Project Description

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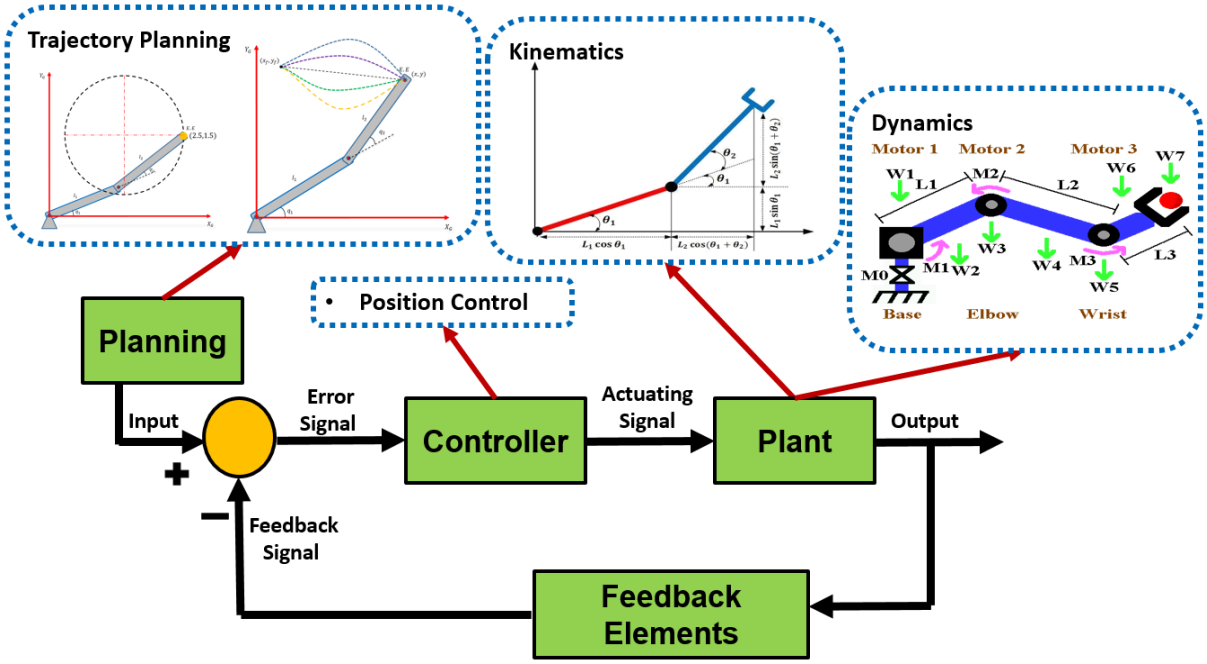
Overview:

The main objective of the Robotics (EDPT1009) course is to go through the robotic systems challenges. One of these challenges is to derive the robotic systems equations of motion through modeling of the robotic manipulators using both kinematic and dynamic approaches. Another challenge is to obtain the desired trajectory for either the manipulator's end effector or its joints to be followed by the manipulator to reach its destination. And finally, to control the robot's motion to follow the designated trajectory to close the loop of the whole system.



All these challenges are going to be highlighted and tackled in the course project, as students will learn how to model a robotic system and how to control its motion to perform the desired task successfully and efficiently. Students will also have the chance to visualize the motion of your created robot through the use of **Simscape Multibody** connecting **SOLIDWORKs** and **MATLAB/Simulink**.

This document is to introduce the Robotics course project objectives highlighting the project's regulations and draft milestones plan including a brief description for each milestone, the milestone weight and expected deadline.

