Global Initiative for Academic Networks

Ministry of Human Resource Development, Government of India

A Short Course On

Optimization: Applications, Algorithms and Computation

September 12th to 24th, 2016

Overview

Optimization is essentially the art, science and mathematics of choosing the best among a given set of finite or infinite alternatives. A new impetus to the development of optimization began with dramatic development of linear programming in the late 1940's. Though currently optimization is an interdisciplinary subject cutting through the boundaries of mathematics, economics, engineering, natural sciences, and many other fields of human Endeavour it had its root in antiquity. Scientists and engineers are increasingly turning from the simulation of complex processes to the optimization and design of complex systems. Many important design problems involve not only continuous variables with nonlinear relationships but also discrete decisions giving rise to mixed-integer nonlinear programming problems. Applications of NLP and MINLP arise in electrical engineering and the modeling of the power grid, chemical engineering, and communication engineering. The topics of this course includes classification of optimization problems, need for optimal design, formulation of optimal design problems, Linear programming, Quadratic Programming, Non linear Optimization, Convex Optimization,, Integer programming and Mixed Integer Non Linear Programming and applications in Mechanical and Electrical Engineering. Course participants will learn these topics through lectures, algorithm developments and hands on experiments. Also case studies and assignment will be shared to stimulate research motivation of participants

Objectives

The primary objectives of the course are as follows:

1. Provide the participants with the theoretical aspects of the optimization Methods and explore the case studies of applications of optimization techniques in various engineering problems.
2. Provide the participants with a strong understanding of and the confidence in the formulative steps involved in the optimization algorithm development.
3. To provide hands on practice to develop real-live problems solving capabilities amongst the participants.
4. To develop competency of doing research amongst participants using the state of the art Optimization Techniques, and numerical solvers.

Modules	This two-week course consists of 24 lectures (1.5 hours each) plus 12 two-hour tutorials. Each day is structured to have two lectures in the morning followed by a tutorial in the afternoon that provides an opportunity to enforce the morning's material, through exercises, programming and modeling studies. **Module A: Introduction to Optimization, Applications, and Modeling: September 12.** Lecture 1: Introduction to optimization: concepts of objective and constraints; variables types; classification of optimization problems; iterative methods; simple methods (coordinate and steepest descend); course outline. Lecture 2: Applications of optimization: power-system engineering, control, analysis of scientific data, design of complex structures (solar cells, molten-salt solar power plants). Modeling languages and interfaces to optimization; AMPL, GAMS, JuMP, and octave (Matlab). The NEOS server. Tutorial 1: Examples of steepest/coordinate descend; quadratic line-search; online and open-source software resources (download, installation, and first examples). Exercise: power-grid case study (extended in week two to integer variables). **Module B: Unconstrained and Bound-Constrained Optimization: September 13 – 15.** Lecture 3: Optimality conditions (1^{st} and 2^{nd} order); basic methods; iterative methods; nonlinear line-search. Taylor's theorem and Newton's method. Lecture 4: Quasi-Newton methods, Broyden family of methods, variational properties, limited-memory quasi-Newton. Tutorial 2: Programming quasi-Newton methods in octave/Matlab; quasi-Newton convergence examples; application to least-squares problems. Lecture 5: Conjugate-gradient methods: convergence and termination. Preconditioning and spectral analysis for large-scale optimization. Example PDE models. Lecture 6: Restricted-step methods: line-search and trust-region methods. Levenberg-Marquard method: global convergence analysis; minimization of a quadratic subject to trust-region bounds. Tutorial 3: Implementation of preconditioned conjugate-gradient methods in octave/Matlab; example of line-search failure. Lecture 7: Bound constraints: optimality conditions and projection-based methods for convex quadratic objectives. Lecture 8: Nonlinear bound constrained optimization: projected gradient-type methods; extensions of conjugate-gradient and limited-memory methods for large-scale bound-constrained optimization. Tutorial 4: Modeling obstacle problems as bound-constrained optimization problems; implementation of methods based on unconstrained solvers. **Module C: Constrained Optimization: September 16 – 20.** Lecture 9: Optimality conditions: 1^{st} and 2^{nd} order conditions; Karush-Kuhn-Tucker (KKT) conditions; constraint qualifications; geometric interpretations; Lagrange multipliers and sensitivity analysis. Lecture 10: Convexity an sufficient optimality conditions; duality: Lagrangian and Wolfe-dual. Tutorial 5: Equivalent convexity cnditions. Modeling and solving constrained optimization in JuMP/AMPL; interpretation of solver output and multipliers; practical sensitivity analysis, e.g. multiple right-hand sides.

