МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ
ФЕДЕРАЛЬНОЕ АГЕНСТВО ПО ОБРАЗОВАНИЮ

ГОСУДАРСТВЕННОЕ ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ПРОФЕССИОНАЛЬНОГО ОБРАЗОВАНИЯ

САНКТ-ПЕТЕРБУРГСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ, МЕХАНИКИ И ОПТИКИ

Факультет систем управления и робототехники

ОТЧЁТ

ЛАБОРАТОРНАЯ РАБОТА №3

Вариант №14

По дисциплине**: «Иммитационное моделирование роботехнических систем»**

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Задание: Сформировать xml модель для TENDON connected 2R planar mechanism. Напишите скрипт на Python с моделью, данными и методами просмотра.

Кинематическая схема представлена на рисунке 1:

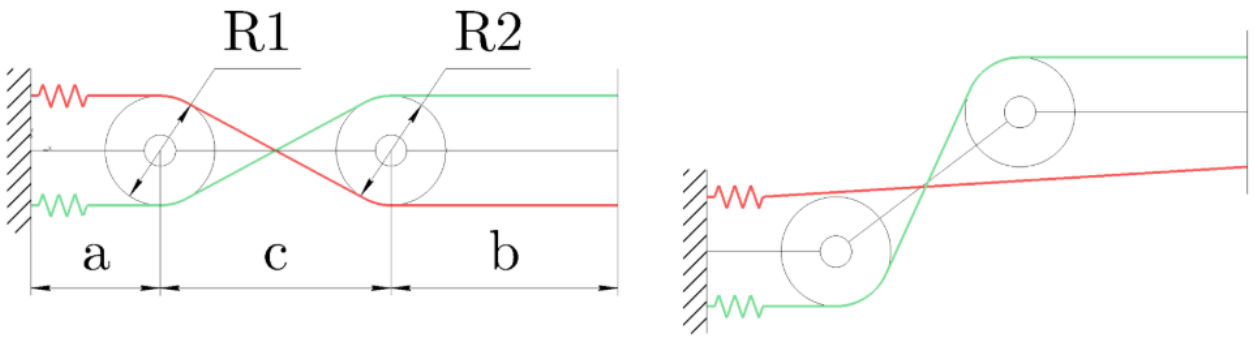


Рисунок 1 - tendon connected 2R planar mechanism

Входные данные для варианта №14:

$$R_1 = 0.035 \text{ м};\ R_2 = 0.032 \text{ м}; a = 0.076 \text{ м}; b = 0.049 \text{ м}; c = 0.098 \text{ м}.$$

Pause mode in MuJoCo:

