Work Assignment I: Modeling, motion control and trajectory generation of an exoskeleton arm or leg (Matlab & robotics toolbox)

Definition of standard trajectories

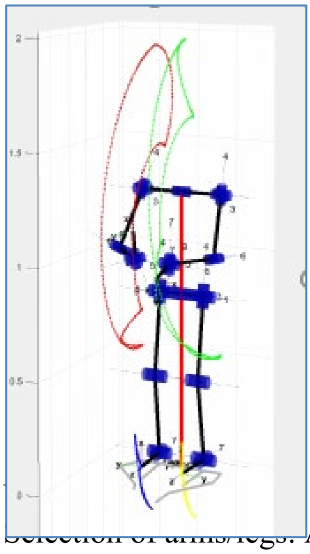
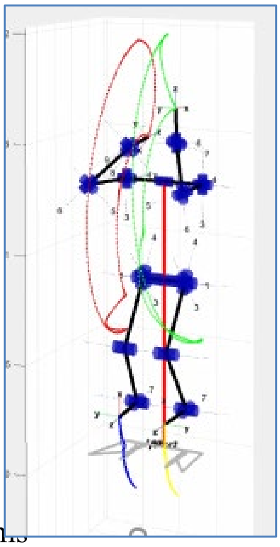
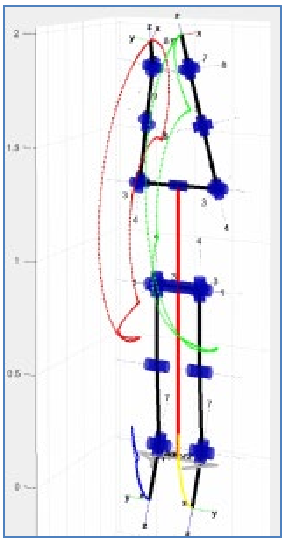
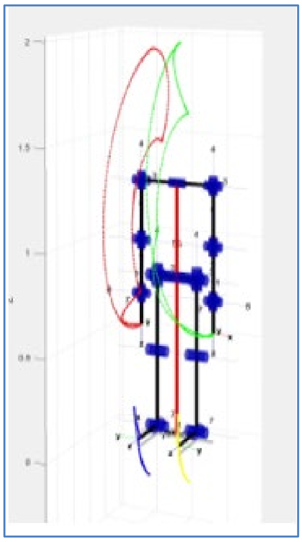
Next, we give the **instructions** for defining the "standard trajectories" you will address in this work assignment. These trajectories can be associated with classical motions done in sports, training, rehabilitation, dances, special waving, or any humanoid motion that can be useful (e.g., pick and place). The trajectories should not be too long, but should involve the motion of **all joints** in the arms/legs at least once (i.e., avoid pure planar motions).

Definition of standard trajectories: It should include

- Title for the trajectory
- Selection of arms/legs/full body
- Description of the selected standard trajectory for the mandatory part: a link to a video showing the motion you will later implement in your robot. It can be a video from the internet, or a recording of your own arms/legs making the activity.
- Please, make sure the trajectory involves the motion of all the joints.

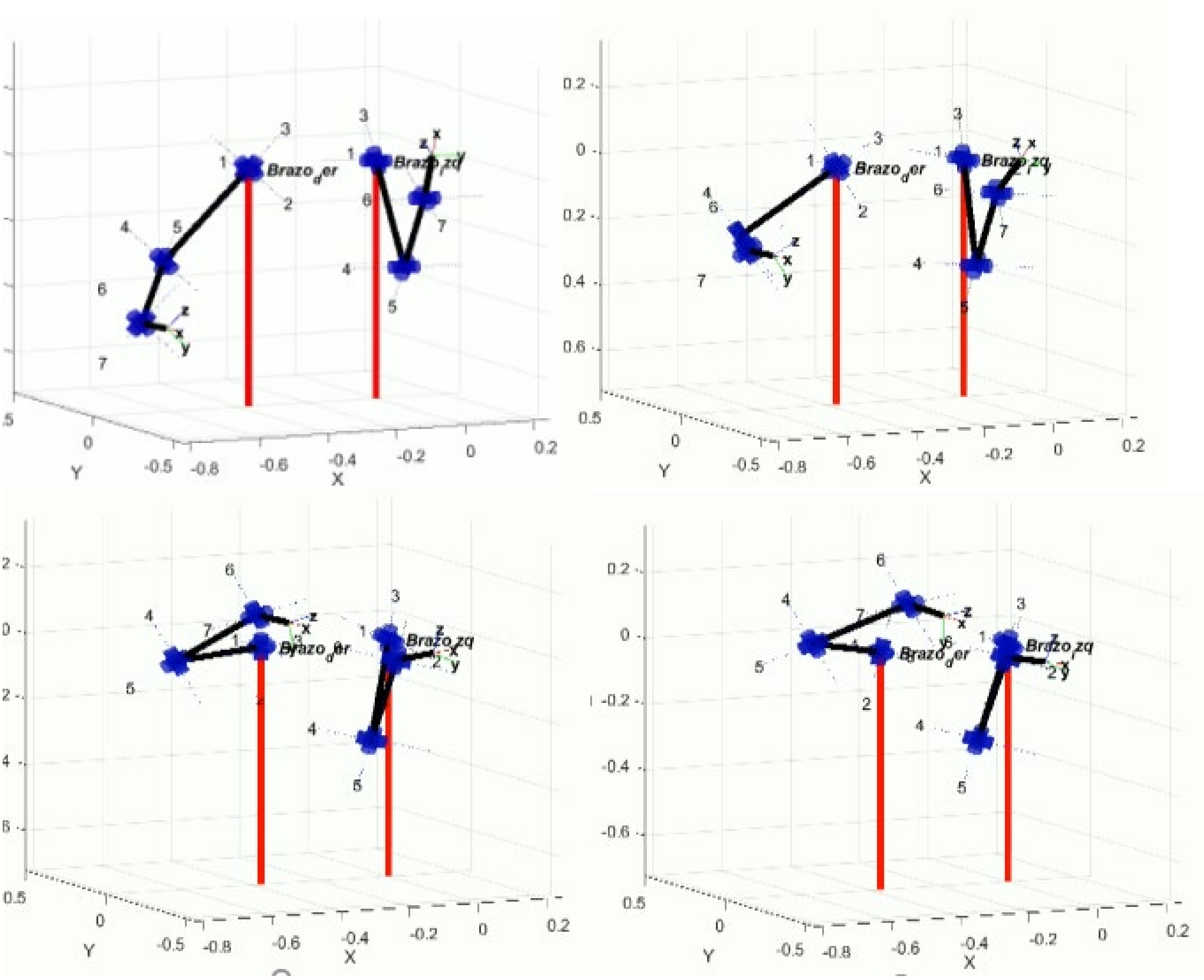
Examples of trajectories:

