

CEOC

Centro de Estudos em Optimização e Controlo
(Centre for Research in Optimization and Control)

Computability and Algorithms

Scientific Reports 2003-2005

Universidade de Aveiro
Departamento de Matemática

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Scientific report 2003

1. Computability and Algorithms

1.1 Activities during 2003

1. Complexity Theory.

Previous work on two-dimensional compaction has been published in 2003 in an international journal with referee.

Also during the year of 2003 a PhD dissertation was concluded and submitted (approved May 2004 on the classification of instances of NP-hard Problems, in terms of their computational cost.

2. Computational Geometry.

Our research interest in 2003 was the study of art gallery and illumination problems in order to build approximation algorithms. We developed an anytime algorithm to compute successively better approximations of the optimum to minimum vertex guard. An experimental evaluation of the algorithm has been done, in which standard computational geometry algorithms and constraint programming techniques are used in a hybrid way. We also started research work on methods for generating random polygons. Besides its manifest theoretical interest, the generation of random geometric objects has applications that include the testing and verification of time complexity for computational geometry algorithms. We developed two different methods for generating random orthogonal polygons with a given number of vertices.

During that year, 3 MSc dissertations were supervised, a local seminar and 2 communications in international conferences were presented. Also a book chapter and a paper in a conference proceedings, both international and with referees, were published.

3. Quantum Computation.

Subsequent to previous work on Computer Arithmetic, along 2002 and 2003, joint research was developed together with members of the control

theory group from CEOC. This has resulted on the publication in 2004 of two papers in an international journal with referee.

Also during 2003 a PhD project was prepared (and started October 2003) in the area of quantum computation. Preliminary reading resulted in the publication of a report and a local seminar on Shor's Algorithm.

Research work on quantum arithmetic started with the design of a $\mathcal{O}(1)$ adder, which explores the use of redundant number systems under the quantum paradigm.

1.2 Output indicators

Number of Publications	2003
Books	0
Papers in international journals	2
Papers in national journals	1
Number of Communications	
in International Meetings	2
in National Meetings	0
Reports	0
Organization of seminar and conferences	3
Advanced training	
number of PhD theses	0
number of Master theses	0

1.3 List of publications

- **Articles in International Journals (including book chapters)**

1. A.M. Almeida and R. Rodrigues, "Trees, Slices and Wheels: On the Floorplan Area Minimization Problem", NETWORKS, vol 41(4), (2003), 235-244.
2. A. P. Tomás, A. L. Bajuelos and F. Marques, "Approximation Algorithms to Minimum Vertex Cover Problems on Polygons and Terrains", LNCS 2657, Springer-Verlag,(2003), 869-878.

- **Articles in National Journals (including book chapters)**

1. A. F. Pereira e M. R. D. Rodrigues, "O Problema das Torres de Hanoi: a lenda, algoritmos e generalizações", Gazeta de Matemática, n. 144, Janeiro de 2003, 8-16.

1.4 List of talks

- **Talks at International Conferences**

1. Antonio Leslie Bajuelos, “Approximation algorithms to minimum vertex cover problems on polygons and terrains”, ICCS 2003, June 2-4, St. Petersburg, Russia.
2. Antonio Leslie Bajuelos, “Approximation algorithms to minimum vertex cover problems on polygons”, X EGC, June 16-17, 2003, Seville, Spain.

1.5 List of organized seminars and conferences

- **Organized seminars**

1. Ana Paula Tomás, “Geração de Polígonos Ortogonais”, Seminários do CEOC, December 5, 2003, Universidade de Aveiro.
2. António Pereira, “Uma Introdução à Computação Quântica”, Seminários do CEOC, October 24, 2003, Universidade de Aveiro.
3. Miguel Calejo, “Web Application Maker - a declarative web database tool”, Seminários do CEOC, October 17, 2003, Universidade de Aveiro.

