1st Brazilian Workshop on Interior Point Methods

Abstracts

27-28 April 2015

Brazil - Campinas - UNICAMP - IMECC

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Plenary conferences

Large-scale optimization with BlockIP, a specialized IP solver for block-angular problems

Castro, Jordi

BlockIP is an efficient implementation of a specialized IP algorithm for block-angular problems. This algorithm solves the normal equations using sparse Cholesky factorizations for the block constraints, and a preconditioned conjugate gradient (PCG) for the linking constraints, relying on a power series preconditioner. In the first part of the talk we will present some of the features of BlockIP, including an outline of the algorithm. In the second part we will report results in the solution of two particular pplications using BlockIP. The first problem comes from the data privacy field, providing linear, quadratic and convex optimization roblems. Results will be given for instances of up to 25 millions of variables and 300000 constraints. The second is a multiperiod variant of a facility location problem. BlockIP is used within a cutting plane framework for the solution of this MILP. Results will be rovided for instances of up to 200 binary variables and subproblems of 200 million of continuous variables. In both applications BlockIP resulted to be far more efficient than state-of-the-art solvers.

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Inexact search directions in interior point methods for very large-scale optimization

Gondzio, Jacek

In this talk we are concerned with the interior point methods for optimization. Many large-scale problems cannot be solved with methods which rely on exact directions obtained by factoring matrices. For such problems, the search directions have to be computed using iterative methods. We address the problem of how much of inexactness is allowed without noticeably slowing down the convergence compared with the exact IPM. We argue that (except for some very special problems) matrix-free approaches have to be applied to successfully tackle truly large scale problems. We provide new theoretical insights and back them up with computational experience.

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Solving the normal equations system arising from interior point methods for linear programming by iterative methods

Oliveira, Aurelio Ribeiro Leite

The development of sophisticated software to solve linear optimization problems by interior point methods have started since early works. There are three main research lines aimed to improve the efficiency of such methods for solving large-scale problems: the reduction of the total number of iterations; implementation techniques to obtain fast iterations; specific methods for particular classes of problems. This talk deals with the second one. Iterative methods are used to solve the linear systems, the most expensive step of interior point methods, mainly when the Cholesky factorization is prohibitive. Special attention is given to the normal equation systems. Since such linear systems are highly ill-conditioned near a LP solution, the design of specially tailored preconditioners is an important implementation issue. Some preconditioning strategies are presented.

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A Brief History of Computational Linear Programming

Veiga, Geraldo

The development of algorithms and computational tools for linear optimization parallels that of digital computers. In spite of early studies on systems of linear inequalities dating back to Fourier, an algorithm prototype proposed by De la Vallée-Poussin in the early 20th century went unnoticed. The critical turning point comes in 1947, when George Dantzig created the Simplex Method intended ?to be computable?, an almost exact contemporary of the first digital computer. William Orchard-Hays produced the first successful LP software using a product-form of the inverse, setting the stage for rapid development of the field with sparse numerical linear algebra techniques that allowed for the solution of large scale problems. A change in paradigm occurred with Khachiyan's Ellipsoid Method establishing polynomial complexity for LP, even if without practical computational impact. Interior point methods first introduced by Narendra Karmarkar not only improved the theoretical complexity for LP, but also promised great performance gains in comparison to the Simplex Method. Improved variants of the method were implemented with advanced techniques for the solution of sparse linear systems at the core of every interior point method iteration, confirming some of the initial performance claims. Meanwhile, Simplex based implementations became more efficient, incorporating a number of heuristics in the basic algorithm and improved linear algebra computations. Nowadays, both the Simplex and Interior Point methods are offered side by side in a number of highly successful optimization packages. Challenges remain in implementations for parallel architectures usually dependent on implementations that explore special problem structures.

