German University in Cairo (GUC)
Faculty of Engineering & Materials Science (EMS)
Mechatronics Department (MCTR)

EDPT1009-Robotics ***Winter 2021***

Project Milestone 02

Objective:

The second milestone of the project is with the following details:

Milestone 02	Deadline Date	Description
M-02 (5%)	Wednesday 10th November, 2021	1. Develop the **DH convention** of the limb. 2. Obtain the assigned limb's **Forward Position Kinematics** equations using **MATLAB/Simulink**. 3. Input the same joint angles used for the kinematics equations on the **Simscape Multibody** and sense the position of the end effector to be the same as that obtained by the kinematic equations with simple tolerance. 4. Finalize the limb fabrication process (full hardware fabrication) and test the system movement (motors, sensors, etc.) through **Open Loop** testing using simple **Arduino** codes.

**The weight of each deliverable is stated above.*

Note: EVALUATIONS for this milestone will take place on Wednesday 10th November, 2021 to see all your hardwares ready and fully fabricated and the simulations performed so be ready =). Evaluations schedule and location will be announced soon.

Requirements:

The requirements from this milestone of the project are as follows:

1. Each team is required to assign the robot's frames following the DH-convention (X-Z axes ONLY) (this requirement should be done **on paper** (it is preferred to place a screenshot of your robot on a Word document and insert arrows on the joints to represent the X and Z axes of each joint)).
2. Evaluate the DH-parameters to fill the DH-parameters table for your robot using the assigned frames on paper. (You can use excel sheet **(DH_param.xlsx)** on the CMS and edit the values of (θ, d, a, α) for each joint, insert the links' length as designed in the CAD model of your limb (actual dimensions of your robot), modify the number of links and joints as your assigned limb's model)).

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3. Make sure that the assigned axes for each joint in the robot done in the first requirement of this milestone are the same to those placed on each joint on the **Simscape Multibody** model of your limb. If the axes are not the same (rotated by a certain angle that would be positive or negative 90 degrees in most to the cases), then use a transform block  before the revolute joint that has the transformed frame and edit the rotation matrix to transform the frame to be identical to that assigned in the previous requirements for the simulation to be the same as the mathematical representation of the system.
4. Evaluate the **Forward Position Kinematics** of your assigned limb by performing the following steps on **MATLAB\Simulink environment**:
    a. **On MATLAB:** Prepare a MATLAB function to evaluate the Total Homogeneous Transformation Matrix (T) between each joint (i) and its preceding joint ($i-1$). The script should be represented as a function that takes as input each row in the obtained DH-parameters table as angles and lengths of the robot (from the filled excel sheet **(DH_param.xlsx)** using **xlsread('DH_param.xlsx') if used**) and outputs the corresponding homogeneous transformation function. The function should be named as: **T = transformation_func(θ,d,a,α)**. (Note that the function should take as input the angles of the robot in a symbolic manner and the lengths as constant numbers as present in the filled excel sheet to output a symbolic transformation function).
    b. **On MATLAB:** Prepare a MATLAB function to obtain the position of the end effector from the multiplication of the transformation functions obtained. The function should be named as follows: **X = forward_kinematics_func()**. (Note that the function should call the previously created function **T = transformation_func(θ,d,a,α)** several times (indicating the number of rows in the filled DH table) and multiply these matrices to obtain the overall matrix between the base frame and the end effector, then extract the position of the end effector. This function should output a vector having the X, Y and Z positions of the end effector in a symbolic manner).
    c. **From MATLAB to Simulink:** Copy the output equations for X, Y and Z and place them in a MATLAB function in the Simulink environment to visualize the response for different angles of the robot.

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You can perform only two test cases by inserting random angles to the joints as constants and the other case using the maximum position of the robot ex: zeros for all joints. Analyse the system performance.

d. **In Simscape Multibody:** Simulate the motion of the robot using the same input angles used in the forward position kinematics equations obtained previously and visualize the motion of the robot's end effector and compare it with the output responses for the X, Y and Z axes of the robot obtained by the calculations of the forward position kinematics (DH-convention).

5. Finalize the limb fabrication process (full hardware fabrication) and test the system movement (motors, sensors, etc.) through **Open Loop** testing using connection to the power supply or using simple **Arduino** codes.

Submission:

The submission of the 2nd milestone will be in the form of a **Google Drive Link** having a ZIP file named (EDPT1009-TeamNumber-M02.zip), the Google Drive Link should be submitted through:
https://docs.google.com/forms/d/e/1FAIpQLSclYRcVhx0h7zWvvoBx_LkZ0datUehGk7c5Z07qox-w-d_7pQ/viewform?usp=sf_link

The contents of the zip file:

1. **PDF file** includes the following requirements. **Note build on the report done in the previous milestone.**
   - The coordinate frame assignment.
   - The DH-convention table.
   - The DH-convention final matrix (Total Homogeneous Transformation Matrix between the end effector and the base frame).
   - Screenshots of the simulations performed and comments on the results of the cases tested. Results of Simscape Multibody (MATLAB/Simulink) including the comments on the system performance based on the different inputs provided and the stating the limitations/constraints of the system.
2. **ZIP file** includes the following items:
   - **DH_param.xlsx** of the robot (if used).

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- **STL files** of the robot (if any modifications are done in this milestone).
- **XML file** exported (final XML file).
- **Simulink .slx file** of the system actuated by the inputs required (Simulink and Simscape Multibody).
- **MATLAB.m files** of the required matlab functions.

3. **Narrated video** that includes the following:
   - **Video1.mp4** for the Simscape Multibody simulation and MATLAB functions responses. You should include in the video the analyses of the motion of the robot, commenting on the performance in terms of the rotations performed for each joint (about which axis) taking into consideration the coordinate frames placed on the robot links and joints and commenting also on the limitations/constraints of the system's motion.
   - **Video2.mp4** for the fully fabricated hardware, motors connected and tested in an open loop manner.

The deadline of the **submission** is on **Wednesday 10th November, 2021 at 11:59 PM**. Late Submissions will result in deduction from the grade of this deliverable.

Be Ready for EVALUATIONS for this milestone that will take place on Wednesday 10th November, 2021. Evaluations schedule and location will be announced soon.