Scientific report 2004

2. Computability and Algorithms

2.1 Activities during 2004

1. Complexity Theory.

A PhD dissertation was completed, on the Classification of Instances of NP-hard Problems in terms of their computational cost.

- Ana Maria Carvalho de Almeida, “ Uma Digressão em NP: como avaliar a complexidade de uma instância”, Departamento de Matemática, Universidade de Coimbra, 18 de Maio de 2004

2. Computational Geometry.

Our research interest in 2004 was the study of Art Gallery and Illumination Problems to find algorithms that obtain approximate solutions. We propose an anytime algorithm to compute successively better approximations of the optimum to MINIMUM VERTEX GUARD (MVG) problem, where the goal is to find the minimum number of vertex guards that are necessary to completely guard a given polygon. An experimental evaluation of the algorithm is being done, in which standard Computational Geometry Algorithms and Constraint Programming techniques will be used in an hybrid way.

3. Quantum Computation.

Under the topic of Quantum Arithmetic Circuitry, a class of $O(1)$ adders for quantum redundant computation was developed and reported. A paper on a special class of very efficient quantum adders was prepared, submitted and approved for presentation in an international conference to be held in 2005.

We started joint research work with the Quantum Computation Group of the Departamento de Matemática Aplicada, E. U. Informática, Universi-

dad Politécnica de Madrid, Spain. Quantum algorithms for the division are under development (to be concluded in 2005).

We are working on the theoretical definition of a universal set of simple quantum base gates under the redundant qudit paradigm. The problem of quantum circuit minimization is also being considered.

A beta version of a symbolic quantum algorithm simulator was developed and subsequently tested with Grover's database algorithm. The test results were very promising and we are expecting to achieve a stable first release during 2005.

2.2 Output indicators

Number of Publications	2004
Books	0
Papers in international journals	5
Papers in national journals	0
Number of Communications	
in International Meetings	2
in National Meetings	0
Reports	2
Organization of seminar and conferences	4
Advanced training	
number of PhD theses	1
number of Master theses	1

2.3 List of publications

- **Articles in International Journals (including book chapters)**

1. A. Pereira, R. Rodrigues, "Minimal Convergence Conditions for Multiplicative Normalization Division", *Journal of Mathematical Sciences (Series of Contemporary Mathematics and Its Applications, Special volume "Aveiro Seminar on Control, Optimization, and Graph Theory")*, N.Y. (USA), Vol. 120, N. 1, (2004):.
2. Eugénio Rocha, A.Sarychev, A.Pereira, R.Rodrigues. Control-theoretic methods for design of algorithms of digital arithmetic. *Journal of Mathematical Sciences (Series of Contemporary Mathematics and Its Applications, Special volume "Aveiro Seminar on Control, Optimization, and Graph Theory")*, N.Y. (USA), Vol. 120, N. 1, (2004): 995-1005.
3. Bajuelos A. L., Tomás, A. P., Marques F. Partitioning Orthogonal Polygons by Extension of All Edges Incident to Reflex Vertices: lower and upper bounds on the number of pieces, LNCS 3045, Springer-Verlag, Berlin (Germany), (2004): 127-136.

4. Tomás A. P., Bajuelos A. L.: Quadratic-Time Linear-Space Algorithms for Generation Orthogonal Polygons with a Given Number of Vertices, LNCS 3045, Springer-Verlag, Berlin (Germany), (2004): 117-126.
5. Tomás A. P., Bajuelos A. L.: Generating Random Orthogonal Polygons, LNCS 3040, Springer-Verlag, Berlin (Germany), (2004): 364-373.

2.4 List of talks

- **Talks at International Conferences**

1. Antonio Leslie Bajuelos: Quadratic-time, linear-space algorithms for generating orthogonal polygons with a given number of vertices, 20th European Workshop on Computational Geometry, March, 24-26, 2004, Seville Spain.
2. Antonio Leslie Bajuelos: Partitioning orthogonal polygons by extension of all edges incident to reflex vertices: lower and upper bounds on the number of pieces, Workshop on Computational Geometry and Applications, ICCSA 2004, May, 14-17, 2004, Assisi, Italy.

