Robotic Systems Engineering
Coursework 3: Actuators, Mechanisms and Robot Dynamics

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To get full credit for an answer, you are *required* to provide a .pdf report, and a fully working coding solution by filling in the provided code templates. These templates provide additional information on how to implement each script. **Do not remove anything from the templates, and try to only fill-in the code in the specified fields.** For the coding questions, you are also expected to include a simple breakdown of your algorithms in the report. When ready, *upload* your 'cw3' package on Moodle along with your submitted coursework report, in .zip or .rar extension. The necessary ROS packages are available on the course's *GitHub repository*.

Actuators and Mechanisms

1. A conveyor belt inside a candy factory carries colourful hard candy of quasi-spherical shape (e.g. Skittles, M&Ms etc.). The candy is assumed to be stationary with respect to the conveyor, which moves at a constant velocity which cannot be altered. The conveyor belt is approximately 20cm wide and the candy appears randomly along its width. Assume the weight and shape of the candy is known. You are asked to implement a robotic system in addition to the conveyor belt to extract a candy of any given colour and place it in a separate basket. The system should be able to perform the task as fast as possible. Ensure that you are designing a minimum viable system to solve the task, hence, avoid for example redundancy in your manipulator design as well as your actuator and sensor choices. Propose a robotic system to perform the task. In your answer, address the following. (**Recommended answer is up to 50 words per sub-question.**)

   a. Required degrees of freedom of your manipulator in Cartesian space. [report - 2 pts]

   b. Manipulator topology (serial/parallel) and design. You are free to reference commonly utilised designs and robot types. Also state a reasonable choice of end-effector. [report - 2 pts]

   c. Choice of actuators (e.g. stepper motors, AC motors, brushed or brushless DC motors, pneumatics, hydraulics etc.) and transmission. This will vary greatly with your manipulator design. [report - 2 pts]

d. Choice of sensors (both, required for driving the manipulator as well as determining the correct object). [report - 2 pts]

e. Discuss a component of the proposed system (e.g. joints, actuators, sensors) which would be prone to wear from repeated task execution. How could the wear be minimised? [report - 3 pts]

f. Assume, only candy with the previously specified colour above a certain weight threshold (e.g. > 5 grams) should be placed in the basket. How could you modify your system to be able to consider this additional factor without modifying the conveyor? [report - 4 pts]

[15 pts]

Robot Dynamics

2. Complete the following tasks by filling in the ”cw3q2/iiwa14DynStudent.py” python class code template, to compute the dynamic components for the KUKA LBR iiwa14 manipulator. A simple code breakdown in the report is required for all subquestions. In the cw3q2 folder you can find three files.

    - iiwa14DynStudent.py: This is the class template for the questions below.
    - iiwa14DynBase.py: This class includes common methods you may need to call in order to solve the questions below. You should not edit this file.
    - iiwa14DynKDL.py: This class provides implementations to the questions below in KDL in order to check your own solutions. You should not edit this file.

    a. Write a script to compute Jacobian at the centre of mass for the iiwa14 manipulator. [report - 2 pts, code - 3 pts]

    b. Fill in the appropriate class method to compute the dynamic component $\mathbf{B}(\mathbf{q})$ for the iiwa14 manipulator. [report - 2 pts, code - 8 pts]

    c. Fill in the appropriate class method to compute the dynamic component $\mathbf{C}(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}}$ for the iiwa14 manipulator. [report - 2 pts, code - 6 pts]

    d. Fill in the appropriate class method to compute the dynamic component $\mathbf{g}(\mathbf{q})$ for the iiwa14 manipulator. [report - 2 pts, code - 5 pts]

[30 pts]

3. Describe the Huygens-Steiner theorem. Your answer should include a description of its hypothesis and of its derivation. Explain why it is important in robotics applications. [report - 7 pts]

4. Define the forward and inverse dynamics problems, and highlight their main applications. Describe what are the difficulties of each problem. [report - 8 pts]

5. In this question, you are tasked with computing the joint accelerations throughout the trajectory defined in the bagfile ”cw3q5/bag/cw3q5.bag” using dynamic components. You should also plot the computed joint accelerations. You only need to edit the ”cw3q5.py” file, and the corresponding launch file. Note that a coding template is **not** provided for this question. For the dynamic components, you can use either your own implementation from Q2, or the corresponding KDL class.

   a. Load the bag from the bagfile. What type of message does the bagfile contain? How many messages does the bagfile have, and what is the content of the messages? [report - 3 pts, code - 4 pts]

   b. Is this a problem of forward or inverse dynamics? [report - 3 pts]

   c. Publish the trajectory to the appropriate topic to see the robot moving in simulation. [report - 2 pts, code - 3 pts]

   d. Subscribe to the appropriate topic, and calculate the joint accelerations throughout the trajectory using dynamic components. [report 3, code - 12 pts]

   e. Plot the joint accelerations as a function of time in your python script. [report - 5 pts, code - 5 pts]

   Synchronising ROS rate, bagfile reading, rviz executing the trajectory, and the function calling can prove tricky. Thus, adding artificial delays in parts of the script is allowed.

   [40 pts]

END OF COURSEWORK