2015 ACC Workshop Proposal

Nonlinear Optimization: Techniques for Engineering

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Topics:

This full-day workshop will be a practical guide for those using multivariable, constraint handling, nonlinear optimization. Although theoretical analysis behind techniques will be revealed, the takeaway will be participants' ability to:

- Define the objective function (cost function)
- Incorporate hard constraints in the search
- Convert constraints to appropriately weighted penalties
- Choose an appropriate optimizer
- Choose appropriate convergence criteria and thresholds
- Choose initialization and number of trials to be confident in finding the global optimum

The short-course will cover common gradient-based optimization techniques (Incremental Steepest Descent, Cauchy, Newton, Levenberg-Marquardt) and direct-search techniques (Heuristic, Hook-Jeeves, Particle Swarm, and Leapfrogging) that represent the fundamentals of most approaches.

This workshop is based on a popular interdisciplinary graduate engineering course. Participants will receive course notes of approximately 200-pages, and software to provide exercises and access to code. Exercises and code can be implemented in any environment, but Excel/VBA will used as in-workshop examples and exercises. Participants are invited to bring a computer with Excel version 2010 or higher for in-class exploration. There are currently more than 80 functions and over 20 optimization algorithms in the simulator.

Most exercises are for 2-dimensional applications for visual understanding of the surfaces and methods, but the methods and techniques are scalable to high dimension. Several N-D examples will be provided.

Rationale:

Optimization means seeking the best outcome or solution, and is a fundamental tool for modeling, model-based control, forecasting, design, analysis and diagnosis, supervisory economic operation, safety, precision, sustainability, and etc. We desire an efficient procedure to find the best solution with minimal computational and experimental effort. Part of this short-course is about the search logic, or the optimizer algorithm.

However, the major challenges in optimization are often not

- the mathematics of the algorithm,

but the clear and complete statement of

- the objective function (the outcome you wish to minimize or maximize),
- constraints (what cannot be violated, exceeded, etc.),
- the decision variables (what you are free to change to seek a minimum),
- the model (how DVs relate to OF and constraints),
- the convergence criterion (the indicator of whether the algorithm has found the min or max and can stop, or needs to continue),

and choosing

- the DV initialization (what locations, values),
- the number of starts from randomized locations to be confident that the global optimum has been found, and
- the appropriate optimization algorithm (for the function aberrations, for utility, for precision, for efficiency).

This short-course addresses all of those elements.

Prerequisite skills

Any undergraduate engineering or mathematics program should have provided an adequate experience with topics in calculus, analytical geometry, linear algebra, vector/matrix notation, statistics, and computer programming. The short course will review essential topics that are commonly un-remembered from undergraduate courses.

Format:

Full-day. Presentation from laptop computer (need projector and screen). In-class explanations need black/white board or flipchart. Students should have tables for their laptops and course notes.

Presenter:

R. Russell Rhinehart – see bio at the end.

Workshop Schedule:

AM – Session 1
Introductory Concepts and Definitions
Gradient based concepts - Cauchy, Incremental Steepest Descent, Newton
Problems and Improvements – Levenberg-Marquardt.
Problems and Constraints
Break

AM – Session 2
Penalty Weighting
Multiple Optima
Multiple Starts
Lunch

PM – Session 1
Convergence Criteria
Surface aberrations – discontinuities, stochastic, narrow valleys
Simple Direct Methods – Heuristic Cyclic, Hook-Jeeves
Multi-Player Direct Methods – Leapfrogging, Particle Swarm
Break

PM – Session 2
Comparisons
Objective Function Formulation
End

Intended Audience:

The workshop is designed for those needing to understand the optimization applications. This is a practical guide on the use of best practices from conventional methods, with examples to illustrate the choices and techniques. Supporting theory will be addressed, but the take-away will be the ability to specify objective functions, include constraints, select an appropriate optimizer, and specify initialization and convergence criteria.

The intended audience is engineering employees, students, and faculty who use nonlinear optimization techniques.

Expected Enrollment:

I suspect there will be 20 participants, roughly 1/3 students, 1/3 faculty, and 1/3 from industry. This short-course is based on an interdisciplinary engineering graduate course, the most popular one at the university. I continue to modify the workshop materials, hopefully to increase its appeal to industrial participants. I also plan on doing my own marketing to professional and university groups in the Chicago area.

Completeness:

I'd like to include more topics, but it's only a one-day workshop. I believe that with the basic concepts from the workshop, individuals will have the ability to understand the more advanced techniques. There are next generation optimizers (like ant colony, differential evolution, simulated annealing, or genetic algorithms), there are build-on techniques for the objective functions (like maximum likelihood for regression, or minimizing the probability or undesired outcomes), next levels in the decision variables (like random keys for sequencing of class variables), and a variety of techniques for determining convergence (like steady state). I can't cover everything, but hopefully can provide the grounding so that participants can independently move in the other directions.

Presenter Bio:

This workshop will be presented by Russ Rhinehart.

Dr. R. Russell Rhinehart, professor in the School of Chemical Engineering at Oklahoma State University, holds the Amoco Endowed Chair, and has experience in both industry (13 years) and academe. He was Head of the School from 1997 to 2008, and 2011 to 2012. Russ is Past President of the American Automatic Control Council, and was Editor-in-Chief of ISA Transactions from 1998 to 2012). He is a Fellow of ISA, a CONTROL Automation Hall of Fame inductee, and received the 2009 ISA Distinguished Service Award, the 2013 Fray International Sustainability Award, and numerous teaching excellence recognitions.

His 1968 B.S. in Chemical Engineering and subsequent M.S. in Nuclear Engineering are both from the University of Maryland. His 1985 Ph.D. in Chemical Engineering is from North Carolina State University.

He is coauthor of the textbook, Applied Engineering Statistics, and has contracts with Wiley for books on Nonlinear Regression and on Optimization Applications. He authored six handbook chapters on modeling, uncertainty, process control, and optimization.

Russ teaches modeling, optimization, and process control courses; and has developed short courses for industrial participants offered through ISA or directly to companies related to statistical process control, instrument and control systems, modeling, and model-based control.