- **Talks at National Conferences**

1. None in 2004.

- **Seminars**

1. R. Rodrigues, “CC - Complicações Computacionais”, Ciclo de Conferências em Matemática, Departamento de Matemática, Universidade de Aveiro, Abril 2004.
2. A. Pereira, “Um passeio no mundo dos quantas”, Departamento de Engenharia Informática da Universidade de Coimbra, UI&D CISUC - Centro de Informática e Sistemas da Universidade de Coimbra, March 2004.
3. A. Pereira, “On Redundant Quantum Arithmetic”, Dep. de Matemática Aplicada, E. U. Informática, Universidad Politécnica de Madrid, Spain, November 2004.

2.5 List of reports (including proceedings)

- 1. A. Pereira and R. Rodrigues, “An $O(1)$ Adder for Quantum Arithmetic”, Cadernos de Matemática CM04/I-13, Dep. de Matemática, Univ. Aveiro, April 2004.
 2. A. Pereira e R. Rodrigues, “O Algoritmo Quântico de Shor para o Problema da Factorização”, Cadernos de Matemática CM04D/04, Dep. de Matemática, Univ. Aveiro, June 2004

2.6 List of organized seminars and conferences

- **Organized seminars**

1. Pedro Quaresma de Almeida (Universidade de Coimbra), "Sistemas de Dedução - Provadores Automáticos de Teoremas", April 16, 2004, Universidade de Aveiro.
2. Fábio Marques (Escola Superior de Tecnologia de Águeda), "Minimização do Número de Vigilantes em Galerias de Arte por Aproximações Sucessivas", October 22, 2004, Universidade de Aveiro.
3. Manuel Abellhanas (Universidade Politécnica de Madrid), "Geometric graphs: some problems and applications", November 12, 2004, Universidade de Aveiro.
4. Sandra Pinto, "Álgebras de Boole Monádicas", December 10, 2004, Universidade de Aveiro.

2.7 List of PhD and MSc dissertations

- **PhD dissertations**

1. Ana Maria Carvalho de Almeida, " Uma Digressão em NP: como avaliar a complexidade de uma instância", (supervised by Rosália Rodrigues), Departamento de Matemática, Universidade de Coimbra, 18 de Maio de 2004

- **MSc dissertations**

1. Marques, F.: Minimização do Número de Vigilantes em Galerias de Arte por Aproximações Sucessivas, (supervised by Ana P. Tomás and Antonio L. Bajuelos), University of Porto, (2004).

Scientific report 2005

3. Computability and Algorithms

3.1 Activities during 2005

1. Complexity Theory.

Subsequent to the PhD dissertation completed in 2004 by Ana Maria de Almeida, some work is being developed on the *Classification of Instances* of NP-hard Problems in terms of their computational cost. We search for a relationship between the established *Instance Complexity Classes* and the different *Types of Heuristics*.

2. Computational Geometry.

In *Computational Geometry* there are lots of different works related to visibility or illumination but most of them cannot be applied to real life, since they deal with ideal concepts. In fact, light sources have some restrictions, for instance, they cannot illuminate an infinite number of points because their light naturally fades as the distance grows. Applying this restriction, light source in the plane can only illuminate objects within a specific range. We associate this restriction with *1-good illumination*, *Triangle-covering* or *Well-covering*, considering quality conditions for the illumination of objects. Some algorithmic strategies were implemented, in order to solve the problem of 1-well illuminating a point in $O(n)$ and another that solve the problem of 1-well illuminating a line segment in $O(n^2)$ time. This last result can be extended to polygonal lines, circumferences or any polynomial curve as long as it can be partitioned in constant time.

