AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

AER 540 - Intermediate Dynamics
Fall 2014
Prof. James Richard Forbes

Course Project Outline
(Last Updated: September 7, 2014)

Students are to derive the equations of motion of a reasonably sophisticated mechanical, aerospace, or robotic system, and numerically simulate the system. Students may work individually or in groups of two. Students may, and are encouraged to, pick a system that is related to their thesis work or the focus of their masters degree. 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, and bio.

What does "reasonability sophisticated system" mean? The system should be composed of more than one rigid body; a system composed of rigid bodies and particles is also acceptable. 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. Students are also encourage to, but do not have to, perform some sort of stability analysis. Listed below are some suggestions.

1. A two-degree-of-freedom inverted pendulum (`http://www.quanser.com/products/2dof_pendulum`).
2. A three-degree-of-freedom helicopter model (`http://www.quanser.com/Products/3dof_helicopter`).
3. Any one of the interesting devices found at `http://www.quanser.com/`.
4. A quad-rotor helicopter.
5. A rigid-body spacecraft with a telescoping robot arm.
6. A rocket with thruster gimbal dynamics.
7. A rigid-body aircraft with hinged (i.e., pseudo-flexible) wings.
8. A spherical robot (or just a ball) rolling on an inclined plane.

Students are encouraged to discuss possible projects 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 September 16, 2014. The kinematic analysis is due October 16, 2014. The dynamic analysis is due November 25, 2014. At each stage a write-up in IEEE format is required that must be submitted through Dropbox on CTools. (The IEEE template is provided on CTools.) The final project 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) through Dropbox on CTools, but they must submit their own individual matlab code (as a .zip file). The pdf files submitted through Dropbox on CTools must be named as follows:

Proposal `Lastname1_Lastname2_540_proposal.pdf`,

Kinematics `Lastname1_Lastname2_540_kinematics.pdf`,

Dynamics `Lastname1_Lastname2_540_dynamics.pdf`, and

Final Report `Lastname1_Lastname2_540_final_report.pdf`,

where `Lastname1` and `Lastname2` are the last names of the group member. 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 modeling. 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 modeling 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 modeled 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, 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 modeled, 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. 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 students learn, but to give students an opportunity to work on a project related to their thesis or the focus of their masters degree, and to practice writing journal/conference papers. Writing clear, concise, and consistent papers is a crucial skill. Think of this project as a chance to get a jump on your thesis work and practice writing technical papers!