ADS-1: A New General-Purpose Optimization Program

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Abstract

THE automated design synthesis (ADS) program is a general-purpose optimization program intended for application to a broad spectrum of engineering design problems. The program offers a wide variety of state of-the-art optimization algorithms for nonlinear constrained (or unconstrained) function minimization. Although the ADS program was developed principally for design applications, it is also useful as an aid in the teaching and learning of optimization methods because of the wide variety in the available algorithms. The optimization process is segmented into three basic levels; strategy, optimizer, and one-dimensional search. At each level, several options are available so that a total of over 100 possible combinations can be created. Emphasis is placed on easy use of the program. All information is transferred via a single parameter list. Default values are provided for all internal program parameters, such as convergence criteria, and the user is given a simple means of overriding these defaults.

Contents

Purpose

The ADS program solves the following nonlinear constrained optimization problem: find the set of design variables X that will minimize $F(X)$, subject to

$$g_j(X) \leq 0 \qquad j=1,m$$

$$h_k(X) = 0 \qquad K=1,\ell$$

$$X_i^\ell \leq X_i \leq X_i^u \qquad i=1,n$$

where $F(X)$ is the objective function, $g_j(X)$ and $h_k(X)$ are inequality and equality constraints, respectively, and X_i^ℓ and X_i^u are side constraints that limit the region of search for the optimum.

Development of the ADS program was motivated by the need for a general-purpose optimization capability containing a variety of methods to meet the needs of differing design applications.[1] ADS is written in a consistent, user-friendly manner so that the various methods can be directly compared. This allows the user to rapidly determine the method best suited to a particular class of problems. It is recognized that some of the available algorithms will be found to be inefficient or otherwise obsolete, except perhaps for educational purposes. The modular program structure allows for future deletion of options that the users find to be of minimal value, as well as expansion to include new methods as they are developed. The program is written in FORTRAN for easy transportability between computers. Finally, the source code is available in the public domain, making it convenient for the user to modify the code to meet specific needs. (The principal author may be contacted regarding program availability.)

Program Organization

The general organizational structure of a program using ADS as the optimizer, as well as the structure of the ADS program itself, is shown in Fig. 1. An important feature of this structure is that ADS does not directly call any user-supplied subroutines for function or gradient evaluations. Control is always returned to the calling program when information is needed. This provides considerable flexibility in program organization, including restart capability and multilevel optimization. The program is written in standard FORTRAN and is easily transportable between computers.

Program Options

At each level of the optimization process, several user-defined options are available. Three parameters are provided to ADS to identify the options desired. These are the parameters ISTRAT, IOPT, and IONED. Tables 1-3 list the available strategies, optimizers, and one-dimensional search options, respectively.

Not all combinations of strategy, optimizer, and one-dimensional search are meaningful. For example, constrained one-dimensional search is not meaningful when minimizing unconstrained functions. Table 4 identifies the combinations of algorithms available in the ADS program. In the table, an X is used to denote an acceptable combination of strategy,

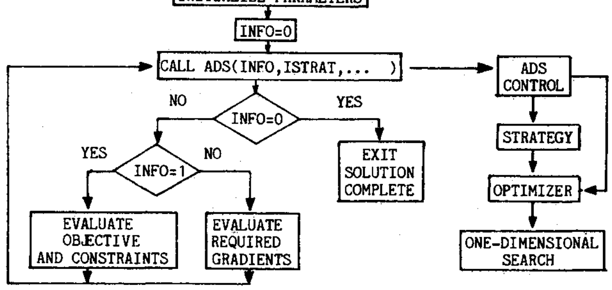

Fig. 1 ADS program organization.

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Table 1 Available strategies

ISTRAT	Strategy to be used
0	None. Go directly to the optimizer.
1	Sequential unconstrained minmization using the quadratic exterior penalty function method.
2	Sequential unconstrained minimization using the linear extended interior penalty function method.
3	Sequential unconstrained minimization using the quadratic extended interior penalty function method
4	Sequential unconstrained minimization using the cubic extended interior penalty function method
5	Augmented Lagrange multiplier method
6	Sequential linear programming
7	Method of inscribed hyperspheres (method of centers)
8	Sequential quadratic programming

Table 2 Available Optimizers

IOPT	Optimizer to be used
0	None. Go directly to the one-dimensional search (this option is used only for program development)
1	Method of feasible directions for constrained minimization
2	Fletcher-Reeves conjugate direction algorithm for unconstrained minimization
3	Modified method of feasible directions for constrained minimization (similar to the generalized reduced gradient method)
4	Davidon-Fletcher-Powell (DFP) variable metric method for unconstrained minimization
5	Broydon-Fletcher-Goldfarb-Shanno (BFGS) variable metric method for unconstrained minimization

Table 3 Available one-dimensional search options

IONED	One-dimensional search option to be used
1	Find brackets on the minimum of an unconstrained function
2	Find the minimum of an unconstrained function using the Golden Section method
3	Find the minimum of an unconstrained function using the Golden Section method followed by cubic polynomial interpolation
4	Find the minimum of an unconstrained function by first finding bounds and then using polynomial interpolation
5	Find the minimum of an unconstrained function by polynomial interpolation/extrapolation without first finding bounds on the solution
6	Find brackets on the minimum of a constrained function
7	Find the minimum of a constrained function by using the Golden Section method
8	Find the minimum of a constrained function by using the Golden Section method followed by cubic polynomial interpolation
9	Find the minimum of a constrained function by first finding bounds and then using polynomial interpolation
10	Find the minimum of a constrained function by polynomial interpolation/extrapolation without first finding bounds on the solution

Table 4 Program options

IOPT	0	1	2	3	4	5
ISTRAT						
0	X	X	X	X	X	X
1	0	0	X	0	X	X
3	0	0	X	0	X	X
4	0	0	X	0	X	X
5	0	0	X	0	X	X
6	0	X	0	X	0	0
7	0	X	0	X	0	0
(8)	0	X	0	(X)	0	0
IONED						
1	X	0	0	0	0	0
2	X	0	X	0	X	X
3	X	0	X	0	X	X
4	X	0	X	0	X	X
5	X	0	X	0	X	X
6	X	0	0	0	0	0
7	X	X	0	X	0	0
8	X	X	0	X	0	0
9	X	X	0	(X)	0	0
10	X	X	0	0	0	0

optimizer, and one-dimensional search. An example is shown by the heavy line on the table, indicating that constrained optimization is to be performed by sequential quadratic programming (ISTRAT = 8) using the modified method of feasible directions (IOPT = 3) and polynomial interpolation with bounds for one-dimensional search (IONED = 9).

Summary

Throughout the development of the ADS program, two considerations have been dominant: 1) create a unified, state-of-the-art optimization capability for application to design problems of practical interest, and 2) maintain the flexibility to easily expand the code as the state-of-the-art advances. It is hoped that a carefully designed program structure and basic capability, coupled with maximum user interaction can provide a practical and reliable design capability for the broadest application.

Acknowledgment

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References

[1] Vanderplaats, G. N., Sugimoto, H., and Sprague, C. M., "ADS-1: A New General-Purpose Optimization Program," Paper 83-0831, *Proceedings of 24th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Materials Conference*, Lake Tahoe, Nev., May 1983.