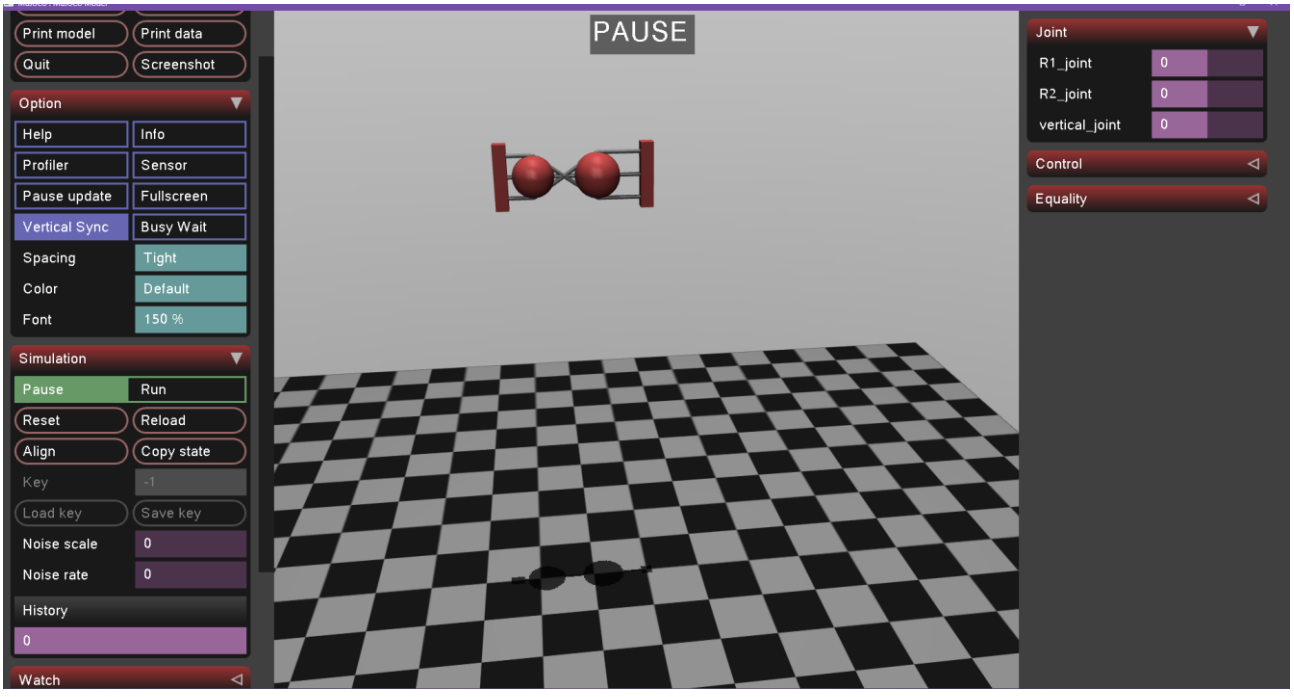


Figure 1 – Pause mode

Run mode in MuJoCo:

