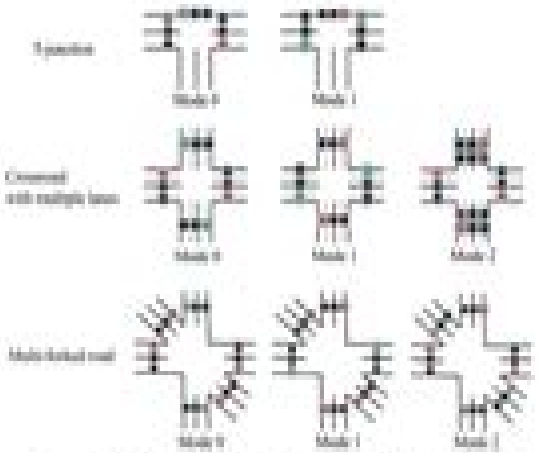
Traffic Signal Optimization using Quantum Annealing

Intersection State Definitions

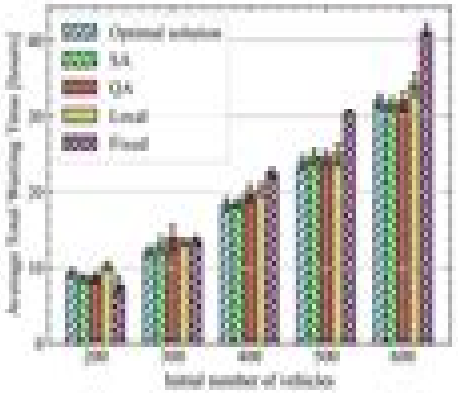


QUBO Formulation

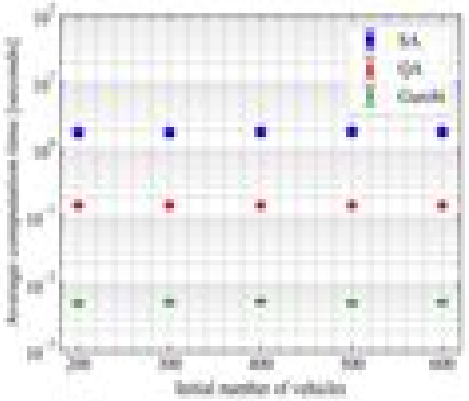
$$\min_{\vec{x}} H(\vec{x}) := -\sum_{i,m} C_{im} x_{im} - \beta \sum_{i,m,j,n} B_{ij} R_{im,jn} x_{im} x_{jn} - \gamma \sum_{i} \left(\sum_{m} x_{im} - 1 \right)^2$$

Results

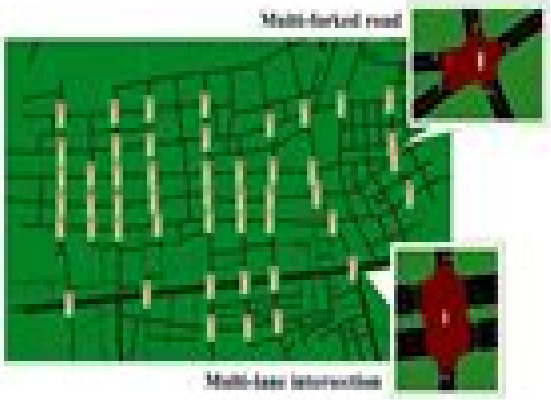
Total Waiting Time



Computation Time



Real-World Map Used in Simulation



- **Efficient Traffic Signal Optimization:**
  The QUBO model reduces vehicle waiting times at complex intersections, achieving a reduction of up to 28.9% in high-traffic scenarios.

- **Quantum vs. Classical Solver Performance:**
  Owing to hardware limitations, D-Wave quantum annealer is currently less accurate and slower than classical solvers such as Gurobi.

Quadratic Unconstrained Binary Formulation for Traffic Signal Optimization on Real-World Maps
Reo Shikanai | Journal of the Physical Society of Japan | DOI:10.7566/JPSJ.94.024001

Journal of the Physical Society of Japan

Topics In Optimization

Kohei Arai,Rahul Bhatia,Supriya Kapoor

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Intelligent Computing Kohei Arai,Rahul Bhatia,Supriya Kapoor,2019-06-22 This book presents the proceedings of the Computing Conference 2019 providing a comprehensive collection of chapters focusing on core areas of computing and their real world applications Computing is an extremely broad discipline encompassing a range of specialized fields each focusing on particular areas of technology and types of application and the conference offered pioneering researchers scientists industrial engineers and students from around the globe a platform to share new ideas and development experiences Providing state of the art intelligent methods and techniques for solving real world problems the book inspires further research and technological advances in this important area **Computer Engineering on Overview : Elective** Mohammed Ridha,Abdullah ridha,Nanh Ridha,2020-05-30 I explained the optional or secondary topics for the Department of Computer Engineering but they are also necessary in the near future and also important for students of higher studies to obtain preliminary information on OPTIMIZATION WEB PROGRAMMING MOBILE PROGRAMMING BASICS OF COMPUTER VISION DEEP LEARNING BIG DATA DATA MINING AND ARTIFICIAL INTELLIGENCE Introduction to Methods for Nonlinear Optimization Luigi Grippo,Marco Sciandrone,2023-05-27 This book has two main objectives to provide a concise introduction to nonlinear optimization methods which can be used as a textbook at a graduate or upper undergraduate level to collect and organize selected important topics on optimization algorithms not easily found in textbooks which can provide material for advanced courses or can serve as a reference text for self study and research The basic material on unconstrained and constrained optimization is organized into two blocks of chapters basic theory and optimality conditions unconstrained and constrained algorithms These topics are treated in short chapters that contain the most important results in theory and algorithms in a way that in the authors experience is suitable for introductory courses A third block of chapters addresses methods that are of increasing interest for solving difficult optimization problems Difficulty can be typically due to the high nonlinearity of the objective function ill conditioning of the Hessian matrix lack of information on first order derivatives the need to solve large scale problems In the book various key subjects are addressed including exact penalty functions and exact augmented Lagrangian functions non monotone methods decomposition algorithms derivative free

methods for nonlinear equations and optimization problems The appendices at the end of the book offer a review of the essential mathematical background including an introduction to convex analysis that can make part of an introductory course

