Advanced Algorithms for Hydropower Dispatch

S&T Briefing
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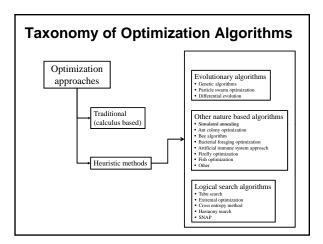
About This Project

- **Title: *Advanced Optimization Algorithms for Hydropower Dispatch* (S&T Project ID# 486)**
- **FY2011 support graciously provided by Reclamation's Science and Technology Research Program.**
- **David A. Harpman, Principal Investigator**
- **Collaborators: Argonne National Laboratory and Colorado State University.**
- **Further details can be found at: http://www.usbr.gov/research/science-and-tech/projects/**
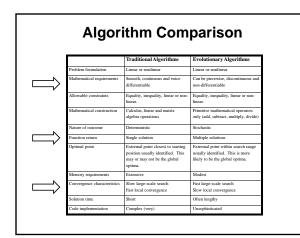
Research Objectives

- **Investigate practical application of these approaches.**
- **Explore performance characteristics of these algorithms on hydropower problems of specific interest to Reclamation, and others.**
- **Potentially, develop solvers for installation at Reclamation powerplants.**
- **Scholarly products.**

Progress in Optimization Techniques

- **Traditional optimization methods, based on calculus, date back to Sir Isaac Newton (circa 1670).**
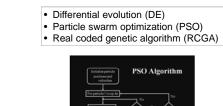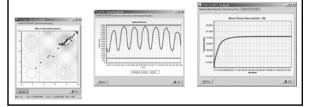- **Research on heuristic optimization algorithms not practical until microcomputers became widely available (circa 1980).**

ISAAC NEWTON 1643-1727
DEUTSCHE BUNDESPOST 100

$$b_{t+1} = b_t - \left[\frac{\partial^2 \ell}{\partial b_t \partial b_t} \right]^{-1} \times \frac{\partial \ell}{\partial b_t}$$

Taxonomy of Optimization Algorithms

Optimization approaches

Traditional (calculus based)

Heuristic methods

Evolutionary algorithms
- Genetic algorithms
- Particle swarm optimization
- Differential evolution

Other nature based algorithms
- Simulated annealing
- Ant colony optimization
- Bee algorithm
- Bacterial foraging optimization
- Artificial immune system approach
- Firefly optimization
- Fish optimization
- Other

Logical search algorithms
- Tabu search
- Extremal optimization
- Cross entropy method
- Harmony search
- SNAP

Algorithm Comparison

	Traditional Algorithms	Evolutionary Algorithms
Problem formulation	Linear or nonlinear	Linear or nonlinear
Mathematical requirements	Smooth, continuous and twice differentiable	Can be piecewise, discontinuous and non-differentiable
Allowable constraints	Equality, inequality, linear or non-linear.	Equality, inequality, linear or non-linear.
Mathematical construction	Calculus, linear and matrix algebra operations	Primitive mathematical operators only (add, subtract, multiply, divide)
Nature of outcome	Deterministic	Stochastic
Function return	Single solution	Multiple solutions
Optimal point	Extremal point closest to starting position usually identified. This may or may not be the global optima.	Extremal point within search range usually identified. This is more likely to be the global optima.
Memory requirements	Extensive	Modest
Convergence characteristics	Slow large-scale search Fast local convergence	Fast large-scale search Slow local convergence
Solution time	Short	Often lengthy
Code implementation	Complex (very)	Unsophisticated

Algorithms Explored

- Differential evolution (DE)
- Particle swarm optimization (PSO)
- Real coded genetic algorithm (RCGA)

Phases of Development

- **Initial development on unconstrained test problems.**
- **Application to constrained hydropower dispatch problem.**
- **Construction of testing environment.**

Progress To-Date

Algorithm	Test Program	Unit Dispatch	Economic Dispatch	Testing Environment
PSO	Complete	Working prototype	Complete	Complete
DE	Complete	Working prototype	Complete	Complete
RCGA	Complete	TBD	Complete	Complete
Bees	TBD	TBD	TBD	TBD
Lambda Search	NA	TBD	Complete	NA

Progress To-Date (2)

- Meetings with collaborators.
- Concurrent report writing.
- Planned technical seminar for Reclamation Staff.
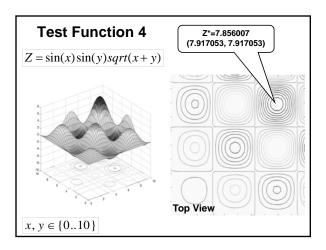- Ongoing experiments.
- Other.

Planned Experiments

- N-trials with statistical analysis.
- Initialization approaches.
- Stopping criteria.
- Parameter settings, variants.
- Problem specifications.
- Algorithm performance.
- Other.

Suggestions, Comments & Guidance

For information about this research, please contact:

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Test Function 4

Z*=7.856007
(7.917053, 7.917053)

$$Z = \sin(x)\sin(y)sqrt(x+y)$$

Top View

$$x, y \in \{0..10\}$$

Live Demo (1)

Real coded genetic algorithm (RCGA)

Live Demo (2)

Hydropower dispatch with RCGA