Also we are working and developing the concept of the *Minimum Illumination Range* (MIR) *Voronoi diagram* (or *Embracing Voronoi diagram*). The MIR *Voronoi diagram* merges the notions of proximity and convex dependency and this diagram is motivated by optimization problems on *good illumination*. We give some properties of the MIR *Voronoi diagram* in order to better understand the concept and developing two different

algorithms for computing the diagram. This is an ongoing work which is part of the PhD dissertation of Inês Matos.

As part of Ana Mafalda Martins PhD thesis, a particular type of orthogonal polygon (*grid n-ogons*) and related problems were studied. Of these problems, the *covering problems* for the particular subclasses of *grid n-ogons* (THIN and the FAT *grid n-ogons*) are the ones that motivate us more.

It was also investigated how our algorithm to compute approximate solutions of Minimum Vertex Guard (MVG) problem can be used to solve the MVG problem in which the light sources have a restricted angle of illumination (floodlight illumination problem).

Two MSc dissertations are taking place under the scientific supervision of Antonio L. Bajuelos Dominguez in the area of the Computational and Combinatorial Geometry.

Members of our sub-group have participated in the following project: "ALEN - Algorithm Engineering", Facultad de Informática da Universidad Politécnica, Madrid, Spain.

During 2005 Scientific Cooperation took place with Manuel Abellanas Oar and Gregorio Hernández (Universidad Politécnica de Madrid, Spain), Belen Palop (Universidad de Valladolid, Spain), Ferrán Hurtado (Universidad Politécnica de Cataluña, Spain) and Ana Paula Tomás (Faculdade de Ciências, Universidade do Porto, Portugal).

During 2005 Inês Matos visited (for two months and supported by the Calouste Gulbenkian grant) the Departamento de Matemática Aplicada of the Universidad Politécnica de Madrid, Spain.

3. Quantum Computation.

Under the topic *Quantum Arithmetic Circuitry*, a class of $O(1)$ adders for quantum redundant computation was accomplished. A paper on a special class of very efficient quantum adders was published in 2005 and presented in an international conference. By making use of that adder, algorithms for division are now being studied in order to achieve *sub-linear* complexity.

A general purpose *Symbolic Quantum Computation Simulator* (SQCS) is also being developed. SQCS is a *Mathematica* package for the simulation of quantum algorithms. It has been tested on most of the well-known quantum algorithms, such as Grover's database search, but can also be a useful tool in the teaching and learning of the basics of quantum computation. Existing quantum computer simulators only handle limited magnitude problems (e.g., simulation of quantum circuits with up to 30 qubits). The design and principles presented in SQCS allow for problem instances that are only limited by the amount of entanglement taking place during the simulation of an algorithm, not by the size of the underlying Hilbert space. On this work, one paper was published in 2005 and another one accepted for publication and presentation at an international conference in 2006.

3.2 Output indicators

Number of Publications	2005
Books	0
Papers in international journals	3
Papers in national journals	0
Number of Communications	
in International Meetings	5
in National Meetings	1
Reports	4
Organization of seminar and conferences	4
Advanced training	
number of PhD theses	0
number of Master theses	2

3.3 List of publications

- **Articles in International Journals (including book chapters)**

1. Abellanas M. Bajuelos A.L., Hernández G., Matos I.: "Good Illumination with Limited Visibility", in Proc. of International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2005), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, (2005): 35-38.
2. Martins A. M., Bajuelos A.: "Some properties of FAT and THIN grid n-ogons", in Proc. of International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2005), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, (2005): 361-365.
3. António Pereira, Rosália Rodrigues, "Redundant Quantum Arithmetic", *Adaptive and Natural Computing Algorithms*, Proceedings of the International Conference in Coimbra, Portugal, (Ribeiro, B., Albrecht, R.F., Dobnikar, A., Pearson, D.W., Steele, N.C., eds.), Springer Verlag, Wien (ISBN: 3-211-24934-6): 280-283, 2005.

