Third Task for SRS

Salam Ali

503263

In this project, we build a tendon-driven mechanism in MuJoCo using an XML model. The XML file defines the bodies, joints, geometry, and constraints needed to simulate the structure.

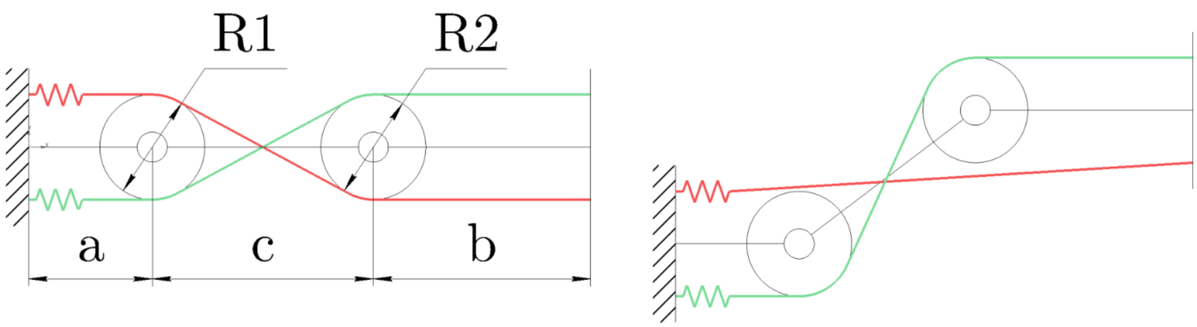

Figure 1: Passive RR mechanism

Given values from table:

503263	TENDON	0.045	0.02	0.034	0.075	0.052

While defining the model, we noticed that the distance between the two circle centers was smaller than the sum of their radii. This created a geometric inconsistency, leading to an overlap between the two shapes. To fix this, we adjusted the radius of the first circle to 0.025, allowing the geometry to fit properly without intersection.

1.XML building:

- Left bout at position $\begin{pmatrix}0 & 0 & 0\end{pmatrix}$.

  1. Middle bar from position $\begin{pmatrix}0 & 0 & 0\end{pmatrix}$ to position $\begin{pmatrix}0.034 & 0 & 0\end{pmatrix}$.

  2.plotinng two points s_1, s_2 at the first bound at positions $\begin{pmatrix}0.002 & 0 & \pm 0.0135\end{pmatrix}$.

- Drawing first pully center at position $\begin{pmatrix}0.034 & 0 & 0\end{pmatrix}$.

  1.Drawing bar from point $\begin{pmatrix}0 & 0 & 0\end{pmatrix}$ to point $\begin{pmatrix}0.127 & 0 & 0\end{pmatrix}$.

  2.Drawing the first pully at the initial position of this new body $\begin{pmatrix}0 & 0 & 0\end{pmatrix}$.

  3.Plotting points s_3, s_4 on the first pully at the positions $\begin{pmatrix}0 & 0 & \pm 0.0127\end{pmatrix}$.

  4.Drawing the center of the second pully at the position $\begin{pmatrix}0 & 0 & 0.052\end{pmatrix}$.

  - Drawing the second pully at position $\begin{pmatrix}0 & 0 & 0\end{pmatrix}$.
  - Plotting points s_5, s_6 on the second pully at the points $\begin{pmatrix}0 & 0 & \pm 0.01\end{pmatrix}$

- Plotting two points s_7, s_8 at the second bound at positions $\begin{pmatrix}0.073 & 0 & \pm 0.012\end{pmatrix}$.
- Drawing the second bound at position $\begin{pmatrix}0.075 & 0 & 0\end{pmatrix}$.

- Drawing tendons.

  1.First one $s_1 \to s_3 \to s_6 \to s_8$.

  2.Second one $s_2 \to s_4 \to s_5 \to s_7$.