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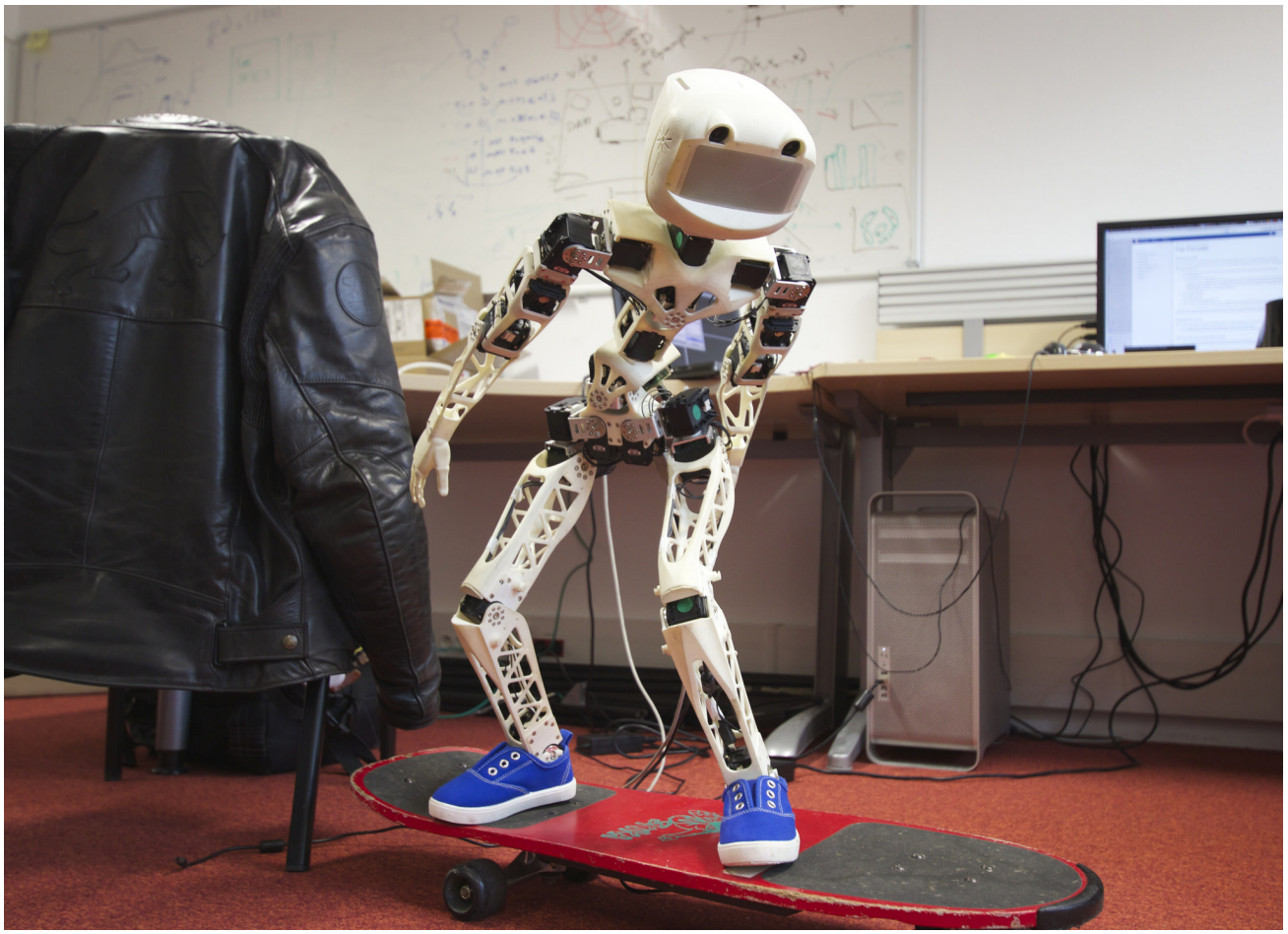
Objectives:

The robot which is of interest in this year's project is **Poppy Humanoid Robot =) (Open Source)**. The objectives of the project are mainly to be able to **model and analyse ONE of the limbs** of the humanoid robot (obtain the kinematics, dynamics, trajectory and control of the selected limb) using **MATLAB/Simulink**. In addition, build a **simulation environment** of the visualization of the limb's motion through **Simscape Multibody**. Furthermore, build the **hardware** of the selected limb to perform the same movement as that of the simulation (3D printing, motor selection, circuit development, coding (**Arduino** is recommended (basic codes and Arduino connection to MATLAB), etc.).



