Department of Aerospace Engineering
IIST, Thiruvananthapuram
Multi-disciplinary Optimisation (AE 844)

9:30AM-12:30PM
07/05/2018
(C104 - D4)

Maximum Marks: 100

Note:

1. All questions are compulsory.
2. Clearly state all the assumptions/approximations in the derivations/answers.
3. Diagrams that are not legible will not be graded. Extra credit will be given for clear and concise answers.

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1. (a) What is the necessity for using multi-disciplinary optimisation methodology during the design of complex systems like aircraft? [4]

   (b) Is it wise to use high fidelity analysis tools during the preliminary design process? If yes, what are the advantages? If no, why not? [4]

2. (a) Define convexity of a function. [4]

   (b) Is the function $f(x) = x(1-x)$ convex? [4]

   (c) How is the rate of convergence of an optimisation algorithm defined? List all the different types of convergence rates. [4]

3. Given an objective function $f(x) = \frac{1}{2}x^T Ax - b^T x,\ x \in \Re^n$, prove that the conjugate gradient method reaches the optima x^* in exactly n iterations provided that A is positive definite. [12]

4. (a) Define pareto optimality for multi-objective optimisation. [4]

   (b) Outline the ϵ-Constraint method. [6]

   (c) List the advantages of the ϵ-Constraint method. [3]

5. (a) Computer simulations of flow over an airfoil are deterministic in nature. Multiple CFD runs with same parameters (mesh-size, convergence criteria, turbulence model etc.) are expected to yield the same lift values. Hence, it is not reasonable to use least squares fit (which is a non-interpolating fit) to generate surrogate models for such cases. Comment. [4]

   (b) A linear regression model is fit in $x \in \Re^n$ for an objective function f using N datapoints where $N > n + 1$. Gradient descent technique was used to obtain the regression coefficients w_i. w_i thus obtained are unique. Comment. [4]

   (c) What is aliasing error? How is it overcome during sampling for surrogate models? [4]

6. (a) How can genetic algorithm (GA) be used for multi-objective optimisation? Outline the potential advantages and disadvantages as compared to the standard gradient based algorithms. [6]

   (b) Discuss the criteria for selection of a specific scaling method and a selection method in GA? [5]

   (c) What is the advantage of real-coded GAs over binary-coded GAs? [4]

7. (a) An aircraft is to be designed to fly over a range of cruise velocities from v_1 to v_2. Can this problem be posed as a robust design problem? If yes, how? If no, why not? [4]

   (b) Given $y = f(x)$, derive the equations for μ_y and σ_y using first order moment method of uncertainty propagation in terms of μ_x and σ_x. Complete derivation expected. [6]

8. A CFD calculation is performed over an aircraft defined by n design parameters. The CFD solution thus obtained is post-processed to calculate m objective functions of interest (like lift, drag, pitching moment etc.). Assuming that the computational cost of one CFD run is C, write down the computational cost of the entire Jacobian matrix calculation for forward step finite difference, central finite difference and complex step method. [6]

9. A given optimisation problem involves three disciplines. Disciplines two and three are coupled together, also, discipline one and three are coupled together. Assume standard notation for all the variables. Also assume that the objective function and the constraints are dependent on state variables from all the three disciplines. In other words, there are no local objective functions or constraints.

   (a) Write the mathematical definition of the problem using IDF and MDF architectures in standard notation. [6]

   (b) Draw the XDSM for the IDF architecture. [4]

   (c) Draw the XDSM for the MDF architecture. [4]
