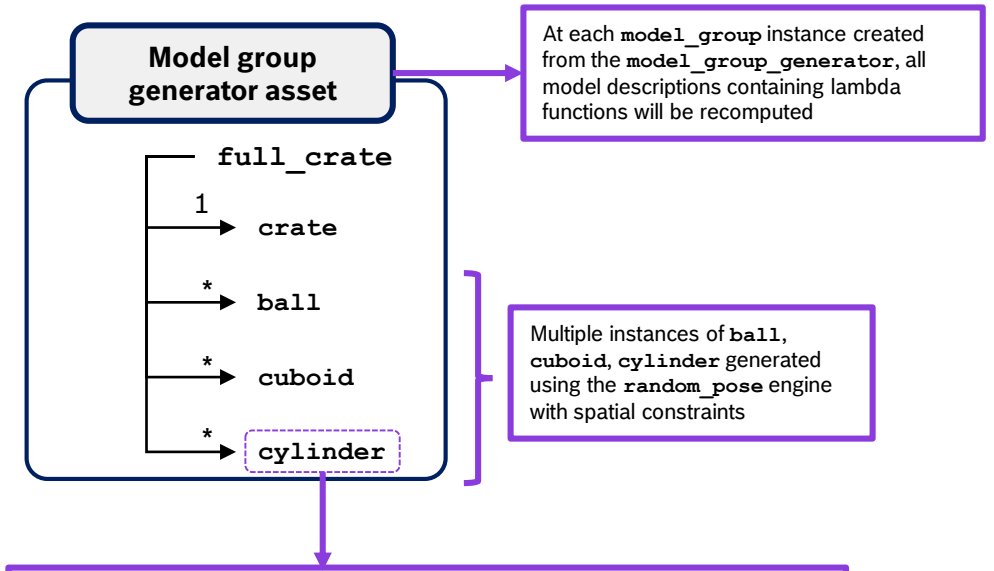


Model factory
Using model factory functions

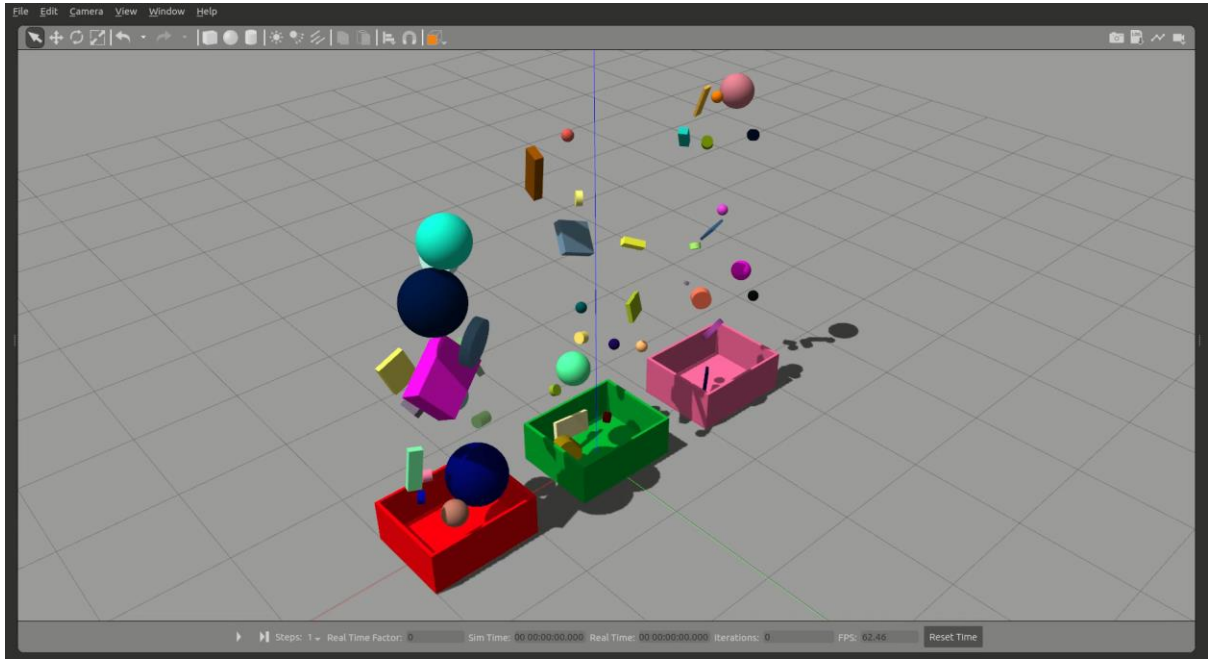
- Complete single-link models can be creaters using the **`pcg_gazebo.creators`** submodule
- Primitives **`box`**, **`sphere`**, **`cylinder`** are available and generated data includes
  - Inertial tensor based on the geometry's dimensions
  - Visual and collision information
- **`extrude`** allows the generation of models from meshes extruded from **`shapely`** geometry objects
- **`mesh`** creators allow the computation of approximated geometries using the input mesh that can be used as simplified collision geometry and input for computation of the moments of inertia
- Models can be parametrized with fixed value inputs or lambda functions