Xml

```
<mujoco model="tendon">

    <option gravity="0 -9.81 0" integrator="Euler"/>
    <statistic center="0 0 0" extent="0.2"/>

    <visual>
        <rgba haze="0.9 0.9 0.95 1"/>
    </visual>

    <default>
        <joint axis="0 1 0" damping="0.00005"/>
        <geom type="capsule"/>
    </default>

    <asset>
        <texture name="texplane" type="2d" builtin="checker"
                 rgb1="0.2 0.2 0.2" rgb2="0.2 0.2 0.2"
                 width="512" height="512" mark="none"/>
        <material name="matplane" reflectance="0"
                  texture="texplane" texrepeat="1 1" texuniform="true"/>
    </asset>

    <worldbody>

        <light pos="0 0 0.25" />
        <light pos="0 0 3" dir="0 0 -1" directional="false" />

        <geom name="floor" pos="0 0 -0.14" size="0 0 1"
              type="plane" material="matplane" conaffinity="15" condim="3"/>

        <body pos="0 0 0">

            <geom name="left_bound" type="box"
                  size="0.002 0.03 0.03"
                  rgba="0.3 0.5 1 1" pos="0 0 0"/>

            <geom fromto="0 0 0 0.034 0 0"
                  rgba=".8 .8 .3 .6" size=".002"
                  contype="0" conaffinity="0"/>

            <site name="s1" pos="0.002 0 0.0135" size=".002" rgba="1 1 0 1"/>
            <site name="s2" pos="0.002 0 -0.0135" size=".002" rgba="1 1 0 1"/>

            <body pos="0.034 0 0">
                <joint name="elbow"/>

                <geom fromto="0 0 0 0.127 0 0"
                      rgba=".8 .8 .3 .6" size=".002"/>

                <body name="pulley1_body" pos="0 0 0">
                    <joint name="pulley1_hinge" type="hinge"
                           axis="0 1 0" stiffness="5" damping="0.005"/>
```

```
                    <geom name="Pulley" type="cylinder"
                          fromto="0 .005 0 0 -.005 0"
                          size=".0125"
                          rgba=".3 .3 .9 .9"/>

                    <site name="s3" pos="0 0 0.0127" size=".002" rgba="1 1 0 1"/>
                    <site name="s4" pos="0 0 -0.0127" size=".002" rgba="1 1 0 1"/>
                </body>

                <body pos="0.052 0 0">
                    <joint name="wrist"/>

                    <geom fromto="0 0 0 0.073 0 0"
                          rgba=".8 .8 .3 .6" size=".002"/>

                    <body name="pulley2_body" pos="0 0 0">
                        <joint name="pulley2_hinge" type="hinge"
                               axis="0 1 0" stiffness="5" damping="0.005"/>

                        <geom name="Pulley2" type="cylinder"
                              fromto="0 .005 0 0 -.005 0"
                              size=".01"
                              rgba=".3 .3 .9 .9"/>

                        <site name="s5" pos="0 0 0.01" size=".002" rgba="1 1 0 1"/>
                        <site name="s6" pos="0 0 -0.01" size=".002" rgba="1 1 0 1"/>
                        <site name="s7" pos="0.073 0 0.012" size=".002" rgba="1 1 0 1"/>
                        <site name="s8" pos="0.073 0 -0.012" size=".002" rgba="1 1 0 1"/>
                    </body>

                    <body>
                        <geom name="right_bound" type="box"
                              size="0.002 0.03 0.03"
                              rgba="0.3 0.5 1 1"
                              pos="0.075 0 0"/>
                    </body>
                </body>
            </body>
        </body>
    </worldbody>

     <tendon>

         <spatial stiffness="5" rgba="0.4 0.2 1 1" width="0.0015">
             <site site="s1"/>
             <geom geom="Pulley" sidesite="s3"/>
             <site site="s3"/>
             <geom geom="Pulley2" sidesite="s6"/>
             <site site="s8"/>
         </spatial>

         <spatial stiffness="5" rgba="0 0.85 0.7 1" width="0.0015">
             <site site="s2"/>
             <geom geom="Pulley" sidesite="s4"/>
             <site site="s4"/>
             <geom geom="Pulley2" sidesite="s5"/>
             <site site="s7"/>
         </spatial>

     </tendon>

</mujoco>
```