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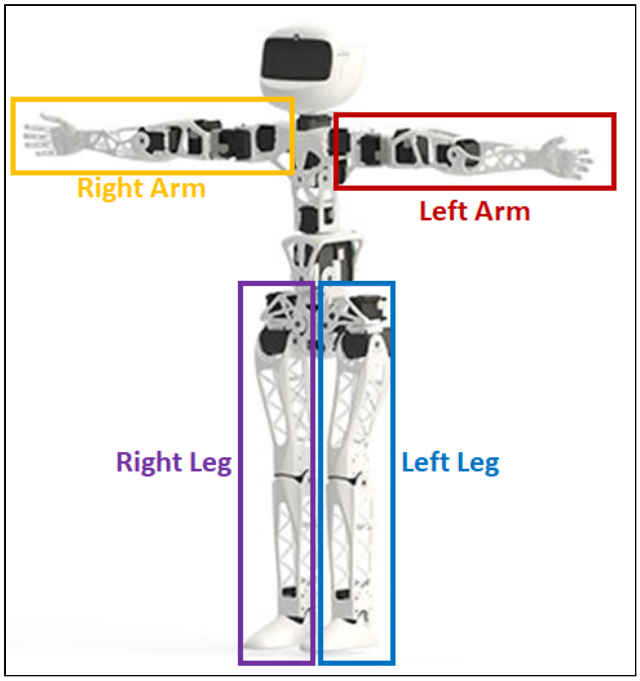

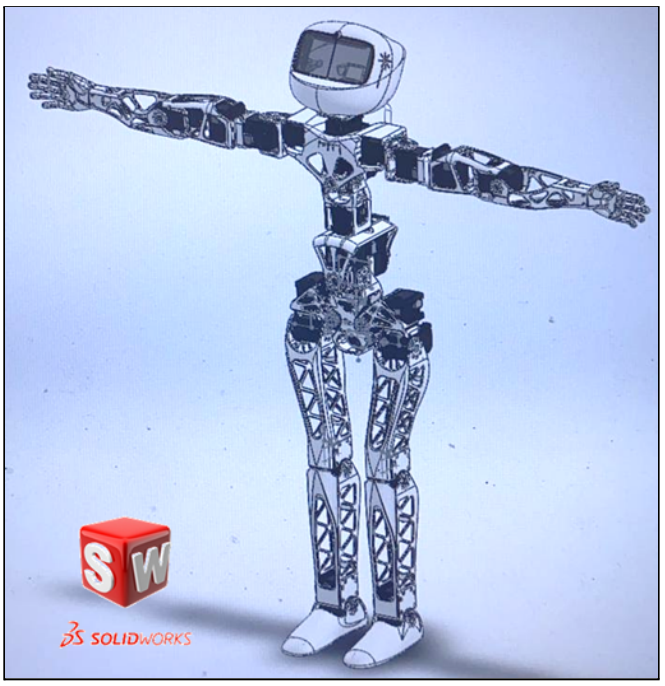

Project Regulations:

- The project team consists of **3-5 members cross tutorials**.
- Each team will have the chance to choose a limb from Poppy Humanoid robot to work on (**right arm, left arm, right leg or left leg**).
- The selected limb will be assigned to teams based on a **first come first serve** method (each team is required to prioritize the selection of the limbs, these priorities will be considered during project assignment as we are keen on building several humanoid robots from the limbs).
- **Students that are not assigned** to teams are going to be **randomly** clustered and get assigned to a random project.
- Registration of **less than 3 members or more than 5 members** will NOT be considered and the project selection will be canceled.
- Once the team is formed, NEITHER changes in the team's members NOR in the assigned project will be acceptable.
- The grading of each milestone will be divided into two categories:
    - **Group Grade:** by which the team performance will be graded in terms of fulfilling the required tasks and submitting all the required material for

each milestone that will be illustrated below and in the upcoming project's announcements
- **Individual Grade:** by which each team member will be graded on his/her contribution in each milestone, details of the individual team member grading will be announced and illustrated in later notifications.

- The evaluation process of the milestones will follow two procedures based on the milestone requirements:
  - **Online Submissions:** each team will be requested to submit the requirements of the milestone through Google forms. These requirements may include: reports, narrated presentations, codes, videos and others.
  - **Evaluations:** two evaluations will be conducted throughout the project, the evaluations timings are presented below. Evaluation method will be announced soon.
  - **Exhibition:** one of the two evaluations will be in the form of an exhibition that will take place by the end of the semester for each team to demonstrate his work in front of invited Drs, TAs and students.