Model group generators
Generating sets of dynamically generated models




```
- tag: cylinder
  description:
    type: cylinder
    args:
      length: "max(0.05, 0.2 *__import__('numpy').random.random())"
      radius: "max(0.05, 0.2 *__import__('numpy').random.random())"
      name: cuboid
      mass: "max(0.01, __import__('numpy').random.random())"
      color: xkcd
```



- **ball**, **cuboid** and **cylinder** properties represented by lambda functions
- New model properties are generated each time an instance of the model is created

SDF Jinja Templates

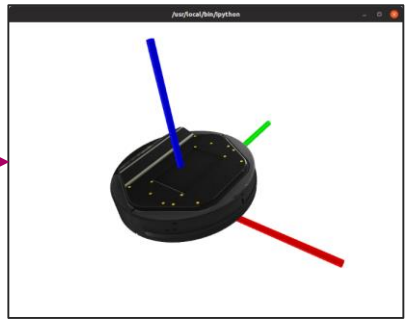
Templating robot descriptions

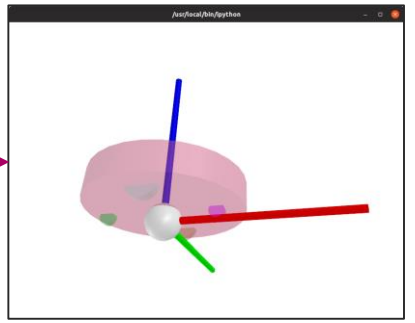
```
{% set base_link = 'base_link' %}

{% if namespace|length > 0 %}
    {% set base_link = [namespace, base_link]|join('/') %}
{% endif %}

<link name="{{ base_link }}">
    <pose>0 0 0 0 0 0</pose>
    <inertial>
        <pose>0 0 0 0 0 0</pose>
        <mass>{{ parameters.base_link_mass }}</mass>
        {{ inertias.solid_cylinder_inertia(
            parameters.base_link_mass,
            parameters.base_link_radius,
            parameters.base_link_length,
            "z") }}
    </inertial>

    <visual name="visual">
        <pose>0 0 0 0 0 0</pose>
        <geometry>
            <mesh>
                <uri>$(find pcg_kobuki_description)/meshes/kobuki/main_body.obj</uri>
                <scale>1 1 1</scale>
            </mesh>
        </geometry>
    </visual>

    <collision name="collision">
        <pose>0 0 0.005737 0 0 0</pose>
        <geometry>
            <cylinder>
                <radius>0.175</radius>
                <length>0.06553</length>
            </cylinder>
        </geometry>

        <surface>
            {{ physics.collision_friction_properties(
                sdf_version=sdf_version|default(1.6, true),
                mu=base_link_friction|default(0.3, true),
                mu2=base_link_friction2|default(0.3, true),
                friction=base_link_friction|default(0.3, true),
                friction2=base_link_friction2|default(0.3, true)
                ) }}
        </surface>
    </collision>
```

`kobuki` robot description written as a SDF Jinja template

Processing the Jinja template, generate SDF and instantiate a **`SimulationModel`** object

```
In [1]: from pcg_gazebo.simulation import SimulationModel

In [2]: from pcg_gazebo.parsers import parse_sdf

In [3]: from pcg_gazebo.utils import process_jinja_template

In [4]: output_xml = process_jinja_template('kobuki.sdf.jinja', parameters=dict(namespace='kobuki', mode='default'))

In [5]: sdf = parse_sdf(output_xml)

In [6]: model = SimulationModel.from_sdf(sdf.models[0])

In [7]: model.show(mesh_type='visual')

In [8]: model.show(mesh_type='collision')
```





