Aerospace Structural Design
Spring 2019

Assignment of Major Project

This "Major Project" comprises the most significant factor in determining your final grade and assesses your ability to incorporate the various topics covered throughout the semester. While the choice of the particular aerospace structure to be designed is left up to each team, there are several criteria that must be met so that each team project is reasonably and equitably challenging.
And remember: "*A bad design with a good presentation is doomed eventually. A good design with a bad presentation is doomed immediately.*"–Akins 20th law of spacecraft design

1. Team
   - Each team will be self-assembled according to student preferences. Students should assess how proposed projects could provide utility to other courses (e.g., senior capstone design).
   - For purposes of scheduling, etc., there will be a total of 11 teams, likely 10 teams having 4 students/team and 1 team having 3 students/team.
   - Three-person teams will be graded fairly relative to the four-person teams and will be allowed to present oral presentations in the last available time slots.
2. Project Requirements

   Each aerospace structural design problem must include/consider:
   - A minimum of **four parts**, all parts being tied or merged together to form an overall structural assembly (where the presence and effects of fasteners need not be considered).
   - (689 Students) **One** topologically optimized part converted to a parameterized design that fully interfaces with the overall structure.
   - A minimum of **five design variables** (one of which is **discrete**) and **four output variables** (performance metrics).
   - A well-formulated **objective function** based on at least **two** of the output variables.
   - A minimum of **two constraints**.
   - A feature that requires consideration of the effects of **thermal-mechanical coupling** <u>or</u> the utilization of **at least one composite material part** <u>or</u> the consideration of **buckling as a failure criterion** (or other complexity agreed to by the instructor).

   In assessing their unique design problem, each team should produce:
   - A full Abaqus FEA model of the problem, scripted to allow iterative analysis-driven design.
   - Some form of analytical approximation model that estimates at least two of the performance metrics (this may be of relatively low fidelity, but is intended to provide a "sanity check" with regard to the FEA solution).
   - A carefully constructed DOE and resulting "Pareto frontier" and "factor effects" plots, which should be used to justify the elimination of one or two design variables (if reasonable).
   - A scripted FEA-based optimization procedure of the team's choosing and associated results (final optimization must be started from at least $N + 1$ distinct locations in the design space, where N is the number of design variables retained after the DOE).

3. Deliverables/Schedule
   - **March 8:** Initial intro. of team and oral presentation (**single "quad chart"**; 10% of grade)
     - Goal is to summarize project concept (no new work beyond a few generated images; graded solely on clarity of information).
     - Slide in **.pdf format** due to instructor and TA emails by 8PM on March 7. Include names of all team members.
   - **April 5:** Intermediate report due (five pages maximum + oral presentation; 20% of grade). Report to include:
     - Oral presentation of single quad chart summarizing status; slide in **.pdf format** due to instructor and TA emails by 8PM on April 4.
     - An abstract describing the aerospace structural design problem (maximum 250 words).
     - Figures and text describing the structural analysis problem (individual part configuration, assembly layout, load and displacement boundary conditions, material properties).
     - Figures and text describing the design problem (design variables, performance metrics, goals, constraints, DOE and optimization tools to be used).
     - A description of expected design findings (i.e., what kind of features do you expect the best design to have?). Use your intuition; you will not be graded on your accuracy.
     - As an *appendix* to the five-page report, attach a draft of the Python script which should be in progress by this time.
   - **April 29, 30:** Oral presentation of final results (10 slides and 15 minutes per team strictly enforced; 30% of grade). For list of required content, see below. Note that attendance at all presentations is not mandatory, but that corrective comments directed at any given team will generally apply to all teams. Slides in **.pdf format** due to instructor and TA emails by 8PM on day before assigned presentation date.
   - **May 6:** Final reports due (15 pages maximum; 40% of grade). Report to contain:
     - **Updated and expanded** content from the intermediate report, including updated abstract. Address FEA (and TopOpt) meshing (refinement and element selection).
     - A description/formulation of the analytical approximation model.
     - The results of the DOE (as detailed above in "Project Requirements"). Include meaningful/interesting stress/deflection/temperature contours resulting from "good" and "bad" designs.
     - Brief benchmarking example demonstrating the capability of your implemented optimization algorithm of choice.
     - The results of the optimization (as detailed above in the "Project Requirements," including topological optimization, comparison with the analytical approximation, etc.). Also include meaningful/interesting stress/deflection/temperature contours resulting from the optimized design. Where does the optimized design lie relative to the Pareto frontier from the DOE?
     - A well-constructed conclusion that summarizes the results and provides recommendations for how an engineering team might proceed with detailed design of the structure considered.
     - As an *appendix* to the 15-page report, attach the final Python script and any other programs used to do the DOE and/or optimization.

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Major Project: Bonus Opportunities

There are three opportunities to earn bonus points on the Major Project. Teams may choose to take advantage of as many or as few of the following as they desire.

1. **Option 1 (2 points; REQUIRED of 689 students)**
   Your objective function must be based on two output variables. Create an animation in this two-dimensional output variable space where the number of frames corresponds to the number of optimizer generations/iterations and where in each frame every design evaluated in the associated generation/iteration is shown, the best design is clearly highlighted, and the best weighted objective iso-line is plotted. An example single frame of this animation is shown in the figure below. Present this animation as part of your final presentation.

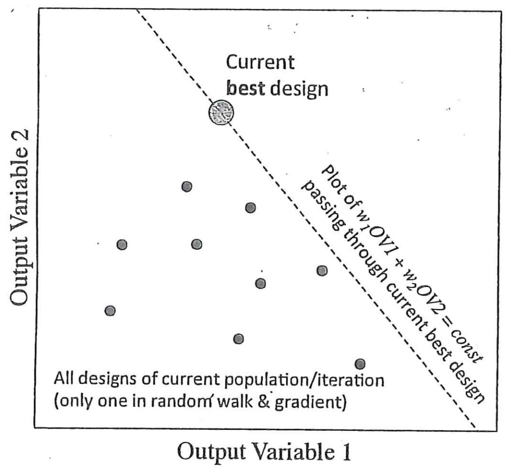

Figure 1: Example single frame of the two-dimensional output evolution animation. Note that population-based methods will show the evolution of entire populations while the single-point methods will show only the current best design and single off-optimal evaluations.

2. **Option 2 (2 points)**
   In your post-processing script, add a feature which saves a screenshot of any design that improves upon the previous best/global best. View must be appropriately zoomed and oriented (**identically across frames**) so as to show major design features clearly. Use a free .gif maker, Windows movie maker, iMovie, etc. to create an animation showing how your best design evolves over iterations/generations. Present this animation as part of your final presentation.
3. **Option 3 (3 points)**
   Virtual Reality environments allow more intuitive discussions of three-dimensional concepts. Using the instructions provided by the TA or instructor, export the finite element results of a "good" design into the MAESTRO VR environment (http://maestrolab.tamu.edu/facility/maestro-vr-annex/) and meet with the instructor for 10 minutes PRIOR to your final presentation to discuss your design, including key areas of stress, buckling, etc., and your thoughts regarding the final optimized configuration (even if it has not yet been determined).