Project Milestones Overview:

- The project weight is **25%** (20% Project + 5% Assignments).
- The project is divided into **5 milestones** covering all the course content.
- Each milestone is weighted based on the complexity of the requirements.
- All milestones will include a simulation platform for coding. The simulation platform required for the course is **MATLAB\Simulink**.
- Visualization of the robot's motion is required using **SimMechanics\ Simscape Multibody**.
- **Hardware** fabrication of the system is required.
- The **course team will provide** you with the **CAD models** of the limbs of the robot ready for **3D printing, assembly and circuit design**.

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Project Milestones Requirements:

Milestone #	Deliverables	Expected Deadline	%
Registration	**Requirements**: ● **Project registration:** each team is required to register through a Google drive link that is going to be activated on Wednesday 13th of October, 2021 and prioritize the limbs of the robot based on your preference: https://docs.google.com/forms/d/e/1FAIpQLSe9Gy_6teA4Td0KkZIbz7g05epA3RelK-zpZ52GOCu31Uz3aA/viewform?usp=sf_link ● The team members are required to fill their names, IDs, the priorities and a contact person's email to contact in case of any problems.	Saturday 16th October, 2021	0%
Milestone 01	**Requirements:** ● Start limb fabrication process (start 3D printing of the robot and purchasing the suitable actuators, sensors, power supply, microcontroller, etc.). ● Design and build the **circuits** of the robot using **Fritzing or Proteus** or other simulation tools to visualize the connections of the actuators, sensors, microcontroller(s), power supply, etc. to be in an enclosed unit. ● Place the **CAD assembly** of the limb in **Simscape Multibody** through the linking between **SOLIDWORKs** and **MATLAB/ Simulink**. ● Analyse and visualize the motion of the limb by actuating the joints using constants, signal builders and sliders as	Wednesday 27th October, 2021 **Expected and To Be Confirmed**	5%

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	inputs to the simulation environment (**Simscape Multibody - MATLAB/Simulink**) ● Assign the frames on the assigned limb (**on paper or by the help of the frames present in Simscape Multibody model**). **To be submitted:** ● Videos having the fabrication steps of the robot, the circuit design, and the simulation performed commenting on the robot's frames and motion due to several joint inputs (constants, signal builders, etc.) ● Codes of the simulation performed and the visualization (**Simscape Multibody - MATLAB/Simulink**).		
Milestone 02	**Requirements:** ● Continue in the limb fabrication process (full hardware fabrication) and test the system movement (motors, sensors, etc.) through **Open Loop** testing using simple **Arduino** codes. ● Develop the **DH convention** of the limb. ● Obtain the assigned limb's **Forward Position Kinematics** equations using **MATLAB/Simulink**. ● Test the equations of the kinematics obtained on the **Simscape Multibody** model by inputting joint angles and sensing the position of the end effector to be the same as that obtained by the kinematic equations with simple tolerance. **To be submitted:** ● Videos of the fabricated limb, the open loop test, the kinematics tested on Simscape Multibody simulation commenting on the results.	Wednesday 10th November, 2021 **Expected and To Be Confirmed + Evaluation**	5%

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	• Report (Word or Latex format) having the steps of the performed analysis DH convention, forward kinematics, robot fabrication steps, circuit diagram. • Codes of the forward kinematics analysis and the visualization of the robot's motion (**Simscape Multibody - MATLAB/Simulink**). **Open Loop Arduino** codes tested.		
Milestone 03	**Requirements:** • Derive the **Forward Velocity** and **Acceleration Kinematics** of the assigned limb using **MATLAB\Simulink**. • Derive the **Inverse Position Kinematics** of the robot using numerical approach simulated on **MATLAB\Simulink** and using trigonometric approach using graphical representation on the limb **on paper**. • Derive the **Inverse Velocity** and **Acceleration Kinematics** using **MATLAB\Simulink**. • Test the equations of the **Forward** and **Inverse Kinematics** obtained on the **Simscape Multibody** model by inputting joint angles/angular velocities/angular accelerations and sensing the position/velocities/accelerations of the end effector and the inverse process to be the same as that obtained by the kinematic equations with simple tolerance. **To be submitted:** • Videos of the kinematics validation on Simscape Multibody simulation commenting on the results.	Wednesday 1st December, 2021 **Expected and To Be Confirmed**	5%