Creating a static Gazebo model with metadata in the **`$HOME/.gazebo/models`** folder

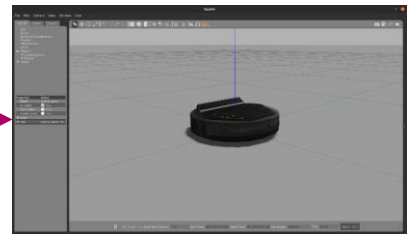
```
In [9]: model.to_gazebo_model()
Out[9]: '/home/[redacted]/.gazebo/models/kobuki'

In [10]: cd /home/[redacted]/.gazebo/models/kobuki/
/home/[redacted]/.gazebo/models/kobuki

In [11]: ls
meshes/  model.config  model.sdf
```

Exporting the URDF file for the **`kobuki`** robot

```
In [12]: urdf = model.to_urdf()

In [13]: urdf.export_xml('kobuki.urdf')
```

Spawn the model to a running instance of Gazebo

```
In [14]: model.spawn()
Out[14]: True
```



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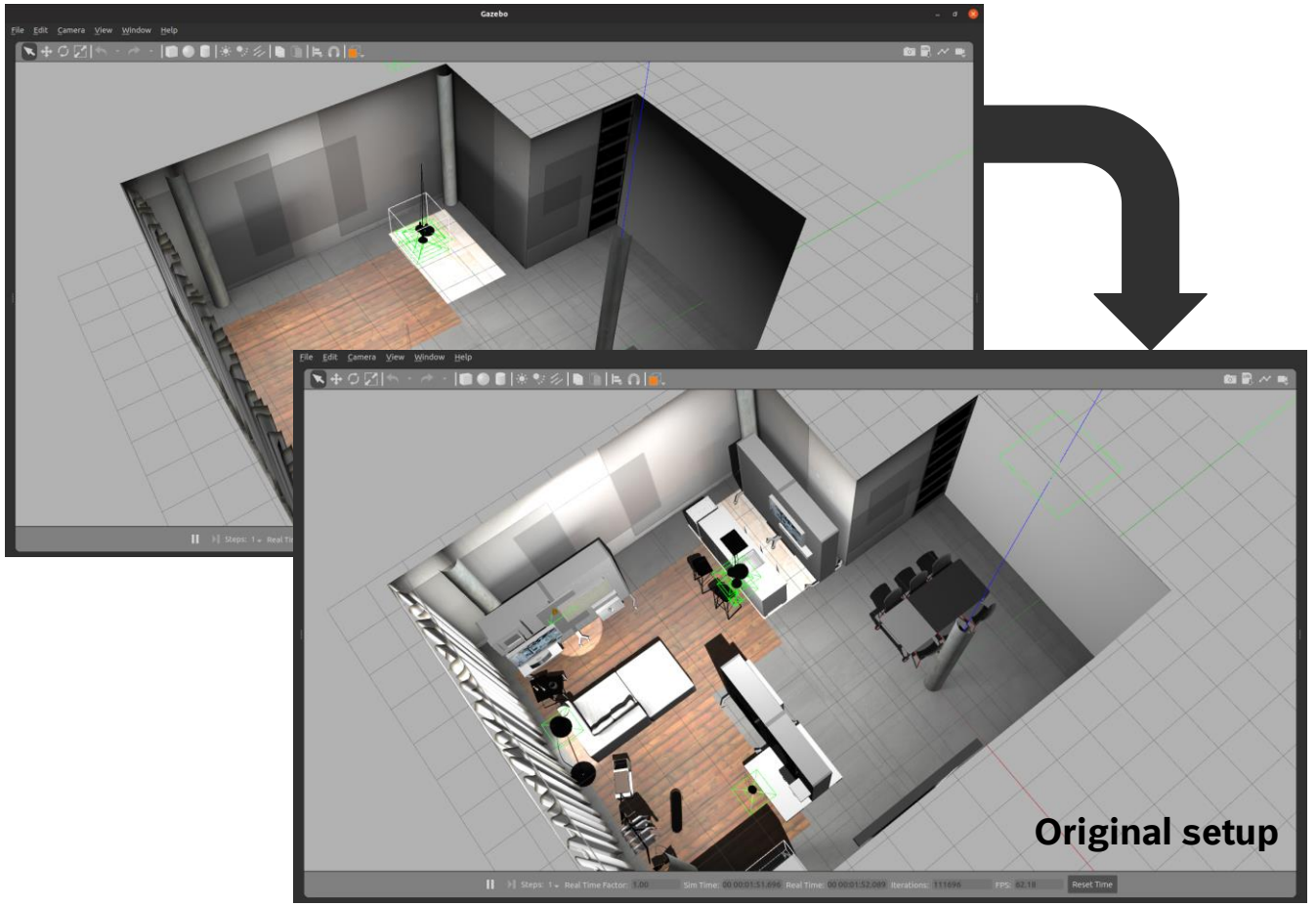
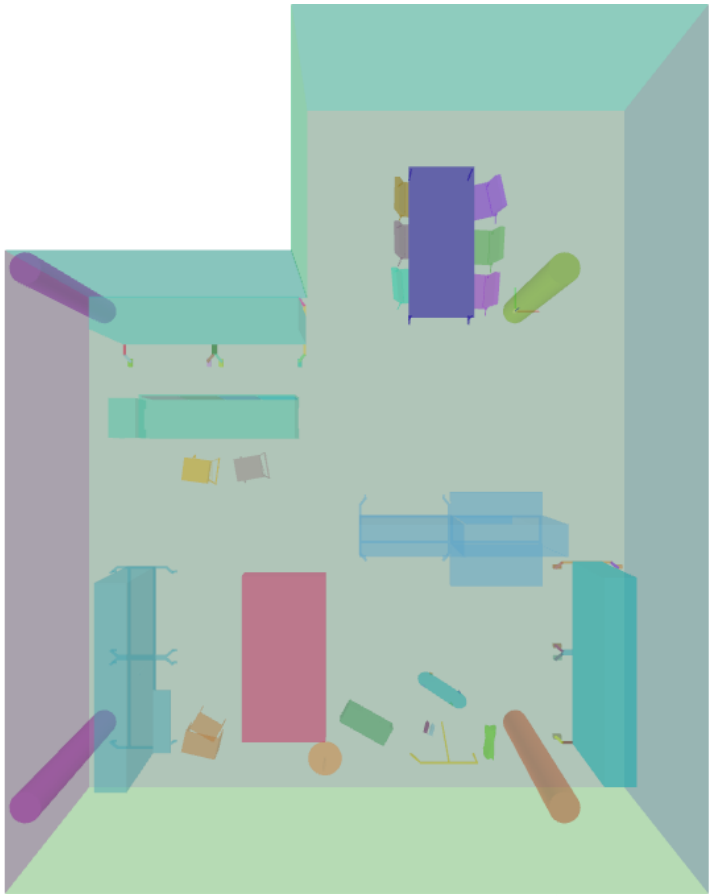
World generators
Generating world configurations

