Optimization using surrogates for engineering design, and some thoughts on working with industry *

J.E. Dennis Jr. †

November 4, 2003

Abstract

This talk will outline the surrogate management framework [6], which is presently built on the filter GPS method for general nonlinear programming without derivatives [5]. This line of research was motivated by industrial applications, indeed, by a question I was asked by Paul Frank of Boeing Phantom Works. His group was often asked for help in dealing with very expensive low dimensional design problems from all around the company. Everyone there was dissatisfied with the engineering state of the art, which was to substitute inexpensive surrogates for the expensive "true" objective and constraint functions in the optimal design formulation. We had been asked the same basic question some time before by Sandia Labs engineers who were designing a shipping container for nuclear waste. When Paul asked the question this time, the ideas behind the surrogate management framework (SMF) based on a GPS meta-algorithm occurred to us, and we hope to demonstrate in this talk just how simple that answer is.

The surrogate management framework is unreasonably effective in practice, where most of the application are extended valued and certainly nondifferentiable. This has forced Charles Audet and me to begin to learn some nonsmooth analysis [7, 8].

There are three aspects to this work: lessons I have learned in working with industry, the mathematical content in the specific work currently underway, which was treated in the first talk, and the gratifying numerical results we have obtained on real problems, e.g. [2, 1]. There is not time to do justice to all these aspects, but I will try to focus on the first and third.

*Work supported by AFOSR F49620-01-1-0013, The Boeing Company, Sandia LG-4253, ExxonMobil, and the LANL Computer Science Institute (LACSI) contract 03891-99-23.

†Computational and Applied Mathematics Department, Rice University - MS 134, 6100 Main Street, Houston, Texas, 77005-1892 (dennis@rice.edu, http://www.caam.rice.edu/∼dennis)

References

[1] AUDET C., BOOKER A.J., DENNIS J.E.JR., FRANK P.D., and MOORE D.(2000), "A Surrogate-Model-Based Method For Constrained Optimization", AIAA no.4891, *Proceedings of the Symposium on Multidisciplinary Analysis and Optimization*.

[2] BOOKER A.J., DENNIS J.E.JR, FRANK P.D., MOORE D.W. and SERAFINI D.B.(1999), "Managing Surrogate Objectives to Optimize a Helicopter Rotor Design - Further Experiments," AIAA Paper 98-4717, St. Louis, September 1998.

[3] AUDET C. (2002), "Convergence results for pattern search algorithms are tight," *Les Cahiers du GERAD* G-2002-56, Montréal. To appear in *Optimization and Engineering*.

[4] AUDET C. and DENNIS J.E.JR. (2003), "Analysis of generalized pattern searches," *SIAM Journal on Optimization* 13, 889-903.

[5] AUDET C. and DENNIS J.E.JR. (2000): "A pattern search filter method for nonlinear programming without derivatives," Technical Report *TR00-09*, Department of Computational and Applied Mathematics, Rice University, Houston Texas.

[6] BOOKER A.J., DENNIS J.E.JR, FRANK P.D., SERAFINI D.B., TORCZON V. and TROSSET M.W. (1999), "A rigorous framework for optimization of expensive functions by surrogates," *Structural Optimization* Vol.17 No.1, 1-13.

[7] CLARKE, F.H. (1990) "Optimization and Nonsmooth Analysis," SIAM Classics in Applied Mathematics Vol.5, Philadelphia.

[8] JAHN J. (1994), "Introduction to the Theory of Nonlinear Optimization," Springer, Berlin.

[9] ROCKAFELLAR R.T. (1980) "Generalized directional derivatives and subgradients of nonconvex functions," *Canadian Journal of Mathematics* Vol.32, 157–180.

[10] TORCZON V. (1997), "On the Convergence of Pattern Search Algorithms," *SIAM Journal on Optimization* Vol.7 No.1, 1–25.