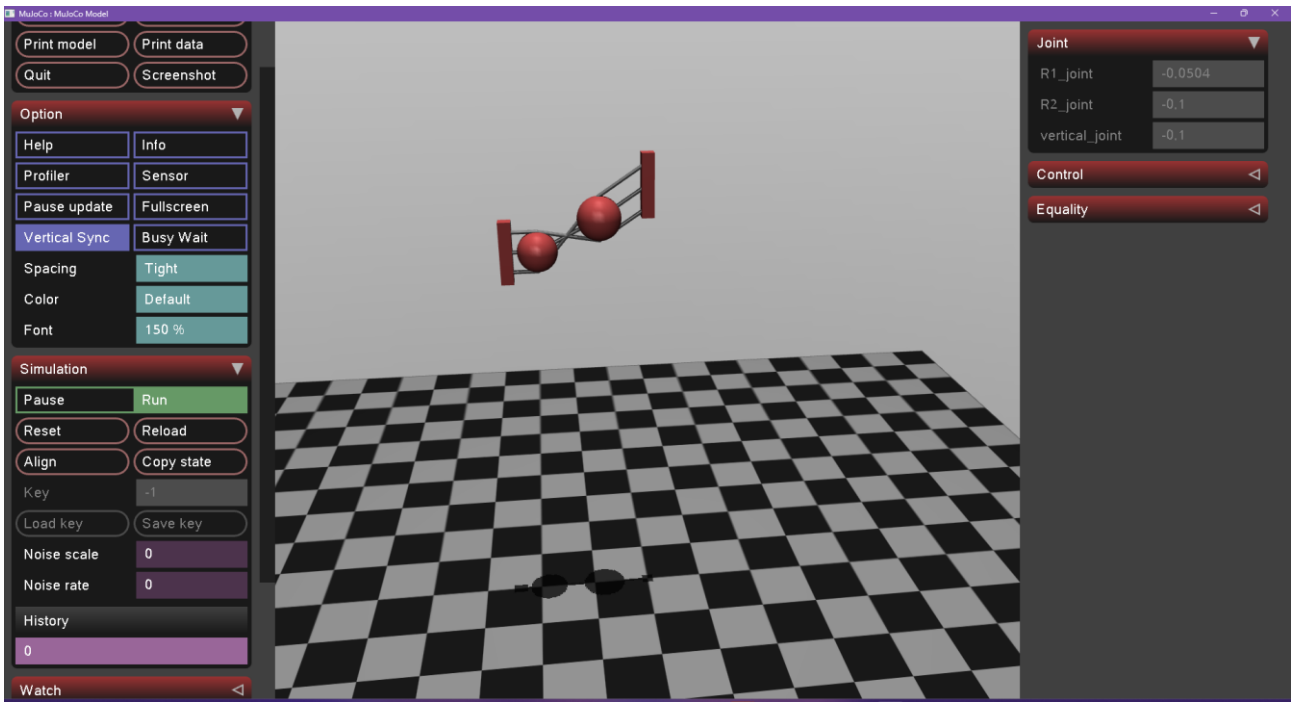


Figure 2 - Run mode

XML модель выглядит следующим образом:

```
<?xml version='1.0' encoding='UTF-8'?>
<mujoco>
    <option timestep="1e-4"/>
    <option gravity="0 0 -9.8"/>

    <asset>
        <texture type="skybox" builtin="gradient" rgb1="1 1 1" rgb2="0.5 0.5 0.5" width="265" height="256"/>
        <texture name="grid" type="2d" builtin="checker" rgb1="0.1 0.1 0.1" rgb2="0.6 0.6 0.6" width="300" height="300"/>
        <material name="grid" texture="grid" texrepeat="10 10" reflectance="0.2"/>
    </asset>

    <worldbody>
        <light pos="0 0 10"/>
        <geom type="plane" size="1 1 0.1" material="grid"/>
```

```
<camera name="side view" pos="1 -2 1" euler="60 0 30" fovy="60"/>
<camera name="front view" pos="0 -2 1" euler="0 0 0"/>

<!-- Неподвижный блок -->

<body name="base" pos="0 0 0.75">
<geom type="box" size="0.01 0.01 0.05" rgba="0.8 0.3 0.3 1"/>
<site name="top_attachment_0" pos="0 0 0.035" size="0.001" rgba="1 0 0 1"/>
<site name="middle_attachment_0" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
<site name="bottom_attachment_0" pos="0 0 -0.035" size="0.001" rgba="0 0 1 1"/>
</body>

<!-- Звено R1 -->

<body name="R1" pos="0 0.076 0.75">
<geom name="R1_geom" type="sphere" size="0.035" rgba="0.8 0.3 0.3 1"/>
<joint name="R1_joint" type="slide" axis="0 0 1" range="-0.05 0.05"/>
<site name="top_attachment_1" pos="0 0 0.035" size="0.001" rgba="1 0 0 1"/>
<site name="middle_attachment_1" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
<site name="bottom_attachment_1" pos="0 0 -0.035" size="0.001" rgba="0 0 1 1"/>
</body>

<!-- Звено R2 -->

<body name="R2" pos="0 0.174 0.75">
<geom name="R2_geom" type="sphere" size="0.032" rgba="0.8 0.3 0.3 1"/>
<joint name="R2_joint" type="slide" axis="0 0 1" range="-0.10 0.10"/>
```

```
        <site name="top_attachment_2" pos="0 0 0.032" size="0.001" rgba="1 0 0 1"/>
        <site name="middle_attachment_2" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
        <site name="bottom_attachment_2" pos="0 0 -0.032" size="0.001" rgba="0 0 1 1"/>
      </body>

      <body name="S" pos="0 0.223 0.75">
      <joint name="vertical_joint" type="slide" axis="0 0 1" range="-0.1 0.1"/>
      <geom type="box" size="0.01 0.01 0.05" rgba="0.8 0.3 0.3 1" mass="0.001"/>
        <site name="top_attachment_00" pos="0 0 0.032" size="0.001" rgba="1 0 0 1"/>
        <site name="middle_attachment_00" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
        <site name="bottom_attachment_00" pos="0 0 -0.032" size="0.001" rgba="0 0 1 1"/>
      </body>

  </worldbody>

   <!-- СУХОЖИЛИЯ -->

  <tendon>
    <spatial name="a">
      <site site="middle_attachment_0"/>
      <site site="middle_attachment_1"/>
    </spatial>

    <spatial name="b">
      <site site="middle_attachment_1"/>
      <site site="middle_attachment_2"/>
```

```
    </spatial>

     <spatial name="c">
        <site site="middle_attachment_2"/>
        <site site="middle_attachment_00"/>
    </spatial>

    <spatial name="tendon2">
        <site site="top_attachment_0"/>
        <site site="top_attachment_1"/>
        <site site="bottom_attachment_2"/>
        <site site="bottom_attachment_00"/>
    </spatial>

    <spatial name="tendon3">
        <site site="bottom_attachment_0"/>
        <site site="bottom_attachment_1"/>
        <site site="top_attachment_2"/>
        <site site="top_attachment_00"/>
    </spatial>

  </tendon>

    <!-- МЫШЦЫ -->

  <actuator>

      <muscle name="lift_muscle" tendon="tendon2" ctrlrange="0 1" force="100" lengthrange="0.2 0.5"/>
```

