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MCDA Research Groups

INESC Coimbra – An interdisciplinary R&D Unit with multi-criteria as the "original fabric"

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Presentation and Organization

The Institute for Systems Engineering and Computers of Coimbra (INESC Coimbra) is a non-profit R&D institute affiliated with the University of Coimbra, which is regularly evaluated by international panels in the framework of the pluri-annual financing by the Portuguese Foundation for Science and Technology. INESC Coimbra was created in 1986 as a branch of INESC, an institute at the national level with branches in the main Portuguese universities. This model evolved in the beginning of this century for the autonomy of those branches and INESC Coimbra became an autonomous institute in January 2002, having as "shareholders" the University of Coimbra (UC) and the INESC holding.

INESC Coimbra integrates presently about 75 researchers, 40 of whom holding PhD degrees in diverse science, technology and management domains, from the Faculty of Sciences and Technology (Departments of Electrical Engineering and Computers, Mathematics and Civil Engineering) of UC, the Faculty of Economics of UC, the University of Beira Interior, and the Polytechnic Institutes of Leiria (where a delegation is located), Coimbra, Setúbal, Viseu and Bragança.

According to its statutory mission, INESC Coimbra aims at contributing to the progress of scientific and technical knowledge, integrating competences in Engineering Sciences and Management Science/Operations Research within a systems engineering approach.

Since becoming an autonomous institute, INESC Coimbra has adopted a form of internal organization structured along three main axes: researchers, competences and projects. R&D clusters are dynamically formed for each project, providing a high flexibility and efficiency in assembling and managing research teams. This form of organization has revealed to be successful, given the interdisciplinary nature of the research team, leading to a high level of scientific publication, participation in projects, as well as a sustained growth of the unit (from 13 PhDs in 2003 to 40 in early 2009) achieved both by the completion of the PhD of junior researchers and the attraction of new researchers with competences in other areas (such as geographical information systems, remote sensing and computational

mechanics) thus enlarging the intervention potential into new fields.

The most distinctive feature of INESC Coimbra is the interdisciplinary nature of its activities within a systems engineering framework. The background fabric is given by the competences in operational research models and methods, namely concerning multi-objective optimization (MOO) and multi-criteria analysis (MCA), coupled with software engineering expertise to develop decision support systems that exploit those competences. Besides originating innovative theoretical and methodological work, these competences provide the ground for interdisciplinary research stemming either from specific problems in application domains (namely in energy and telecommunications) or integrative use of different methodologies.

Areas of intervention

The main intervention areas of INESC Coimbra have been:

- Decision support systems and methodologies - emphasizing multi-criteria and multi-objective models as well as dealing with imprecision/uncertainty; support for collaborative work (groupware) and negotiation processes; evaluation of efficiency in industries and services; analysis and evaluation of investment projects; optimization problems (routing, location, etc.).

- Teletraffic engineering and telecommunication networks planning - dynamic routing methods; reliability of telecom networks; traffic modeling and simulation.

- Regional and urban planning - decision aiding based on Geographical Information Systems; vehicle routing and other network optimization problems; location of infrastructures and facilities.

- Rational use of energy and energy planning - management of demand for energy; electricity consumption models; urban energy planning; energy efficiency in buildings; E3 (energy-environment-economy) studies; electricity markets; quality of service analysis in electrical networks.

In the area of telecommunications, INESC Coimbra has generated innovative work in the application of MOO programming models and methods, as well as heuristics and meta-heuristics, to dynamic routing in multimedia networks, also involving performance analysis issues. The joint work of researchers with expertise in operations research and teletraffic theory led to new MOO dynamic routing methods for multi-service networks and multi-exchange networks, hierarchical MO routing models for MPLS networks, methods for routing computation in multimedia networks, and application of a k-quickest path algorithm to Internet packet routing. On the other hand, this application domain led to the development of algorithmic advances for MOO shortest path problems using labeling schemes and automated reference point-like approaches, for calculating the most reliable pair of

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disjoint paths in a network, and for the computation of the k-quickest paths.