Python code:

```
import mujoco
from mujoco.viewer import launch_passive

model_path = r"C:\Users\user\OneDrive\Desktop\MuJoCo\hazem.xml"
model = mujoco.MjModel.from_xml_path(model_path)
data = mujoco.MjData(model)

for _ in range(100):
    mujoco.mj_step(model, data)

launch_passive(model, data)

input("Press Enter to exit...")
```

2.Simulation Result:

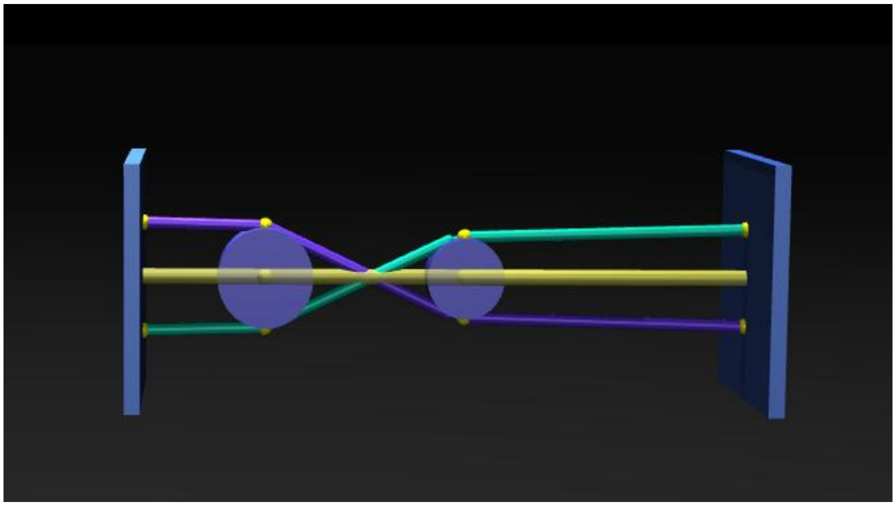

Figure 2: Result

3.Movement Simulation:

To enable the system to move, since it relies on spring-like tendons, we modified the XML file by adding stiffness and damping parameters to the pulley hinge joints (pulley1_hinge and pulley2_hinge). These values were added directly to the joint definitions so the pulleys can rotate properly as the tendons change length, without altering the structure of the model.

To simulate movement, we use this python code:

```
import time
import mujoco
import mujoco.viewer


model_path = r"C:\Users\user\OneDrive\Desktop\MuJoCo\tendon.xml"
model = mujoco.MjModel.from_xml_path(model_path)
data_ = mujoco.MjData(model)


joint1_positions = []
joint2_positions = []

with mujoco.viewer.launch_passive(model, data_) as viewer:
    start_time = time.time()

    while viewer.is_running() and time.time() - start_time < 25:
        step_start = time.time()

        elbow_index = model.jnt_qposadr[
            mujoco.mj_name2id(model, mujoco.mjtObj.mjOBJ_JOINT, 'elbow')
        ]
        wrist_index = model.jnt_qposadr[
            mujoco.mj_name2id(model, mujoco.mjtObj.mjOBJ_JOINT, 'wrist')
        ]

        mujoco.mj_step(model, data_)
        viewer.sync()
        joint1_positions.append(data_.qpos[elbow_index])
        joint2_positions.append(data_.qpos[wrist_index])

        dt = model.opt.timestep - (time.time() - step_start)
        if dt > 0:
            time.sleep(dt)
```

This script loads the MuJoCo model defined in the XML file and runs a real-time simulation to display the motion of the tendon–pulley system. After initializing the model and data, the code opens an interactive viewer using viewer.launch_passive, allowing us to observe the system as it moves.

We were able to move the tendon system, because the motion comes naturally from the mechanical interaction between the joints and the tendons. In our XML model, the tendons act like springs, and the pulleys can rotate because we assigned them stiffness and damping values in their hinge joints.

The stiffness creates a restoring force whenever the tendon path changes, and the damping prevents uncontrolled oscillations. As the simulation runs, the tendon tries to return to its equilibrium length, and this generates forces on the pulleys and joints. These internal forces are enough to create motion in the mechanism, even though no motors or actuators were added.

So, the movement comes entirely from the passive spring-like behavior of the tendons and the controlled rotation of the pulleys—not from any external actuation.