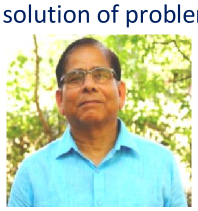
Lecture 11: Linear programming: active-set and simplex methods; pivoting, linear algebra, and stable factorization updates. Efficient updates for large-scale problems.
Lecture 12: Active-set methods for quadratic programming; pivoting schemes; KKT system solves. Dual active-set methods and warm-starts for mixed-integer optimization.
Tutorial 6: Tableau methods; equivalence of tableau, revised simplex, and active-set methods; factorizations in quadratic programming; KKT systems.
Lecture 13: Sequential quadratic programming (SQP) and sequential linear programming (SLP) methods: line-search an trust-region methods; local convergence; convergence from remote starting points (penalty functions and filter methods).
Lecture 14: Interior-point methods for nonlinear optimization: classical barrier methods; modern primal-dual methods; inertia-control and step acceptance; factorizations and iterative solvers.
Tutorial 7: Open-source solvers in AMPL/JuMP; implementation of primal-dual methods for convex quadratic programming in octave/Matlab.
Lecture 15: Augmented Lagrangian methods: bound-constrained and linearly-constrained augmented Lagrangian methods; alternating direction method of multipliers (ADMM).
Lecture 16: Beyond nonlinear optimization (choice of 1-2 topics decided by workshop attendees): (a) multi-objective optimization; (b) derivative-free optimization; (c) PDE-constrained optimization; (d) mathematical program with equilibrium constraints.
Tutorial 8: ADMM in image analysis and compressive sensing (sparse optimization): implementation in octave/Matlab. Modeling exercises in extension topics, e.g.: multi-objective optimization models, PDE-constrained optimization and inverse problems, or equilibrium modeling and complementarity constraints in AMPL.

Module D: Mixed-Integer Nonlinear Optimization: September 21 – 24.
Lecture 17: Modeling with integer variables; applications of mixed-integer optimization; modeling best-practices. Basic algorithmic ingredients: relaxation and separation.
Lecture 18: Branch-and-bound methods for mixed-integer nonlinear optimization; advanced algorithmic features. Outer approximation and Benders decomposition. Overview of solvers.
Tutorial 9: Model building with integer variables: extensions to power-grid problem (transmission switching and network expansion); implementation of outer approximation in JuMP.
Lecture 19: Hybrid methods for mixed-integer optimization; presolve for mixed-integer optimization. Worst-case behavior and disaggregation tricks.
Lecture 20: Branch-and-cut methods; cutting planes for mixed-integer problems; standard cuts such as knapsack covers; mixed-integer rounding; perspective and disjunctive cuts; implementation of mixed-integer solvers.
Tutorial 10: Introduction to MINOTAUR and other open-source solvers; implementation of cutting planes.
Lecture 21: Global optimization of nonconvex problems: basic algorithmic outline: relaxation and separation. Nonlinear branch-and-bound for nonconvex optimization; piecewise linear approximation approaches.
Lecture 22: Spatial branch-and-bound; McCormick underestimators; semi-definite programming relaxations of nonconvex quadratics; tightening bounds (feasibility-based bound tightening and optimality-based bound tightening); exploiting structure.
Tutorial 11: McCormick underestimators for polynomial optimization; semi-definite relaxations for power-grid applications (exploiting network structure).

