FIELD AND SERVICE ROBOTICS (FSR) – a.y. 2024/2025
University of Naples Federico II
Department of Electrical Engineering and Information Technology

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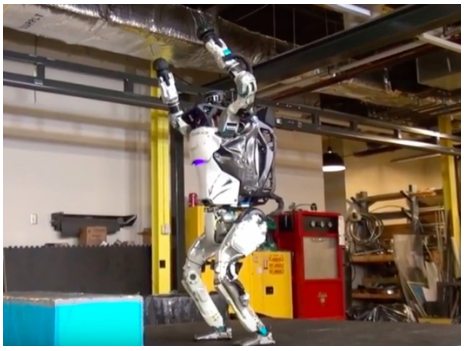
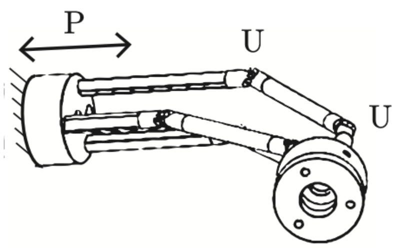
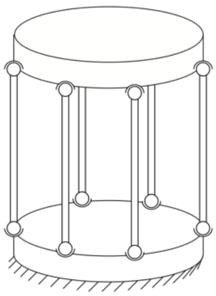
HOMEWORK n. 1




1. Consider the ATLAS robot from Boston Dynamics in the pictures above. On the left, ATLAS is standing. On the right, ATLAS is performing a backflip. If ATLAS actuators can produce unbounded torques, establish whether each of the following statements is true or not, and briefly justify your answer.
   a. While standing, ATLAS is fully actuated.
   b. While doing backflip, ATLAS is fully actuated.





2. Consider the spatial mechanism on the above-left (an experimental surgical manipulator developed at the National University of Singapore, with three identical parts, each with a prismatic joint, P, and two universal joints, U) and the spatial mechanism on the above-right (made by 6 identical bars with all spherical joints). Determine the number of the degrees of freedom for each mechanism, comparing the result with your intuition about the possible motions of these mechanisms. For each mechanism, write its configuration space topology.

3. State whether the following sentences regarding underactuation or fully actuation are true or false. Briefly justify your answers.
   a. A car with inputs the steering angle and the throttle is underactuated.
   b. The KUKA youBot system on the slides is fully actuated.
   c. The hexarotor system with co-planar propellers is fully actuated.
   d. The KUKA iiwa 7-DOF robot is redundant and it cannot be underactuated because we know that all redundant systems are not.

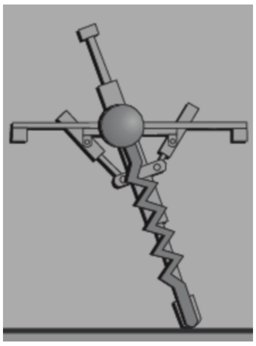
4. State whether each of following distributions are involutive or not and briefly justify your answer. If possible, find the annihilator for each distribution.

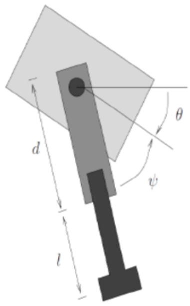
a. $\Delta_1 = \left\{ \begin{bmatrix} -3x_2 \\ 1 \\ -1 \end{bmatrix} \right\}, \boldsymbol{U} \in \mathbb{R}^3$

b. $\Delta_2 = \left\{ \begin{bmatrix} -1 \\ 0 \\ x_3 \end{bmatrix}, \begin{bmatrix} x_2 \\ -\alpha \\ x_1 \end{bmatrix} \right\}, \boldsymbol{U} \in \mathbb{R}^3$ with α the last digit of your matriculation number.

c. $\Delta_3 = \left\{ \begin{bmatrix} 2x_3 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} -2x_2 \\ x_1 \\ -1 \end{bmatrix} \right\}, \boldsymbol{U} \in \mathbb{R}^3$

5. Using the accessibility rank condition, show that a set of Pfaffian constraints that does not depend on the generalized coordinates, $A\dot{q} = 0$, with A constant, is always integrable (completely holonomic system).





6. Consider the Raibert's hooper robot of the picture above. It has the following kinematic constraint in the Pfaffian form $(I + m(l+d)^2)\dot{\theta} + m(l+d)^2\dot{\psi} = 0$, with $q = [\theta \quad \psi \quad l]^T$, with I the moment of inertia of the body and m the leg mass concentrated at the foot. Compute a kinematic model of such a robot and show whether this system is holonomic or not. *[Hint: Use Matlab symbolic toolbox and the* *null* *command to ease your work. Do not care about the physical meaning of the kinematic inputs.]*

NOTE: It is worth recalling not to report theory in the report. Put all the plots you think are the most important to understand the performance of the code you implemented, and critically comment on the results. Attach the code, if present, with your submission in a ZIP file. If you overcome the submission limit on Moodle, you may link in the report a GitHub, Dropbox, or Google Drive link (make these links public, if possible, to avoid waiting for permission to download the files). The software is left free. Matlab is anyway suggested to save time.