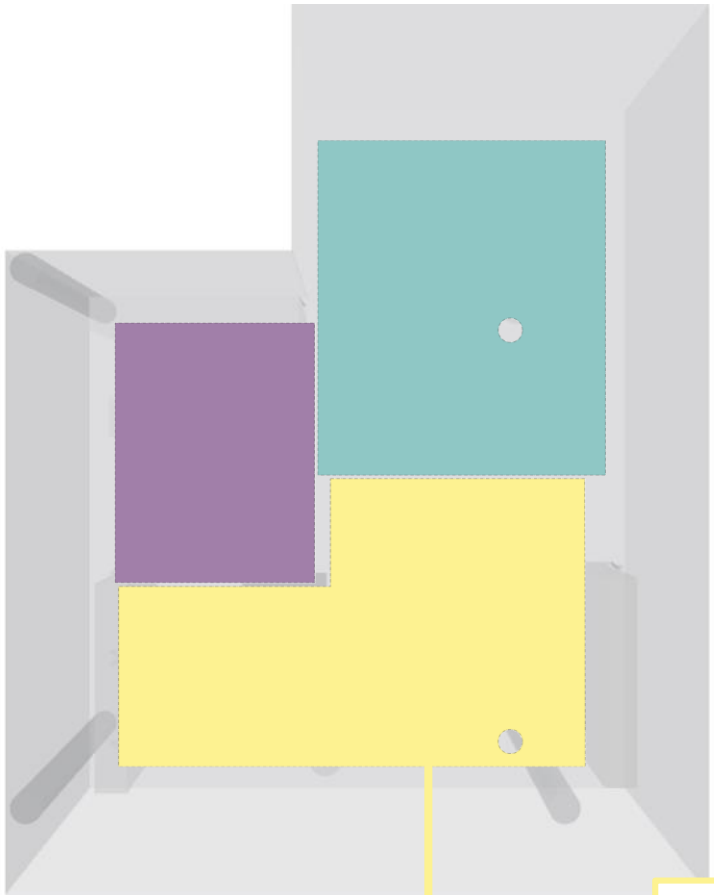


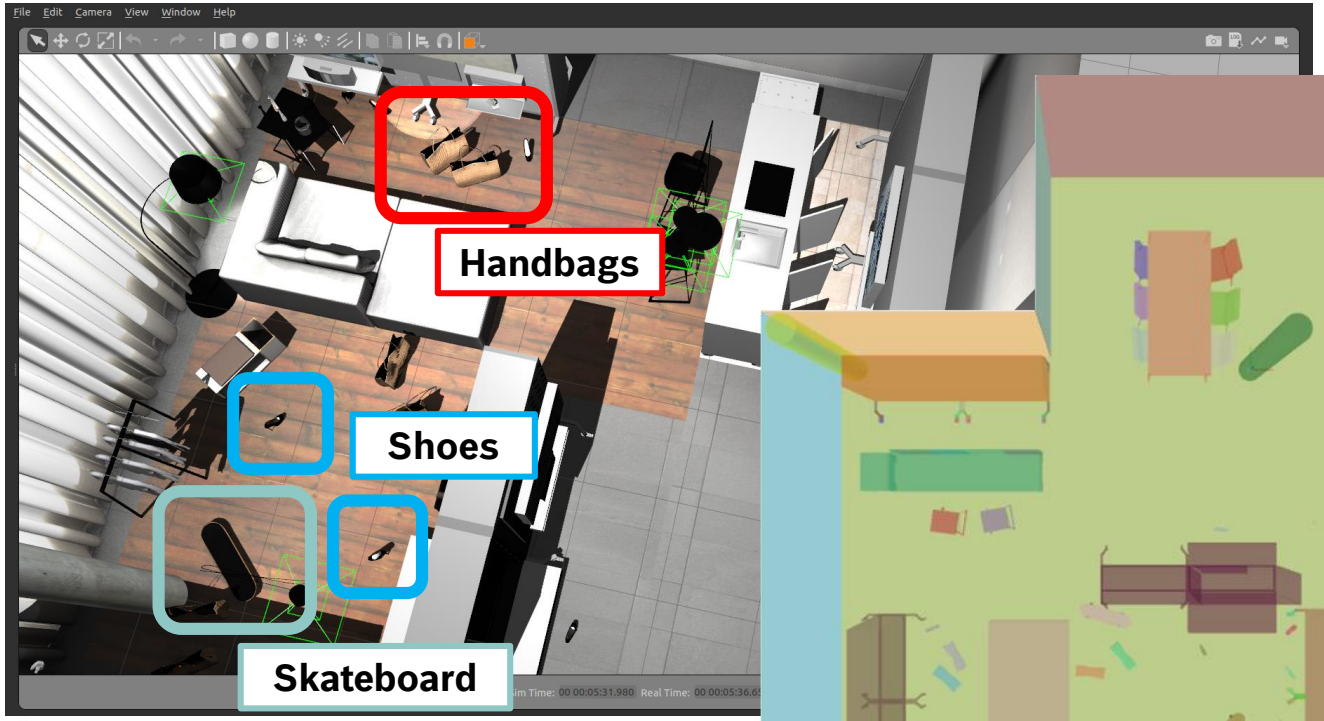
Collision geometries



World generators