Neural Information Processing Sabri Arik,Tingwen Huang,Weng Kin Lai,Qingshan Liu,2015-12-08 The four volume set LNCS 9489 LNCS 9490 LNCS 9491 and LNCS 9492 constitutes the proceedings of the 22nd International Conference on Neural Information Processing ICONIP 2015 held in Istanbul Turkey in November 2015 The 231 full papers presented were carefully reviewed and selected from 375 submissions The 4 volumes represent topical sections containing articles on Learning Algorithms and Classification Systems Artificial Intelligence and Neural Networks Theory Design and Applications Image and Signal Processing and Intelligent Social Networks *TOPICS IN OPTIMIZATION (Volume 31).* G LEITMANN (ED.),1967 **Genre Analysis and Corpus Design** Ulrike Henny-Krahmer,2024-01-22 This work in the field of digital literary stylistics and computational literary studies is concerned with theoretical concerns of literary genre with the design of a corpus of nineteenth century Spanish American novels and with its empirical analysis in terms of subgenres of the novel The digital text corpus consists of 256 Argentine Cuban and Mexican novels from the period between 1830 and 1910 It has been created with the goal to analyze thematic subgenres and literary currents that were represented in numerous novels in the nineteenth century by means of computational text categorization methods To categorize the texts statistical classification and a family resemblance analysis relying on network analysis are used with the aim to examine how the subgenres which are understood as communicative conventional phenomena can be captured on the stylistic textual level of the novels that participate in them *Technometrics* ,2005 **Statistical Learning and Data Sciences** Alexander Gammerman,Vladimir Vovk,Harris Papadopoulos,2015-04-02 This book constitutes the refereed proceedings of the Third International Symposium on Statistical Learning and Data Sciences SLDS 2015 held in Egham Surrey UK April 2015 The 36 revised full papers presented together with 2 invited papers were carefully reviewed and selected from 59 submissions The papers are organized in topical sections on statistical learning and its applications conformal prediction and its applications new frontiers in data analysis for nuclear fusion and geometric data analysis *Practical Optimization* Andreas Antoniou,Wu-Sheng Lu,2007-03-12 Practical Optimization Algorithms and Engineering Applications is a hands on treatment of the subject of optimization A comprehensive set of problems and exercises makes the book suitable for use in one or two semesters of a first year graduate course or an advanced undergraduate course Each half of the book contains a full semester s worth of complementary yet stand alone material The practical orientation of the topics chosen and a wealth of useful examples also make the book suitable for practitioners in the field **Secure Knowledge Management In The Artificial Intelligence Era** Ram Krishnan,H. Raghav Rao,Sanjay K. Sahay,Sagar Samtani,Ziming Zhao,2022-02-22 This book constitutes the refereed proceedings of the 9th International Conference On Secure Knowledge Management In Artificial Intelligence Era SKM 2021 held in San Antonio TX USA in 2021 Due to the COVID 19 pandemic the conference was held

online The 11 papers presented were carefully reviewed and selected from 30 submissions They were organized according to the following topical sections intrusion and malware detection secure knowledge management deep learning for security web and social network Introduction to Linear Systems Analysis Robert Grover Brown,James William Nilsson,1962

Nonlinear Optimization and Related Topics Gianni Pillo,F. Giannessi,2013-06-29 This volume contains the edited texts of the lectures presented at the Workshop on Nonlinear Optimization held in Erice Sicily at the G Stampacchia School of Mathematics of the E Majorana Centre for Scientific Culture June 23 July 2 1998 In the tradition of these meetings the main purpose was to review and discuss recent advances and promising research trends concerning theory algorithms and innovative applications in the field of Nonlinear Optimization and of related topics such as Convex Optimization Nonsmooth Optimization Variational Inequalities and Complementarity Problems The meeting was attended by 83 people from 21 countries Besides the lectures several formal and informal discussions took place The result was a wide and deep knowledge of the present research tendencies in the field We wish to express our appreciation for the active contribution of all the par ticipants in the meeting Our gratitude is due to the Ettore Majorana Centre in Erice which offered its facilities and rewarding environment its staff was certainly instrumental for the success of the meeting Our gratitude is also due to Francisco Facchinei and Massimo Roma for the effort and time devoted as members of the Organising Committee We are indebted to the Italian National Research Council and in particular to the Group on Functional Analysis and its Applications and to the Committees on Engineering Sciences and on Information Sciences and Technolo gies for their financial support Finally we address our thanks to Kluwer Academic Publishers for having offered to publish this volume University of Colorado at Denver Catalog University of Colorado at Denver,2009 **INFORMS Annual Meeting** Institute for Operations Research and the Management Sciences. National Meeting,2005 **EDRA; Proceedings of the Annual Environmental Design Research Association Conference** Environmental Design Research Association,1969 **Topics in Convex Optimization for Machine Learning** Youngsuk Park,2020 Convex optimization has been well studied as a mathematical topic for more than a century and has been applied in practice in many application areas for about a half century in fields including control finance signal processing data mining and machine learning This thesis focuses on several topics involving convex optimization with the specific application of machine learning **Cornell University Courses of Study** Cornell University,2007

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