Consider the Da Vinci® surgical robot, as shown in Fig 1.

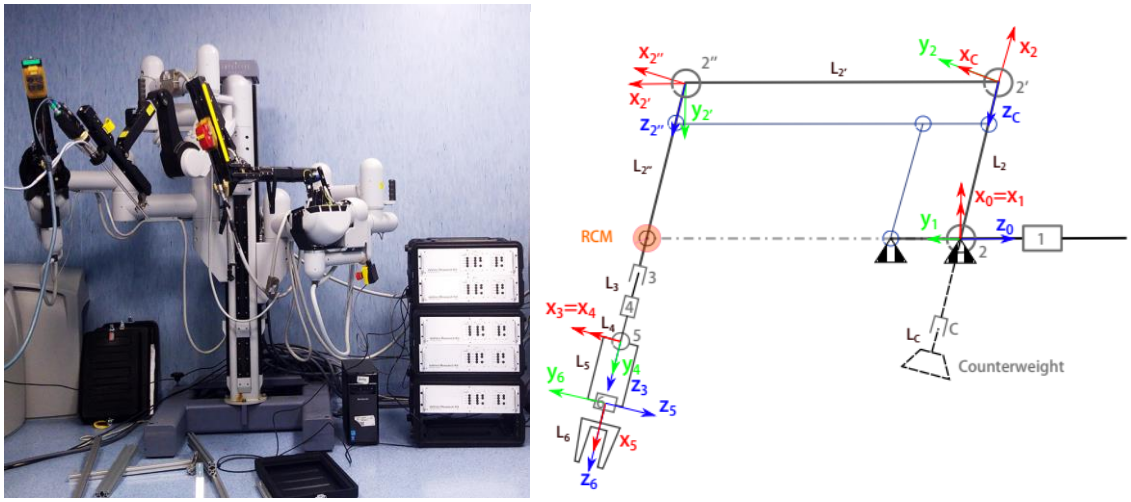

Fig1. Kinematic Structure of Da Vinci® Surgical Robot

The purpose is to extract the exact dynamics of the robot to design the model-based controllers for precise control of the surgical tool. Therefore, the symbolic model of robot dynamics must be accurate (all terms affecting robot dynamics be modeled), and all robot dynamics inertial parameters should be identified. Therefore, it may be proved that all form of robot dynamics can be derived as:

$$\boldsymbol{\tau} = \underbrace{\boldsymbol{M}(\ddot{\boldsymbol{q}}) + \boldsymbol{C}(\boldsymbol{q},\dot{\boldsymbol{q}})\dot{\boldsymbol{q}} + \boldsymbol{G}(\boldsymbol{q})}_{Explicit\ Form} + \boldsymbol{f}_{Other} = \underbrace{\boldsymbol{Y}(\boldsymbol{q},\dot{\boldsymbol{q}},\ddot{\boldsymbol{q}})}_{Linear\ Regression\ Form} \quad \underbrace{\boldsymbol{\phi}}_{Inertial\ Parameters}$$

Therefore, comment on the following questions:

1. Examine different schemes to identify the accurate dynamics of a robot. Divide your answer into classic (white box) and intelligent (black box) methods.

For classic methods, comment on the following questions:

2. How is it possible to calculate the inertial parameters for each link accurately? Divide your comment into two parts—traditional methods and methods based on classic dynamics identification schemes.
3. According to the mechanical structure of the robot, investigate the terms that can affect the dynamics of the robot. How can the parameters of these terms be identified? For example:

$$f_{Elastic} = Kq$$

4. For classic dynamic identification schemes, consider workflow 1, as shown in Fig 2. To achieve accurate dynamic identification of the robot, investigate systematic methods for determining optimal robot excitation trajectories.

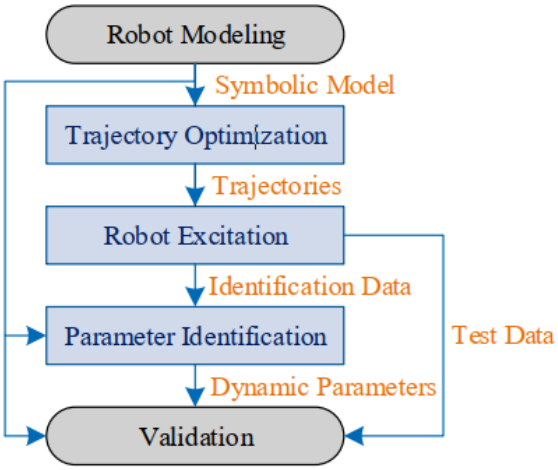

Fig2. Workflow of dynamic model identification

5. One of the main issues in robot inertial parameters identification is the issue of physical consistency. For example, you might identify the mass of each link as a negative value. Therefore, the robot mass matrix may not have a definite positive property, making the model-based controllers (such as IDC) unstable. Investigate how to fix this problem in the identification process.

How to contact teaching assistants: If you have any questions about these exercises, please contact us through Email.

How to submit: Zip your files (codes, reports, etc.) within the format of **R**#_Name_StudentID, and submit them to the LMS website.

Late homework policy: Please submit your assignments on time. If you run out of time, You can still send it as late submission only by one day with the expense of losing some marks depending on the time you submit your work.

Collaboration policy: Collaboration with humans is very beneficial but restricted to the "whiteboard level," meaning that we recommend you to discuss approaches and solutions with your peers, but write your code, reports, and analytical derivations by yourself.

Good Luck & Take care!