Workspaces and pose randomization with collision checking





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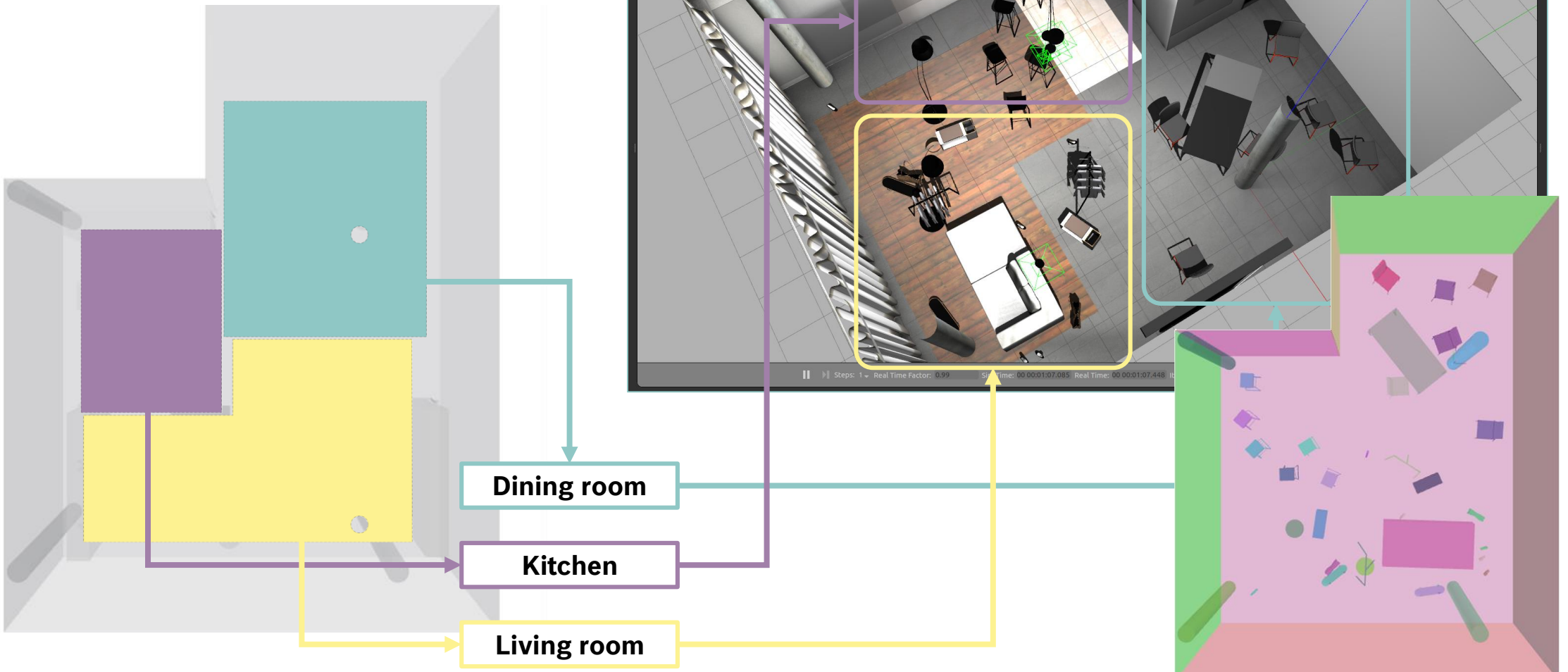
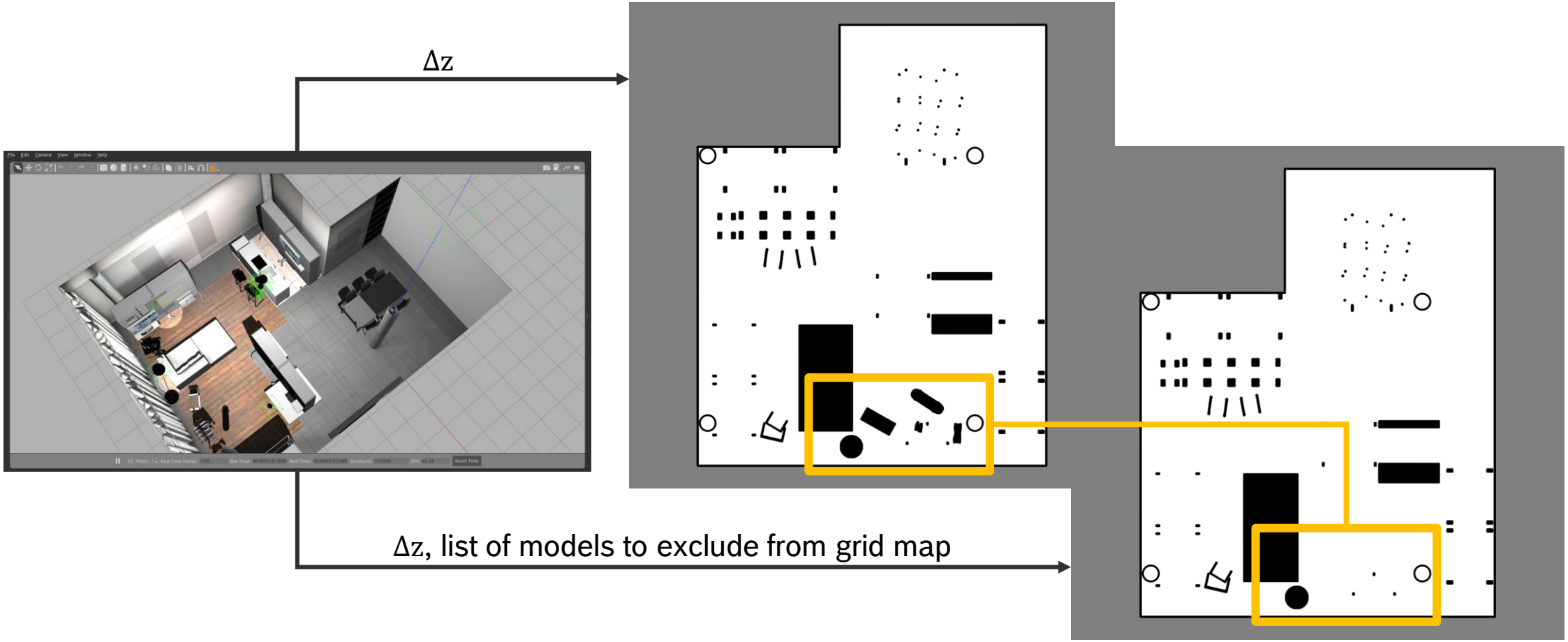
World generators
Pose randomization



