McGill

MECH 642 - Advanced Dynamics
Prof. James Richard Forbes

Course Project Instructions
(Last Updated: January 18, 2019)

Students will complete a project where they are to derive the equations of motion (EoM) of a reasonably sophisticated mechanical, aerospace, or robotic system, and numerically simulate the system. Students may work individually or in groups of two. Masters and PhD students may consider a system related to their thesis topic (i.e., their thesis research).[1] A report using the IEEE journal paper template (single spacing, 10 point font, double column format) is to be submitted. Using the IEEE template the report must be less than or equal to 6 pages (i.e., the length of a conference paper) including title, abstract, figures, etc.

What does "reasonability sophisticated system" mean? The system should be composed of more than one rigid body, or composed of rigid bodies and particles. Students must discuss which (if any) direction cosine matrix (DCM) parameterization they've used, and why they've used it. Numerical simulation results must be included including an "energy" or "momentum" check. Students are encourage to use `matlab` for numerical simulations, but are permitted to use any programming language of their choice. Listed below are some suggestions.

1. A rotary inverted pendulum (`http://www.quanser.com/Products/rotary_pendulum`).
2. Any one of the interesting systems found at `https://www.quanser.com/products/`.
3. A quad-rotor helicopter including the rotating propellers.
4. A rigid-body spacecraft with reaction wheels.
5. A rigid-body spacecraft with a telescoping robot arm.
6. Dual-axis reaction wheel inverted pendulum (`https://www.youtube.com/watch?v=woCdjbsjbPg`).
7. The cubli (`https://www.youtube.com/watch?v=Wm5ErEV2f18`).
8. A rocket with thruster gimbal dynamics.
9. A ball with a nonuniform mass distribution rolling on an inclined plane.

Students are encouraged to discuss possible systems to model with their thesis supervisor, senior PhD students, post-docs, as well as Prof. Forbes. Recreating or extending the results of a textbook example, a conference paper, or journal paper is acceptable provided the textbook, conference paper, or journal paper is properly cited and the notation taught in class is used. (Failure to use the notation taught in class will result in a mark of zero.) Simply "copying" a paper is not acceptable; rational as to why steps are taken is needed. Additionally, students are not encouraged to consider sophisticated friction, damping, or aerodynamics in their project, nor electromechanical dynamics (e.g., the dynamics of a DC motor used to create a torque); focus on the kinematics and dynamics of the problem. Similarly, controller design may be considered (e.g., a simple PD law), but sophisticated controller design should be avoided.

The project will be due in stages. The project proposal is due January 21. The kinematic analysis is due February 18. The dynamic analysis is due March 25. At each stage a write-up in IEEE format is required that must be submitted on myCoures. (The IEEE template is provided on myCoursees.) The final project

[1] To be clear, students may do a MECH 642 project related to their thesis as long as the MECH 642 project material (i.e., derivations, simulation results, etc.) doesn't reappear in their thesis.

report is due the last day of class. Students working in groups of two must each write their own code and "check" their results with their partner, however, such groups of two will write one report. Both students must submit the same report (as a pdf file) on myCourses, but they must submit their own individual `matlab` code (as a .zip file). The pdf files submitted on myCourses must be named as follows.

Proposal `Lastname1_Lastname2_642_proposal.pdf`,

Kinematics `Lastname1_Lastname2_642_kinematics.pdf`,

Dynamics `Lastname1_Lastname2_642_dynamics.pdf`, and

Final Report `Lastname1_Lastname2_642_final_report.pdf`,

where `Lastname1` and `Lastname2` are the last names of the group member(s). Student number(s) must be included in the affiliation.

Outlined below are the "deliverables" for the project proposal, the kinematic analysis, the dynamic analysis, and the final project report. Each stage of the project should built upon the previous stage.

Proposal The proposal must discuss the system the student(s) plan on modelling. If the system is found in a textbook, reference the textbook. If the system is found in a journal/conference paper or many journal/conference papers, reference the journal/conference paper(s). Provide a motivation for why modelling the system is interesting and/or worthwhile. Provide pictures/diagrams to facilitate understanding of the project (e.g., a picture of a quadrotor helicopter). If the system modelled is related to the student(s) research, motivate why the model is needed for research. Approximate length should be less than one page in the IEEE journal paper format.

Kinematics Perform a kinematic analysis. Discuss what reference frames are used, and what attitude parameterization is used (if any), and why that particular attitude parameterization is used. Find position, velocity, and acceleration of points and/or bodies. Approximate length should be one-and-a-half to two pages in the IEEE journal paper format.

Dynamics Discuss forces (if any), the bodies being modelled, their mass properties (i.e., mass, first moment of mass, second moment of mass), etc. Derive the equations of motion using either a Newton-Euler approach or Lagrange's equation. Simulation results would ideally be included, but are not necessary at this stage. Approximate length (excluding simulation results) should be one-and-a-half to two-and-a-half pages in the IEEE journal paper format.

Final Report A final report complete with an introduction, a kinematic analysis, a dynamics analysis, simulation results, and a conclusion must be submitted. Discussion of results should be included in the appropriate sections. Total length of the final report using the IEEE journal paper template (single spacing, 10 point font, double column format) must be no more than 6 pages. (Reports less than 6 pages are acceptable, provided they are clear. Do not make your report longer than it has to be.)

The purpose of the project is to not only apply some of the kinematics and dynamics knowledge taught in the course, but to give students an opportunity to work on a project related to their thesis, and to practice writing journal/conference papers. Writing clear, concise, and consistent papers is a crucial skill.