3.4 List of talks

- **Talks at International Conferences**

1. Bajuelos A. L., "Good Illumination of Points and Line Segments with Limited Range Lights", *11th Spanish Conference on Computational Geometry (XI EGC)*, Universidad de Santander, Santander, Spain, June 27 - 29, 2005.
2. Matos I., "Good Illumination with Limited Visibility", *International Conference of Numerical Analysis and Applied Mathematics (ICNAAM 2005)*, Rhodes, Greece, September 16 - 20, 2005.

3. Bajuelos A.L., "Some properties of FAT and THIN grid n-ogons", *International Conference of Numerical Analysis and Applied Mathematics* (ICNAAM 2005), Rhodes, Greece, September 16 - 20, 2005.
4. Matos I., "Computing the MIR Point in linear time", *III Workshop on Computational Geometry*, Sedano, Spain, November, 2005.
5. António Pereira, Rosália Rodrigues, "Redundant Quantum Arithmetic", *International Conference on Adaptive and Natural Computing Algorithms*, (ICANNGA 2005), Coimbra, Portugal, March, 2005.

- **Talks at National Conferences**

1. Abellanas M. Bajuelos A.L., Hernández G., Matos I.: "Good Illumination of Points and Line Segments with Limited Range Lights", in Proc. of 11th Spanish Conference on Computational Geometry (XI EGC)", Santander, June, (2005). 231-238.

- **Seminars**

1. I. Matos, "Good illumination: a variant to the classical definition of illumination in Computational Geometry", *Seminario de Matemática Aplicada* do Departamento de Matemática Aplicada da Universidad Politécnica de Madrid, June, 2005.
2. I. Matos, "Good illumination: a variant to the classical definition of illumination in Computational Geometry", *VII Seminar on Discrete Mathematics*, Universidad de Valladolid, Spain, June, 2005.

3.5 List of reports (including proceedings)

1. M. Abellanas, A. Bajuelos, G. Hernandez, I. Matos, B. Palop, "Minimum Illumination Range Voronoi Diagrams", Proc. of 2nd International Symposium on Voronoi Diagrams in Science and Engineering (VD2005), Seoul, Korea, (2005).
2. A. M. Martins, A. L. Bajuelos, "Guarding Orthogonal Polygons: Min-Area grid n-ogons", *Cadernos de Matemática*, CM05/I-43, Universidade de Aveiro, October 2005.
3. A. Pereira, R. Rodrigues, "Symbolic Quantum Computation Simulation with Mathematica", *Cadernos de Matemática*, CM05/I-44, Universidade de Aveiro, November 2005.
4. N. Martins, A. L. Bajuelos: "Uma Classificação de Polígonos Simples", *Cadernos de Matemática*, CM05/I-53, Universidade de Aveiro, December 2005.

3.6 List of organized seminars and conferences

- **Organized seminars**

1. I. Matos, "Bem iluminar um ponto em tempo linear e o diagrama de Voronoi MIR", Seminários do CEOC, Universidade de Aveiro, November 11, 2005.
2. A. M. Oliveira Martins (Universidade Católica Portuguesa), "Algumas propriedades dos FAT e THIN grid n-ogons", Seminários do CEOC, Universidade de Aveiro October 21, 2005 .
3. Ana Paula Tomás (Universidade do Porto), "Casamentos estáveis e colocação de professores", Seminários do CEOC, Universidade de Aveiro, March 4, 2005.
4. I. Matos, "Algumas Variantes à Definição Clássica de Iluminação em Geometria Computacional", Seminários do CEOC, Universidade de Aveiro, February 25, 2005.

3.7 List of PhD and MSc dissertations

- **MSc dissertations**

1. Sylvie Lopes Marques: "Teorema da Galeria de Arte e Variantes", iv + 120 p., Universidade de Aveiro, April, 2005 (supervised by Antonio L. Bajuelos).
2. Nuno Martins: "Classificação e Partição de Polígonos Simples", v + 130p, Universidade de Aveiro, October, 2005 (supervised by Antonio L. Bajuelos).