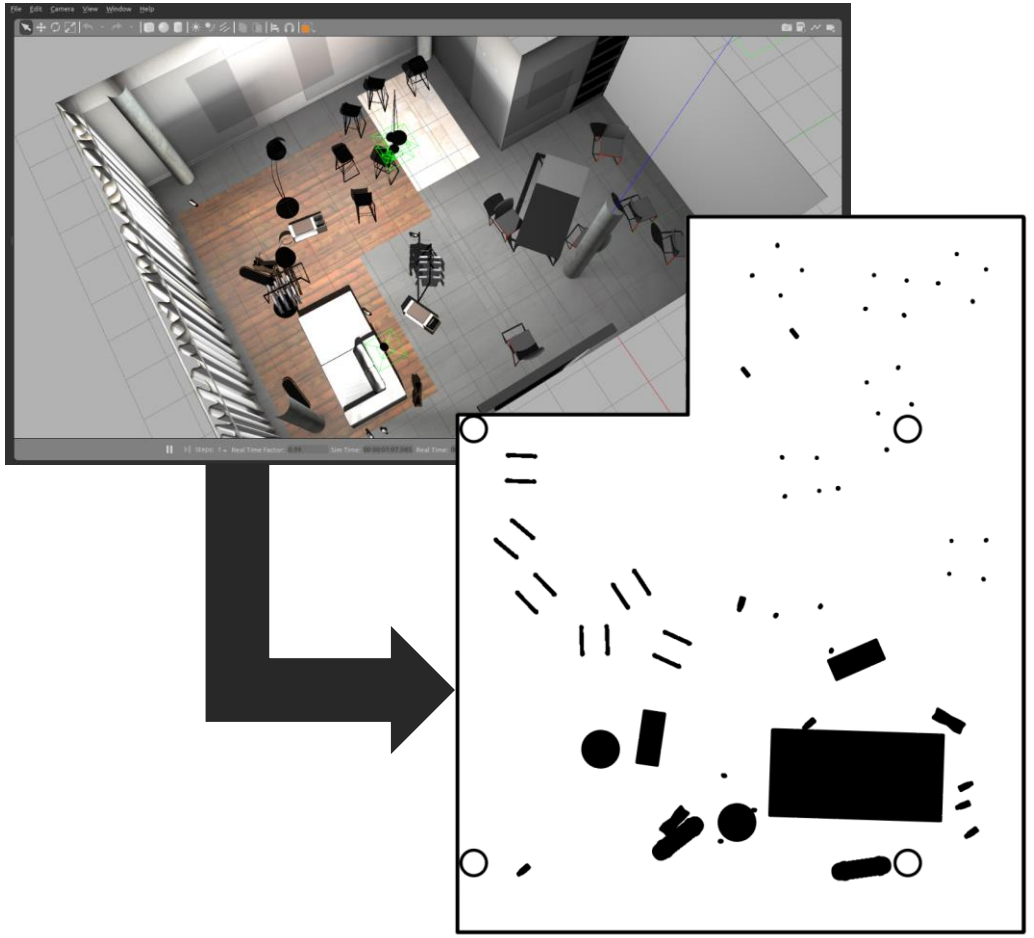
World generators

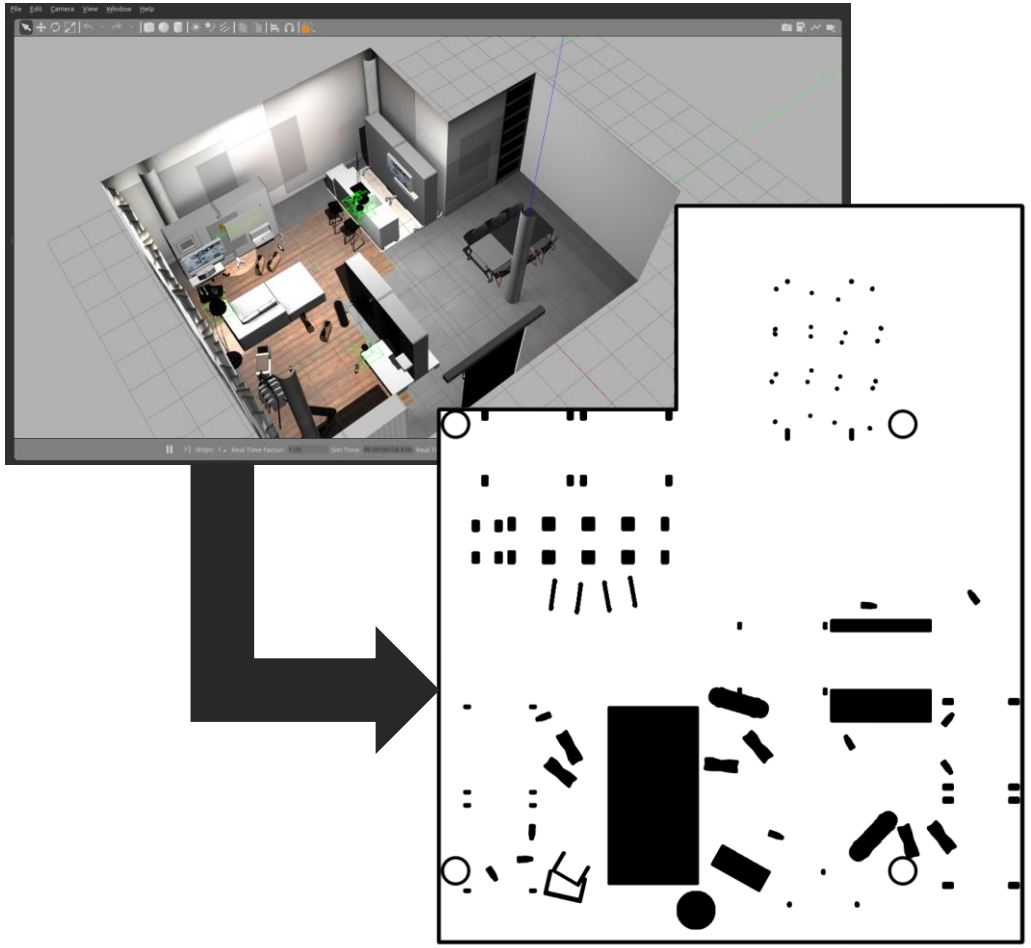
Generating grid maps from Gazebo worlds via ray tracing



World generators

Generating grid maps from Gazebo worlds via ray tracing





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TL;DR

TL;DR

- **`pcg_gazebo_pkgs`** can be used for testing simulation scenarios without editing XML files
- Scripting can be used to generate assets and interact with the simulation
- Dynamic model and world generation allows generation of large number of assets with small effort for testing robotics systems solutions in various contexts
- Python libraries can be used on the simulation building process, along with Jupyter notebooks
- Model editing and inspection
- **`sdf2urdf`** and **`urdf2sdf`** give more possibilities of ways to represent the robot description
- Package available at **`https://github.com/boschresearch/pcg_gazebo_pkgs`** under Apache-2.0 license

THANK YOU

CONTACT

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REPOSITORY

https://github.com/boschresearch/pcg_gazebo_pkgs

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