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Optimization Technique for Problems with an Inequality Constraint

The general optimization technique was developed during a study of electrical propulsion systems in which it was necessary to establish the system design which has minimum mass, M, while the system reliability, R, remains greater than or equal to some desired value R_g. Thus, since M and R are functions of N variables, the problem is to find the minima and maxima values of the function M for variation of the N variables subject to the constraint that $R \geq R_g$, where R_g is a constant.

The general optimization technique makes use of a modified version of an existing technique termed the *pattern search technique*. To apply it to optimization problems having inequality constraints, a new procedure called the *parallel move strategy* was developed.

The *pattern search technique* is based on the conjecture that any set of moves (changes in the independent variables) which have given a better value for the objective M will be worth trying again. The technique has ridge-following properties that make it more desirable for certain function surfaces than, for example, the method of steepest descent, which moves in the direction of steepest slope and thus does not handle ridges very well. The *pattern search technique*, though moving with the general trend of the slope, does not necessarily move in the direction of steepest slope. The moves made by the *pattern search technique* grow with success and become smaller with failure. In the vicinity of the minimum, the moves become very small to avoid overlooking any promising direction.

It has been found empirically that in certain problems the computation time for pattern search increased only as the first power of the number of variables, whereas other techniques may increase with the cube of the number of variables. This feature can be very important when dealing with large numbers of variables.

The *pattern search technique* was developed to use on unconstrained optimization problems. Since the optimization problem for the electrical propulsion system involves the constraint $R \geq R_g$, where R is a function of N variables and R_g is some desired constant, a new procedure called the *parallel move strategy* was developed and used with the *pattern search technique* to solve inequality constraint problems.

The *parallel move strategy* permits the *pattern search technique* to be used with problems involving a constraint; the technique was modified so that the constraint could be handled internally. Two modifications were essential to perform this task. The first modification was to treat points where the constraint was violated as failure in the search, even though the points might otherwise be successes. The second modification to the pattern search technique was to change strategy at points where further exploration by the normal *pattern search technique* will only lead to failures; the modification dictates that the move is made along the tangent plane to the constraint surface passing through a point. If the constraint function is linear, this move is also parallel to the constraint boundary (defined by $R = R_g$). The direction to move in the tangent plane is in the direction of greatest decrease in objective function value, which can be found from the gradient of the objective function.

The *parallel move strategy* has been programmed as a computer subroutine to the pattern search computer program. It could be integrated with any of the slope-sensitive optimization techniques, such as the

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method of steepest descent, to allow them to handle optimization problems with an inequality constraint as the modified search technique now does.

The general optimization program can be applied to the solution of many different types of optimization problems, either with an inequality constraint or without, and is useful even for fairly large numbers of variables (about 15 to 20) if the objective and constraint functions are sufficiently simple.

Note:

Requests for further information may be directed to:

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