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Contributed Abstracts

Continued iteration on predictor corrector interior point method

Berti, Lilian and Oliveira, Aurelio Ribeiro Leite and Ghidini, Carla

In this work the continued iteration is used with the predictor corrector interior point method in order to reduce the total computational time that it needs to obtain a linear programming problem optimal solution. The continued iteration technique consists in determining a new direction to the method, called continued direction, computed with lower effort compared to the interior point method iteration. Although there is an computational effort increase per iteration to compute the continued iteration, the expected reduction in the number of iterations, enables to decrease the total computational time. Some continued directions are proposed. Preliminary computational experiments comparing the predictor corrector method with multiple centrality corrections, combined with the continued iteration are performed for medium to large-scale problems. The results show that the proposed technique is promising.

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An adaptive preconditioner for primal block-angular problems by an interior point method

Bocanegra, Silvana and Castro, Jordi

A specialized interior-point algorithm for some classes of primal block-angular problems solves the normal equations by a combination of Cholesky factorizations and preconditioned conjugate gradient (PCG). This preconditioner considers a few terms of an infinite power series which provides the inverse of the Schur complement of the normal equations. The more terms of the power series, the more accurate the preconditioner, at the expense of increasing the running time. The purpose of this work is to develop an adaptive scheme for the number of terms in the preconditioner at each interior point iteration. This scheme is based on Ritz values, which can be used to estimate the spectral radius of a certain matrix in the power series, which measures the efficiency of the preconditioner. When the preconditioner is not efficient enough, then extra terms should be added in the next interior point iteration. Preliminary results with this scheme will be provided.

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Interior point methods applied to predispatch with network topology manipulation covering bus and transmission lines simultaneously

Carvalho, Silvia Simões and Oliveira, Aurelio Ribeiro Leite

In this work, the interior point methods have been developed for the loss minimization in the generation and transmission of predispatch problem for a hydroelectric system with additional scheduled maneuvers and spinning reserve constraints. The resulting matrix structure is exploited aiming at a more efficient implementation. The consideration of maneuvers and spinning reserve approaches the model to real systems. The developed implementation of proposed method is compared with the predispatch version that does not consider such constraints.

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Improving the splitting preconditioner for linear systems from interior point methods

Casacio, Luciana and Oliveira, Aurelio Ribeiro Leite and Lyra, Christiano

We are concerned with the KKT systems arising when an interior point method is applied to solve large-scale linear programming problems. The choice of an effective preconditioner is essential for the success of the iterative methods approach for solving these systems. We propose a new ordering for the splitting preconditioner, taking advantage of the sparse structure of the original matrix. A formal demonstration shows that performing this new ordering, the condition number of the preconditioned matrix is limited. Case studies show that the proposed idea is competitive with direct methods because the condition number of the system is much better than the original and with the new ordering proposed, the final processing time is reduced.

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A proposal to improve the conditioning of the Splitting preconditioner in the interior points method.

Castro, Cecilia Orellana and Oliveira, Aurelio Ribeiro Leite

The primal-dual interior point methods have become a powerful tool for solving large linear programming problems. Therefore, the development of efficient implementations of these methods is required. Besides reducing the total number of iterations of the algorithm, it is interesting to investigate techniques to accelerate each iteration. In each iteration, the most expensive task is to solve a linear system to find the search direction. Currently, it is usual to work with hybrid approaches to solve this system using iterative methods. In this work, we use the Controlled Cholesky Factorization preconditioner and then the Splitting preconditioner. It is proposed a modification to the choice of the base of the Splitting preconditioner in order to improve the number of condition of the preconditioned matrix and, thus obtain a better performance of the conjugate gradient method. Numerical experiments with this approach are presented.

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Relaxation by Modified Logarithmic Barrier Applied to the Problem of Optimal Power Flow DC with Overload

Coelho, Mayk and Oliveira, Aurelio Ribeiro Leite and Santos Jr., Anésio

The primal-dual Interior Point Methods when applied to optimal power flow problems achieve great results. However, when the system presents overloads in generation and/or transmission, it does not converge due to operating limits violations from the overloads, since some variables cease to be interior for feasible points. In order to eliminate these difficulties a barrier function modification is proposed, replacing the classical logarithmic barrier one by the modified logarithmic barrier. This modification allows for controlled violation in some inequality constraints and can be used in solving problems such as the optimal power flow system with overloads. In practice, such violations can be performed in a short period of time without damaging the system. Finally, computational tests are performed simulating overloaded systems leaving to good results both in time and quality of solution.

