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This Week's Citation Classic

Hooke R & Jeeves T A. "Direct search" solution of numerical and statistical problems. *J. Ass. Comput. Mach.* **8**:212-29, 1961. [Westinghouse Research Labs., Pittsburgh, PA]

In finding the maximum or minimum value of a complicated function, classical methods sometimes fail or are not feasible. 'Direct search' is a means of solving such problems by having a computer follow a simple search strategy. [The *SCI*® indicates that this paper has been cited over 270 times since 1961.]

Robert Hooke and T.A. Jeeves
Research & Development Center
Westinghouse Electric Corporation
Pittsburgh, PA 15235

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"The optimization approach that we called 'direct search' was born because of a problem that didn't respond to classical methods. When this problem showed up we were developing for Westinghouse a device, called OPCON, for controlling poorly understood processes. The rationale of OPCON was that some industrial processes, considered uncontrollable by automation, are run by unskilled operators who maintain some controi by occasionally adjusting knobs until observable results are fairly satisfactory. It seemed to follow that, where no great intelligence is required to accomplish this, an automatic experimenter should succeed at least as well, and OPCON resulted.

"Trying strategies for OPCON, we found an optimal strategy for unimodal functions of one variable (Fibonacci search), only to learn that others had anticipated us by a few months. [1] The next thing we learned that had already been learned before was that solving a one-variable problem often provides no help in solving the corresponding problem with several variables. We finally settled on a simple strategy because OPCON had to be inexpensive, and it was designed for situations where there is little payoff for spending time gathering information that quickly becomes obsolete.

"At this point, in 1956, we received the optimization problem that we couldn't solve by regular methods. It was too complex for analytical solution, and steepest descent methods failed. Experience with OPCON had taught us that information at places remote from the optimum tells little about the location of the optimum, so we turned to the simple strategies or 'direct search' methods, so called because they involved search alone, with no analytical aids such as estimating gradients. Experimenting with various objective functions, we found that the principal hangups occur on long, thin contour curves, so a strategy called 'pattern search' was invented to handle these. This strategy worked on our problem and on some others.

"Thinking that our method might be useful to other people, we submitted it to a journal, where it was speedily rejected as too subjective. Our only claim was that the method sometimes works on problems where all else has failed, problems describable by the medical euphemism 'terminal.' We assumed other journals would take the same attitude until Alan Perlis, then editor of *Communications of the Association for Computing Machinery,* encouraged us to submit the paper to him, and this led to its publication in the *journal of the Association for Computing Machinery.*

"Direct search is a crude, brute force method having no mathematical elegance. Its popularity in terms of citations shows that there are more terminal problems around than one might think. Among real nonlinear multivariate problems, those that are solvable analytically or by socially acceptable numerical methods seem to constitute a set of measure zero. The numerous requests we've received for reprints suggest that for some time there will still be a demand for inelegant methods that can be tried on terminal cases.

1. **Kiefer J.** Sequential minimax search for a maximum. *Proc. Amer. Math. Soc.* **4**:502-6. 1953.