<muscle name="lower_muscle" tendon="tendon3" ctrlrange="0 1" force="100" lengthrange="0.2 0.5"/>

</actuator>

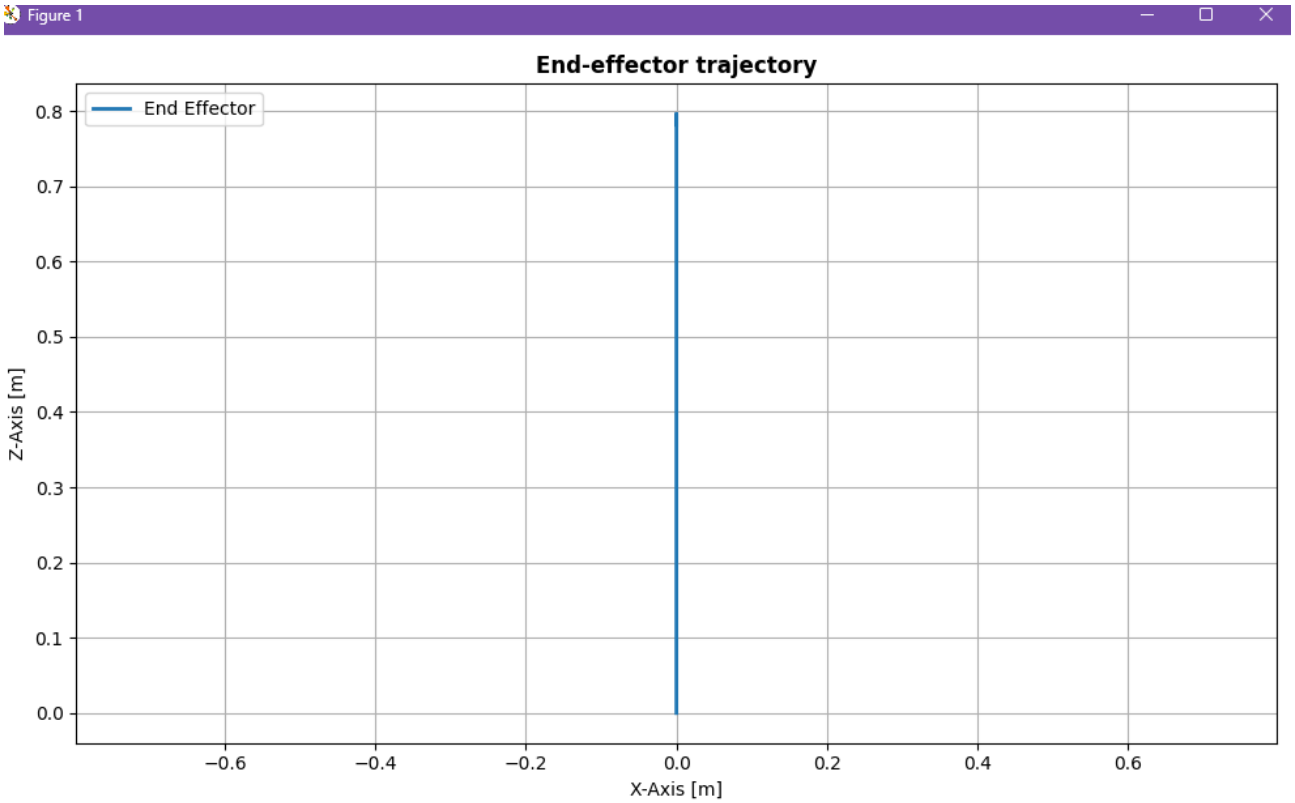
</mujoco>

```
<?xml version='1.0' encoding='UTF-8'?>
<mujoco>
    <option timestep="1e-4"/>
    <option gravity="0 0 -9.8"/>

    <asset>
        <texture type="skybox" builtin="gradient" rgb1="1 1 1" rgb2="0.5 0.5 0.5" width="265" height="256"/>
        <texture name="grid" type="2d" builtin="checker" rgb1="0.1 0.1 0.1" rgb2="0.6 0.6 0.6" width="300" height="300"/>
        <material name="grid" texture="grid" texrepeat="10 10" reflectance="0.2"/>
    </asset>

    <worldbody>
        <light pos="0 0 10"/>
        <geom type="plane" size="1 1 0.1" material="grid"/>

        <camera name="side view" pos="1 -2 1" euler="60 0 30" fovy="60"/>
        <camera name="front view" pos="0 -2 1" euler="0 0 0"/>

         <!-- Неподвижный блок -->

            <body name="base" pos="0 0 0.75">
            <geom type="box" size="0.01 0.01 0.05" rgba="0.8 0.3 0.3 1"/>
            <site name="top_attachment_0" pos="0 0 0.035" size="0.001" rgba="1 0 0 1"/>
            <site name="middle_attachment_0" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
            <site name="bottom_attachment_0" pos="0 0 -0.035" size="0.001" rgba="0 0 1 1"/>
            </body>

            <!-- Звено R1 -->

            <body name="R1" pos="0 0.076 0.75">
            <geom type="sphere" size="0.035" rgba="0.8 0.3 0.3 1"/>
            <joint name="R1_joint" type="slide" axis="0 0 1" range="-0.05 0.05"/>
            <site name="top_attachment_1" pos="0 0 0.035" size="0.001" rgba="1 0 0 1"/>
            <site name="middle_attachment_1" pos="0 0 0" size="0.001" rgba="0 1 0 1"/>
```

```
            <site name="bottom_attachment_1" pos="0 0 -0.035" size="0.001" rgba="0
0 1 1"/>
            </body>

            <!-- Звено R2 -->

            <body name="R2" pos="0 0.174 0.75">
            <geom type="sphere" size="0.032" rgba="0.8 0.3 0.3 1"/>