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A first order interior point algorithm for solving continuous Knapsack optimization problems.

Gonzalez-Lima, Maria and Guevara, Esnil

An algorithm for solving convex quadratic optimization problems with continuous Knapsack constraints is presented. It is based on a primal-dual interior-point method but the search direction is obtained by approximating the Hessian of the objective function by a multiple of the identity matrix. It is well suited for problems where this Hessian is large and dense. Numerical results for Support Vector Machines (SVM) problems will be included.

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A new proposal to modify the controlled Cholesky factorization to improve the interior point method.

Heredia, Manolo Rodriguez and Oliveira, Aurelio Ribeiro Leite

The interior-points methods find optimal solutions by applying Newton's method to the KKT optimality conditions to find the search directions in linear programming problems. However, this implies a resolution of ill-conditioned linear systems. Preconditioned linear systems are used in order to improve the spectral properties of the linear system matrix and thus to obtain an efficient implementation. A preconditioner used in the solution of these systems is the Controlled Cholesky Factorization. We propose a change in the Controlled Cholesky Factorization to reduce the computational time in solving linear systems. This proposal modifies the calculation of the correction parameter when failures occur on the diagonal and reduces the number of restarts during construction of the preconditioner. The improvement obtained using this new modification will be presented in numerical experiments with large-scale problems.

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Interior Point Methods Applied to Basis Pursuit

Kikuchi, Paula Aparecida and Cantane, Daniela Renata and Oliveira, Aurelio Ribeiro Leite

There are many proposed methods for signal reconstruction. However, our focus is on the Basis Pursuit method. When working with overcomplete dictionaries, there exist countless possible combinations to represent the signal. Basis Pursuit finds the sparsest, because it minimizes the sum of the combination coefficients absolute values, i.e., it minimizes the coefficients on norm 1. We will see that the problem in question can be rewritten as a linear programming problem. An existing method is shown for the solution of this problem, the Primal-Dual Logarithmic Barrier Method. Seeking higher efficiency, we will include the affine scaling direction, the centering direction and the nonlinear correction direction in the same method, obtaining the Predictor-Corrector Primal-Dual Logarithmic Barrier Method, of which a variation is also implemented. Computational results with real life problems show the efficiency of the proposed method.

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Interior-Point methods like as an alternative to estimate the context-free grammar parameters

López, Esther Sofia Mamián and Oliveira, Aurelio Ribeiro Leite and Robayo, Fredy Angel Amaya

Natural Language Process (NLP) is an important investigation field. One of its line of research is text parsing. There are many different approaches for parsing work, which consists on a formal analysis by a computer of a sentence or other string of words into its constituents, resulting in a parse tree showing their syntactic relation to each other. The stochastic Free-Context Grammar (SFCG) is a statistical model to syntactic analysis. A SFCGs extend context-free grammars, where each production is assigned a probability. The process to its estimate is called learning grammar which is an automatic process. Usually, the Inside-Outside algorithm is employed to perform such estimations. However, it is limited in practice by its O(n3) complexity. We propose to use an approach based in interior point methods as an lternative to estimate the probabilities rules. We present some results of SFCG estimation when using such methods.

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Nonlinear medium-term hydro-thermal scheduling with transmission constraints

Martins, Leonardo and Azevedo, Anibal and Soares, Secundino

A nonlinear model for medium-term hydro-thermal scheduling problems with transmission constraints is presented. A nonlinear formulation of hydro power production functions of discharge and storage is used for proper representation of head variation in cascaded reservoirs. Transmission networks are formulated as a direct-current power flow model with support for load attainment over multiple levels representing peak and off-peak hours, enabling varying degrees of both network topology and load balance nodes representation over time stages. Computational tests with large case studies are presented.