	Lecture 23: Heuristics for mixed-integer nonlinear optimization. Rounding-based heuristics; feasibility-pump; relaxation-induced neighborhood search. Combination o heuristics with modern implementations. Lecture 24: Mixed-integer PDE-constrained optimization; models and applications; challenges and solution approaches. Mixed-integer optimal control and sum-up rounding: derivation and optimality properties. Tutorial 12: Implementation of heuristic methods in AMPL/JuMP or MNOTAUR; modeling with PDEs (source inversion and control of heat equation); simple discretization schemes.
Examination and Certificates	▪ Examination will be conducted on 24th September, 2016 and Grade Certificate of 2 Credit will be awarded to the participants who passed the examination. ▪ Participation Certificate will be provided to each participant.
Seats	Number of participants for the course will be limited to **Forty.**
You Should Attend If…	▪ You are an engineer or research scientist interested in optimization techniques. ▪ You are a student or faculty from academic institution in Mathematics or any branch of Engineering who do optimization.
Course Registration Fee	▪ **Participants from abroad** : US $500 ▪ **Industry/ Research Organizations:** Rs. 10000/- ▪ **Academic Institutions:** • **Host Institution (**Jabalpur Engineering college): Faculty and students **:Nil** • **Other institution:** ○ **Faculty :** Rs. 5000/- ○ **Student:** Rs. 1000/- (For SC/ST : Rs. 500/-) The above fee includes all instructional materials, computer use for tutorials and free internet facility. Food, transport and accommodation of course participants will be borne by the individual course participants themselves. On the request the participants will be provided with single bedded accommodation on payment basis in the Guest House/Hostel.
Registration Process	Interested participants will have to first register with the GIAN website http://www.gian.iitkgp.ac.in/GREGN for one-time registration with registration fees of Rs.500.00 which will enable them to enroll for any number of courses being offered. Participants then needs to select "Optimization: Applications, Algorithm and Computation" course from the list at "Course Registration". Subsequent registration for this course will have to be done with Jabalpur Engineering College, Jabalpur by submitting the registration form as attached with the brochure, to the Course Coordinator by online and offline mode after receiving confirmation email. They need to enclose the demand draft of requisite fees in favour of "Principal Jabalpur Engineering College, Jabalpur".
Important Dates	Intimation to the shortlisted participants : 31st August 2016 Receipt of Course registration form to course Coordinator : 5th September 2016

The Faculty

Dr. Sven Leyffer is a senior computational mathematician, Mathematics and Computer Science Division, Argonne National Laboratory Argonne, USA. Dr. Sven obtained his Ph.D. in Mathematics (Deterministic Methods in Mixed Integer Nonlinear Programming) from the University of Dundee UK and B.S. in Pure Mathematics from University of Hamburg Germany. He has held post doc positions at Dundee, Northwestern and Argonne. He is an author of one book and more than 100 research papers. Sven is a SIAM fellow, a senior fellow of the University of Chicago/Argonne Computation Institute, and an adjunct professor at Northwestern University. He is the current SIAM Vice President for Programs and serves on the editorial board of the SIAM Journal on Optimization, Computational Optimization and Applications, and Computational Management Science; he also is editor-in-chief of Mathematical Methods of Operations Research and the coordinating editor for nonlinear optimization for Mathematical Programming Computation. In 2006, Leyffer received the Lagrange Prize in Continuous Optimization. He is a world leader in both the theory and the development of large-scale complementarity constraints or integer variables. Dr. Sven has developed numerous solvers and open-source packages including filter SQP and filter MPEC for the solution of nonlinear optimization problems and complementarity constraints and MINOTAUR for the solution of problems with integer variables



Dr. S. S. Thakur is a professor and Head Department of Applied Mathematics Jabalpur Engineering College, Jabalpur. He has published more than 225 research papers and supervised twenty five Ph. D. students. He is a member of editorial board and served as referee of many international Journals. His current work includes Fuzzy Topology, Fuzzy Control Theory, Fuzzy Databases and Fuzzy Optimizations.

Dr. Jyoti Bajpai is working as Assistant Professor in Applied Mathematics, Jabalpur Engineering College, Jabalpur. Her subject of interest includes Intuitionistic Fuzzy Topology, Operation Research and Optimization.

Course Coordinators

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Course Registration

http://www.gian.iitkgp.ac.in/GREGN

Venue

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Global Initiative on Academic Network (GIAN)
Jabalpur Engineering College Jabalpur
A Short Course On
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REGISTRATION CUM ACCOMODATION REQUEST FORM

(To be submitted by the shortlisted candidates only after getting confirmation e-mails from the course coordinator. This form should reach by September 5, 2016)

1. Name (Block Letters): .... M/F: ....

2. Registration ID generated by GIAN Portal: ....

3. Participant Type:

I. Student:
Course (B.E/ B. Tech. /M.C.A/ M. Tech. / M. Sc. /M.Phil. /Ph.D.): ....
Branch & Semester: ....
Student ID Number: ....
Institute: ....

II. Faculty :
Designation: ....
Department: ....
Organization: ....

III. Industry:
Designation/Professional Title: ....
Organization: ....

4. Address: ....
....
....
Tel.: .... Mobile: ....
E-mail: ....

5. Accommodation Required (Yes/ No): ....

The Registration fee of Rupees ....has been paid via Demand Draft No...in favour of ñPrincipal Jabalpur Engineering College, Jabalpurò. Demand Draft has been enclosed herewith.

Date: Signature

Forwarded:

Head of the Institution/ Department
(With Seal)