            <joint name="R2_joint" type="slide" axis="0 0 1" range="-0.10 0.10"/>
            <site name="top_attachment_2" pos="0 0 0.032" size="0.001" rgba="1 0 0
1"/>
            <site name="middle_attachment_2" pos="0 0 0" size="0.001" rgba="0 1 0
1"/>
            <site name="bottom_attachment_2" pos="0 0 -0.032" size="0.001" rgba="0
0 1 1"/>
            </body>

            <body name="B" pos="0 0.223 0.75">
            <joint name="vertical_joint" type="slide" axis="0 0 1" range="-0.1
0.1"/>
            <geom type="box" size="0.01 0.01 0.05" rgba="0.8 0.3 0.3 1"
mass="0.001"/>
            <site name="top_attachment_00" pos="0 0 0.032" size="0.001" rgba="1 0 0
1"/>
            <site name="middle_attachment_00" pos="0 0 0" size="0.001" rgba="0 1 0
1"/>
            <site name="bottom_attachment_00" pos="0 0 -0.032" size="0.001" rgba="0
0 1 1"/>
            </body>

    </worldbody>

      <!-- СУХОЖИЛИЯ -->

    <tendon>
        <spatial name="tendon1">
            <site site="middle_attachment_0"/>
            <site site="middle_attachment_1"/>
            <site site="middle_attachment_2"/>
            <site site="middle_attachment_00"/>
        </spatial>

        <spatial name="tendon2">
            <site site="top_attachment_0"/>
            <site site="top_attachment_1"/>
            <site site="bottom_attachment_2"/>
            <site site="bottom_attachment_00"/>
        </spatial>

        <spatial name="tendon3">
            <site site="bottom_attachment_0"/>
```

```
            <site site="bottom_attachment_1"/>
            <site site="top_attachment_2"/>
            <site site="top_attachment_00"/>
        </spatial>

    </tendon>

        <!-- МЫШЦЫ -->

    <actuator>

        <muscle name="lift_muscle" tendon="tendon2" ctrlrange="0 1" force="100"
lengthrange="0.2 0.5"/>
        <muscle name="lower_muscle" tendon="tendon3" ctrlrange="0 1" force="100"
lengthrange="0.2 0.5"/>

    </actuator>
</mujoco
```