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The advantages of interior point methods for decomposition techniques

Munari, Pedro

Decomposition techniques are essential tools for solving challenging large-scale optimization problems. There is a number of problems in the field of integer programming and nonlinear optimization that can only be effectively solved after applying a technique such as Dantzig-Wolfe or Benders decomposition. Most implementations are based on the simplex method to obtain optimal solutions of linear relaxations. However, as it has been shown by a few researchers, interior point methods (IPM) can offer several advantages to improve the performance of decomposition algorithms. The central solutions provided by IPM can be useful to stabilize the behavior of decomposition algorithms and speed up the running time of the implementations. In this talk, we review the main strategies proposed for combining IPM and decomposition techniques and summarize their results. In addition, we present new results that indicate the positive impact of such combinations for solving vehicle routing problems.

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A new predictor-corrector method for optimal power flow

Probst, Roy Wilhelm

A predictor-corrector interior-point method is developed in order to deal with the AC active and reactive optimal power flow problem. Voltage rectangular coordinates are adopted instead of polar ones, since they allow nonlinear corrections for the primal and dual feasibility conditions and not only for the complementary constraints as in the traditional nonlinear programming methods. A new heuristic is proposed to handle voltage magnitude constraints. Computational experiments for IEEE test systems and a real Brazilian system are presented and show the advantages of the proposed approach.

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Optimal Choice of parameters in Interior Point Methods

Santos, Luiz Rafael and Villas-Bôas, Fernando and Oliveira, Aurelio Ribeiro Leite and Perin, Clovis

We propose a predictor-corrector interior point method for linear programming in a primal-dual context, where the next iterate is chosen by the minimization of a polynomial merit function of three variables: the first one is the step length, the second one defines the central path and the last one models the weight that a corrector direction must have. The merit function minimization is performed by restricting it to constraints defined by a neighborhood of the central path that allows wide steps. In this framework, we combine different directions, such as the predictor, the corrector and the centering directions, with the aim of producing a better direction. The proposed method generalizes most of predictor-corrector interior point methods, depending on the choice of the variables described above. Convergence analysis of the method is carried out as well as numerical experiments, which show that this approach is competitive when compared to well established solvers, such as PCx.

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A Modified Barrier Method for An Optimal Power Flow Problem

Silva, Iara

The purpose of this work is to present a method by the nonlinear rescaling principle. Given a nonlinear optimization problem, this principle relaxes and rescales its inequality constraints resulting in an equivalent problem. The inequality constraints are rescaled by Modified Logarithmic Barrier Function. The qualities of this method over Classical Barrier methods are mentioned in this work. The proposed method is applied to optimal power flow is a nonlinear and non-convex problem. The efficiency of this method and its accuracy are verified by experiments with IEEE electrical test systems.

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A Comparison Among Simple Algorithms for Linear Programming

Silva, Jair and Ghidini, Carla and Oliveira, Aurelio Ribeiro Leite and Velazco, Marta

This work presents a family of simple algorithms for linear programming and a comparison between this family and the optimal pair adjustment algorithm. The optimal pair adjustment algorithm is based on the von Neumann's algorithm which is a very attractive algorithm due to its simplicity. The optimal pair adjustment algorithm was developed as an improvement to the convergence of the von Neumann's algorithm. The family of simple algorithms results from the generalization of the optimal pair adjustment algorithm, including a parameter on the number of chosen columns instead of just a pair. Such generalization preserves the simple algorithms nice features. We present a geometric view of the family of simple algorithms, sufficient conditions for the family of algorithms has better performance that von Neumann's algorithm and significant improvements over the optimal pair adjustment algorithm were demonstrated through numerical experiments on a diverse set of linear programming problems.

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Improvement in the preconditioning of Linear Systems from IPM by the Modified Controlled Cholesky Factorization

Silva, Lino and Oliveira, Aurelio Ribeiro Leite

Preconditioners from Incomplete Cholesky Factorization like Controlled Cholesky Factorization are very important in the Interior Point Method because they play a fundamental role on hybrid approaches of preconditioning with the splitting preconditioner. However, the building of this kind of preconditioner can be affected by breakdowns during the process of factorization. It occur when small or negative pivot are found. In general, when this occur, the diagonal of the matrix is increased by a positive number and the incomplete factorization is restarted. This technique works well to many linear programming problems but the CPU time of solving them can be increased by this approach. In this work we propose a modification in the CCF to deal with breakdowns. The restart of the Incomplete Cholesky factorization can be allowed if the column number where the fail occur is not big. In opposite case, the columns previously calculated are updated and the restart is not allowed.