Basketball Shot
Selection of arms/legs: Full body
Description of the selected trajectory: https://youtu.be/SyvuSxCyfi0?t=86
Legs are bent in order to get some inertia later. Arms begin holding the ball from the left and front-right facing parts. They are then flexed to hold the ball closer to the position of the head. Later, legs are extended in order to push the body up into the air as shoulders are raised to push the ball further up. When this movement is being completed, arms are extended while holding the ball to throw it towards the net as the left hand lets the ball go and the right hand flexes to push it straight.

Selection of arms/legs: Arms
Description of the selected trajectory:
-Left arm: https://youtu.be/fAbUx9NQbH8?t=64
-Right arm: https://youtu.be/hF2XP_jaKmg?t=110
Right arm: movement of the violin bow on the second chord. Initial position: angle of 60 degrees at the elbow. Final position: the arm is compressed to play with the lower part of the violin bow. During the movement, the

bow must be perpendicular to the chords (linear trajectory). Left arm: movement of the left hand along the violin neck in order to place the fingers at different positions. Combined with "vibrato" movement.



Example: Drinking from a glass, right arm. Initial position: arm extended, in the same plane as the shoulder (in the right part of the body), and holding the glass. Final position: the glass is placed near the mouth (in the center part of the body); the hand must hold the glass so that it is in a drinking angle. After this motion, the arm returns to the original position.

Example: Serve in tennis, right arm. Initial position: the right arm is up, with the hand slightly bent backwards. The arm moves to hit the ball until it becomes fully horizontal (and in a relatively left position, compared to the initial position). After this, the arm moves to go in a rest position (arm down).

Example: Rehabilitation motion, right leg. The body is laying on the floor during all the motion. It consists of a series of slow flexion-extension motions for the hip and the knee, that also involves the motion of the ankle. After the motion, return to the initial position.

Model of the arms or legs

Design the geometric model of an exoskeleton (for an arm or a leg) and generate motions, simulating standard rehabilitation movements. The model will be based on the Denavit-Hartenberg (D-H) parameters.

The degrees of freedom of the arm model should include at least:

- Shoulder: **3 dof**
- Elbow: **2 dof**
- Wrist: **2 dof**

For the leg:

- Hip: **3 dof**
- Knee: **1 dof**
- Ankle: **2 dof**

For each case, describe the type of motion (Flexion-Extension, Abduction-Adduction, Circumduction, Pronation-Supination).

1. Place the references in the joints according to the D-H model, and give value to the parameters according to the dimensions of a real arm. Set the limits of movement for each joint according to realistic values.

2. Using the functions and scripts of the **Matlab Robotics Toolbox**:

   - Define the model and represent the arm or leg in a resting position. This will correspond to the position of the arm down, close to the body (vertical) and aligned axes. In the case of the leg, it will correspond to the static standing position (standing with both feet together, legs straight).

   - Check that the movement of each of the joints (e.g., 7 g.d.l. for arm and 6 g.d.l. for leg) is adequate, reproduces the desired movement for that joint, and records specific representative positions for each of them.

   - The Matlab script "plot(arm, q)" is recommended for 3D graphic visualization, where arm is a Matlab object of class **robot**, and **q** is a vector of joint positions in which the robot is represented. With the script “teach(arm, q)”, each joint can be controlled individually, the movement can be visualized on a 3D figure, and the limits of the movement of each joint can be set.

3. Implement the standard trajectories selected, and simulate them in Matlab. The movements must be performed as "**coordinated joint movement**". Represent joint trajectories and speeds, checking that **position and speed limits** are not exceeded. Tune the values if needed.

4. Compute the **Cartesian locations** of the extreme positions of the trajectories, using Matlab. Generate a **rectilinear path** at the start and end locations. Analyze the corresponding **joint trajectories**, check if they are realizable (within ranges), natural or if there is any singularity. If needed, use intermediate positions-orientations (via), to achieve attainable/realizable or more natural movements.