Applied Mathematics Seminar

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Use of Approximation Techniques and Genetic Programming for Optimization and Inverse Problems

by

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Abstract

The techniques to be discussed address the following difficulties of typical real life optimization and inverse problems: function values are obtained by expensive numerical computations, e.g. using an FE package, a CFD code, etc., function values may contain some level of numerical noise, some combinations of variables may produce situations when some of the response quantities cannot be evaluated (domain-dependent calculability). These issues make the application of conventional optimization algorithms problematic. To address them, various approximation techniques have been developed since mid-1970s. Depending on the range of their applicability as compared to the full range of variables, they can be classified as local, mid-range and global approximations. Local approximations require accurate values of sensitivities and do not address the problem of domain-dependent calculability, these considerations limit their applicability. From the mid-1980s techniques based on the response surface methodology are used to solve difficult engineering optimization problems. Usually, they are based on the polynomial approximation of response functions by the least squares fitting procedure using results of runs of the simulation tool over a number of points in the whole range of the variables (global approximation). Such techniques are tolerant to the numerical noise but result in an excessive number of calls for the response function evaluation when the number of variables grows (larger than ten). Also, the quality of global polynomial approximations may not be satisfactory. This presentation is focused on the use of mid-range and global approximations and applications to various engineering optimization and inverse problems. A technique based on the iterative mid-range response surface fitting (also referred to as multipoint approximation method) combines the advantages of both local approximations (it can cope with the large number of design variables) and surface fitting techniques (insensitive to noise). This technique does not require the sensitivity information but makes efficient use of it when such information is available. The issue of the domain dependent calculability is addressed by the appropriate planning of numerical experiments. Several applications of the multipoint approximation method to various engineering optimization problems will be discussed. The second part of the presentation addresses the problem of the choice of the best structure of the approximation functions in order to improve the approximation quality, this becomes particularly beneficial for global approximations. A possibility of the use of simplified numerical models as high quality approximations will be discussed. An alternative approach is based on the genetic programming (GP) methodology which is being developed in the last few years. GP is a branch of genetic algorithms (GA), and the innovation of GPs is the use of more complex structures. While GAs use a string of numbers to represent a solution, the GP creates programs with a tree structure (in our case representing each individual structure of the approximation function) being improved in the genetic process. The potential of the new types of approximations is illustrated by a selection of examples.