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A Hibrid Iterative approach for solving the linear systems from interior point methods

Silva, Marilene and Ghidini, Carla and Oliveira, Aurelio Ribeiro Leite

In this work, we consider the predictor-corrector method, which is one of the most importante variants of interior point methods due to its efficiency and fast convergence. In the predictor-corrector method, we must solve two linear systems at each iteration to determine the predictor-corrector direction. The solution of these systems is the step that requires more processing time and should therefore be performed efficiently. For the solution of linear systems two Krylov subspace methods are considered: MINRES and the conjugate-gradient method. For these methods a preconditioner specially developed for linear systems arising from interior point methods is used. Computational experiments on a set of linear programming problems were performed in order to analyse the efficiency and robustness of the methods when solving such linear systems.

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A New Approach for Finding a Base for the Splitting Preconditioner for Linear Systems from Interior Point Methods

Suñagua, Porfirio and Oliveira, Aurelio Ribeiro Leite

The class of splitting preconditioners for the iterative solution of linear systems arising from Mehrotra's predictor-corrector method for large-scale linear programming problems needs to find a base through a sophisticated process based on the application of a rectangular LU factorization. This class of splitting preconditioners works better near a solution of the linear programming problems when the matrices are highly ill-conditioned. In this study, we develop and implement a new pproach to find a basis for the splitting preconditioner, based on standard rectangular LU factorization with partial permutation of the linear programming scaled transpose constraint matrix. In most cases, this basis is better conditioned than the existing one. In addition, we develop the penalty parameter in Mehrotra's predictor-corrector method in order to reduce ill-conditioning of the normal equations matrix. The success of this approach is guaranteed by the proof of the theorem of convergence of mixed penalty with the barrier parameter. Computational tests show a reduction in the average number of iterations of the preconditioned conjugate gradient method. Also, the increased efficiency and robustness of the new approach is evident by the performance profile.

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Using Controlled Cholesky Factorization in the Normal Equations System Direct Solution from the Interior Point Methods

Tsuchiya, Luciana Yoshie and Oliveira, Aurelio Ribeiro Leite

The most common approach used to solve the normal equations system arising from interior point methods Primal Dual is the direct resolution using the Cholesky factorization of the system. When factoring becomes extremely expensive, due to the number of generated non-zero entries, the use of iterative methods for solving the system, as the preconditioned conjugate gradient method, becomes more appropriate. A preconditioner which can be used is controlled Cholesky factorization (CCF), which is a kind of incomplete Cholesky factorization. In this work, we replace the Cholesky factorization in the linear system direct solution by CCF, in order to reduce both processing time and required storage. In the early iterations, an approximate direction of the original direction is obtained using a very sparse matrix from CCF, speeding up the linear system solution. In later iterations we compute a CCF closer to the full Cholesky, in such a way that the convergence of method is not affected.

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Variants of preconditioned conjugate gradient methods applied to linear systems arising from interior point methods

Velazco, Marta and Oliveira, Aurelio Ribeiro Leite and Coelho, Alessandro

The searching directions in interior-point method are computed through the solution of one or more linear systems. Such systems can be reduced to a positive-definite system called normal equations. Generally, the normal equations systems are solved by direct methods. However, for some classes of large-scale problems, iterative approaches are recommended. The classical approach adopted to solve the normal equations system is the preconditioned conjugate gradient method. This work discusses two preconditioned versions of the conjugate gradient method for solve normal equations system: Preconditioned Conjugate Gradient-Normal Residual and Preconditioned Conjugate Gradient-Normal Error. These versions consider the linear system in form of normal equations. The performances of the preconditioned conjugate gradient versions are compared with the classic one and the results are analyzed using performance profille. The result shows that one of these versions is competitive with the classic one.