Далее необходимо провести параметризацию с помощью VS code:



Таким образом, Error: 0.04622499999999559

Код на Python в среде VS code:

```
import mujoco
import matplotlib.pyplot as plt
import numpy as np
from lxml import etree
import time

f1 = "C:\\Users\\yanan\\.vscode\\506885_GolubevaYana_Task3.xml"
f2 = "C:\\Users\\yanan\\.vscode\\506885_GolubevaYana_Task3_modified.xml"

def swap_par(tree, element_type, element_name, attribute_name, new_value):
    element = tree.find(f'.//{element_type}[@name="{element_name}"]')
    if element is not None:
        element.set(attribute_name, new_value)

a = 0.076
b = 0.098
c = 0.049
R1 = 0.035
R2 = 0.032
base_height = 0.75

tree = etree.parse(f1)

# Настройка модели
swap_par(tree, 'body', 'R1', 'pos', f"0 {a} {base_height}")
swap_par(tree, 'body', 'R2', 'pos', f"0 {b} {base_height}")
swap_par(tree, 'body', 'S', 'pos', f"0 {c} {base_height}")

swap_par(tree, 'geom', 'R1_geom', 'size', f"{R1}")
swap_par(tree, 'geom', 'R2_geom', 'size', f"{R2}")

swap_par(tree, 'site', 'top_attachment_1', 'pos', f"0 0 {R1}")
swap_par(tree, 'site', 'middle_attachment_1', 'pos', "0 0 0")
swap_par(tree, 'site', 'bottom_attachment_1', 'pos', f"0 0 -{R1}")

swap_par(tree, 'site', 'top_attachment_2', 'pos', f"0 0 {R2}")
swap_par(tree, 'site', 'middle_attachment_2', 'pos', "0 0 0")
swap_par(tree, 'site', 'bottom_attachment_2', 'pos', f"0 0 -{R2}")

tree.write(f2, pretty_print=True, xml_declaration=True, encoding='UTF-8')

# Загрузка модели
model = mujoco.MjModel.from_xml_path(f2)
data = mujoco.MjData(model)

# Функция управления
def set_torque(mj_data, time_val, amplitude, frequency, phase):
    if model.nu >= 2:
        data.ctrl[0] = amplitude * np.sin(time_val * frequency + phase)
```

```
        data.ctrl[1] = -data.ctrl[0]
    elif model.nu >= 1:
        data.ctrl[0] = amplitude * np.sin(time_val * frequency + phase)

# Параметры симуляции
SIMEND = 20
TIMESTEP = 0.001
STEP_NUM = int(SIMEND / TIMESTEP)

A = 3
F = 30
P = 0

ee_pos_x = []
ee_pos_z = []

for i in range(STEP_NUM):
    set_torque(data, data.time, A, F, P)

    site_id = 8
    position_EE = data.site_xpos[site_id]
    ee_pos_x.append(position_EE[0])
    ee_pos_z.append(position_EE[2])

    mujoco.mj_step(model, data)
if len(ee_pos_x) > 0:
    midlength = int(len(ee_pos_x)/2)

    plt.figure(figsize=(10, 6))
    plt.plot(ee_pos_x, ee_pos_z, '-', linewidth=2, label='End Effector')
    plt.title('End-effector trajectory', fontsize=12, fontweight='bold')
    plt.legend(loc='upper left')
    plt.xlabel('X-Axis [m]')
    plt.ylabel('Z-Axis [m]')
    plt.axis('equal')
    plt.grid(True)
    plt.tight_layout()
    plt.show()

    base_height_z = 1.0
    error = sum((np.array(ee_pos_z[midlength:]) - base_height_z *
np.ones(len(ee_pos_z[midlength:]))) ** 2)/len(ee_pos_z[midlength:])
    print(f"Error: {error}")
```