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	• Report (Word or Latex format) having the steps of the performed analysis of the forward and inverse kinematics. • Codes of the forward and inverse kinematics analysis and the visualization of the robot's motion (**Simscape Multibody - MATLAB/Simulink**).		
Milestone 04	**Requirements:** • Connection of **Arduino** to **MATLAB/Simulink** sending commands for the robot to move open loop in the hardware level. • Derive several Task-Space trajectories for the robot's end effector to follow (**MATLAB\Simulink**). • Derive the Joint-Space trajectory for the robot's joints to follow using (**MATLAB\Simulink**). • Validate both the joint space and task space trajectories on the Simscape Multibody model to act the same as in the performed simulation analysis. **To be submitted:** • Videos of the trajectory validation on Simscape Multibody simulation commenting on the results. • Report (Word or Latex format) having the steps of the performed analysis of the joint space and task space trajectories. • Codes of the joint space and task space analysis and the visualization of the robot's motion (**Simscape Multibody - MATLAB/Simulink**). **Arduino** codes of connection to MATLAB.	Wednesday 15th December, 2021 **Expected and To Be Confirmed**	5%

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Milestone 05	**Requirements:** ● Derive control algorithms for the motor level control (low level using PID control) (**MATLAB\Simulink**). ● Derive control algorithms for the end effector level control (high level using Fuzzy Logic Control (FLC)) (**MATLAB\Simulink**). ● Test the closed loop system taking into consideration the robot's visualization tool (**Simscape Multibody**). ● Develop a closed loop system on the hardware level to track a certain trajectory or point in the robot's workspace (motor level control/end effector level control). **To be submitted:** ● Narrated presentation having ALL the steps conducted in the project concerning the hardware, simulation environment and analysis of the system commenting on the results. ● Report (Word or Latex format) having ALL steps performed with screenshots and analysis. ● Codes of the control (low level and high level) equations of the assigned limb (**MATLAB/Simulink**) and the visualization (**Simscape Multibody**). **Arduino** codes for the overall project (closed loop system) ● Videos for the fully functioning hardware, the simulation environment performing as required as close as the obtained from the system's equations.	Wednesday 29th December, 2021 **Expected and To Be Confirmed + Exhibition**	5%

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Project Remarks and Resources:

** Registration is open starting from Wednesday 13nd of October, 2021 till Saturday 16th of October, 2021. Link of the registration process can be found below: https://docs.google.com/forms/d/e/1FAIpQLSe9Gy_6teA4Td0KkZIbz7g05epA3RelK-zpZ52GOCu31Uz3aA/viewform?usp=sf_link

** Each team will have the chance to **prioritize the selection of the limbs** of the robot to have a limb of their preference (**right arm, left arm, right leg or left leg**).

** A detailed description for each milestone will be provided with all the required deliverables and the submission details (links for submissions will be provided in each announcement).

** Teams will fabricate the limb from scratch to build a fully functioning hardware, **Zip files** for the **CAD models** of the upper and lower limbs will be available on the **CMS** (extract the files and open them on **SOLIDWORKs** to extract your assigned limb model, you may be asked to perform certain modifications for the models for the motors to fit in the design (Egyptian motors) and edit the mating to add constraints to the system to have a realistic motion in **Simscape Multibody**.

** The **open source Poppy Humanoid Robot** links are available below:

- Poppy Robot: https://www.poppy-project.org/en/ https://www.poppy-education.org/robots/poppy-humanoid/
- For Printing: https://github.com/poppy-project/poppy-humanoid
- For Assembly: https://www.youtube.com/playlist?list=PL8wg9_Kkof8wwqgfFu0iCij73C-4gt95x

** Teams will visualize the motion of the robot using **Simscape Multibody**.

** Full analysis of the robot using **MATLAB/Simulink**.

** An **Exhibition** will take place by the end of the semester to demonstrate your work in front of Drs, TAs, students, etc.. Details of the exhibition will be announced soon.

Best Wishes and Happy Semester
Robotics Team =)