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A polynomial oriented IPM framework for infeasible iterates

Villas-Bôas, Fernando and Oliveira, Aurelio Ribeiro Leite and Perin, Clovis and Santos, Luiz Rafael

In our research, we propose and implement a homotopy continuation method for linear programming problems that generalizes the central path and its neighborhoods for infeasible points in a mathematically symmetrical way. In this IPM framework, directions and steplenghts are polynomials of the real variables (α, μ, σ) , where α is the steplenght, μ is the homotopy parameter and σ models the corrector weight in a predictor-corrector method. Such polynomial framework takes into account numerical issues in the problem's data and allows for the definition of both a polynomial merit function and a neighborhood that can be analytically replaced by the intersection of $O(n)$ polynomial constraints of degree 2. This way, choosing the "best" direction and steplenght comes down to minimizing a polynomial merit function subject to $O(n)$ polynomial constraints of degree 2. Finally, each of these optimization subproblems is analytically solved with little computation effort by exploiting the structure of the set of constraints. The computation results for the entire Netlib problem set had a CPU time of less than 2 times that of PCx, compiled under equal conditions, obtaining the same rate of success.

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Program

Monday 27/04

8:45	**Oppening**
9:00	**Plenary Conference I (Chair: Christiano Lyra)** *A Brief History of Computational Linear Programming* Prof. Geraldo Veiga
10:00	**Cofee-break**
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10:30	*Optimal Choice of parameters in Interior Point Methods* Luis Rafael Santos
10:50	*A polynomial oriented IPM framework for infeasible iterates* Fernando Villas-Bôas
11:10	*The advantages of interior point methods for decomposition techniques* Pedro Munari
11:30	*Interior Point Methods Applied to Basis Pursuit* Paula Aparecida Kikuchi
11:50	*Interior-Point methods like as an alternative to estimate the context-free grammar parameters* Esther Sofia Mamián López
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14:20	*A new proposal to modify the controlled Cholesky factorization to improve the interior point method.* Manolo Rodriguez Heredia
14:40	*Using Controlled Cholesky Factorization in the Normal Equations System Direct Solution from the Interior Point Methods* Luciana Yoshie Tsuchiya
15:00	*An adaptive preconditioner for primal block-angular problems by an interior point method* Silvana Bocanegra
15:20	*Variants of preconditioned conjugate gradient methods applied to linear systems arising from interior point methods* Marta Velazco
15:40	*A Hibrid Iterative approach for solving the linear systems from interior point methods* Marilene Silva
16:00	**Cofee-break**
16:30	**Plenary Conference II (Chair: Aurelio Oliveira)** *Large-scale optimization with BlockIP, a specialized IP solver for block-angular problems* Prof. Jordi Castro

Tuesday 28/04

09:00	**Plenary Conference III (Chair: Daniela Cantane)** *Solving the normal equations system arising from interior point methods for linear programming by iterative methods* Aurelio Oliveira
10:00	**Cofee-break**
	Contributed Section III (Chair: Anibal Azevedo)
10:30	A new predictor-corrector method for optimal power flow Roy Wilhelm Probst
10:50	*Relaxation by Modified Logarithmic Barrier Applied to the Problem of Optimal Power Flow DC with Overload* Mayk Coelho
11:10	*Interior point methods applied to predispatch with network topology manipulation covering bus and transmission lines simultaneously* Silvia Simões Carvalho
11:30	*Nonlinear medium-term hydro-thermal scheduling with transmission constraints* Leonardo Martins
11:50	*A Modified Barrier Method for An Optimal Power Flow Problem* Iara Silva
12:10	**Lunch**
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14:20	*A first order interior point algorithm for solving continuous Knapsack optimization problems.* Maria Gonzalez-Lima
14:40	*Continued iteration on predictor corrector interior point method* Lilian Berti
15:00	*A proposal to improve the conditioning of the Splitting preconditioner in the interior points method.* Cecilia Orellana Castro
15:20	*Improving the splitting preconditioner for linear systems from interior point methods* Luciana Casacio
15:40	*A New Approach for Finding a Base for the Splitting Preconditioner for Linear Systems from Interior Point Methods* Porfirio Suñagua
16:00	**Cofee-break**
16:30	**Plenary Conference IV (Chair: Pedro Munari)** *Inexact search directions in interior point methods for very large-scale optimization* Prof. Jacek Gondzio
17:30	**FAPESP Project Meeting**