In the energy domain a strong emphasis has been placed on issues dealing with energy efficiency and rational use of energy. MCA models and methods for the evaluation of energy efficiency actions have been proposed. Novel MOO optimization models based on genetic algorithms / evolutionary programming have been developed for the design and choice of remote load control actions and power factor compensation in distribution networks. This R&D effort fostered by applications led to the development of innovative methodological work in evolutionary programming, namely related with adaptive parameters and robustness analysis. Also, a stream of research has been pursuit dealing with MOO models for the study of energy-environment-economy interactions based on input-output analysis by combining expertise of economics and energy systems. This cross-fertilization is also displayed in the methodological work on electricity markets and market integration.

Application problems in regional and urban planning fostered the development of methodological work coupling MCA with Geographic Information Systems (GIS) for decision support. On the other hand, GIS tools are used to facilitate the practical understanding of vehicle routing, infrastructures and facility location problems, and the implementation of network optimization methods.

Regarding MOO/MCA software packages have been developed for MOLP (such as the interactive environments TRIMAP, TOMMIX and SOMMIX), for MO mixed integer LP, for performance aggregation using additive value function (VIP - Variable Interdependent Parameters for multi-criteria choice problems) and interactive robustness analysis and parameters' inference for multi-criteria sorting problems (IRIS). Some downloadable demo versions are available at http://www.inescc.pt/ingles/produtos.php.

International cooperation

Besides other less formalized R&D cooperation projects in several topics with colleagues in European and (North and South) American universities, INESC Coimbra is involved in the COST Action "Algorithmic decision theory" (www.algodec.org) as well as in the Decision Deck project (www.decision-deck.org/). INESC Coimbra 's researchers have also a very active role in the initiative Energy for Sustainability of the University of Coimbra, which is integrated in the MIT – Portugal Program (www.mitportugal.org).

The organization of international scientific events has been a relevant vector of the activity of INESC Coimbra, including the 11th International Conference on MCDM (August 1994) and the 52th Meeting of the EURO Working Group on MCDA (October 2002). In the last years, the other focused events have been organized: Mini-EURO Conferences on "Managing Uncertainty in Decision Support Models" (2004) and "Operational Research Models and Methods in the Energy Sector"

(2006), Group Decision and Negotiation Conference (2008), International Conference on Decision Support for Telecommunications and Information Society (DSTIS, in cooperation with the Lacnosci Institut – Poland, to be held in September 2009). Extended papers of the communications presented at these events have been included in special issues of journals, such as the European Journal of Operational Research (2), Decision Support Systems, Energy Policy, International Journal of Energy Sector Management, Group Decision and Negotiation, and the Journal of Telecommunications and Information Technology.

Some ongoing streams of research involving MOO/MCA

Multi-criteria group decision and negotiation: development of approaches enabling the actors to progress in group decision and negotiation processes without demanding complete information about the way how they evaluate the alternatives, by emphasizing methodologies based on preference exploration and learning.

Multi-criteria classification: development of approaches combining statistical techniques, such as clustering, with MCA preference models, such as outranking relations, for classifying objects in classes, which my be ordered, partially ordered or having no underlying order.

Multi-objective programming based on solution populations: development of approaches based on populations of solutions, such as genetic/evolutionary algorithms and particle swarm) for MOO problems, enabling a detailed characterization of Pareto fronts, techniques of preserving solution diversity and including guiding mechanisms to guide the search according to preferences; robustness evaluation embedded in the evolutionary process; development of adaptive operators.

Development of new MOO/MCA approaches for location and routing problems, interactive decision support systems to respond to the challenges of equipment location in technological and social support networks, involving fast computational procedures and adequate Human-computer interfaces.

Multi-criteria analysis of multi-service telecommunications networks for different planning, project and management problems, taking into account the growing relevance of multidimensional, heterogeneous and service-dependent quality of service (QoS). This involves routing models for Wavelength Division Multiplex (WDM) networks, multidimensional and multi-objective routing for Multi-Protocol Label Switching (MPLS) in Internet networks, multi-attribute models for resilient (fault-tolerant) routing in MPL networks.

Exploiting the links and complementary features of Data Envelopment Analysis (DEA) with both MOO and MCA.

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A sample of recent publications (2008 and 2009)

INESC Coimbra's researchers published about forty papers in international scientific journals in 2006-2008, in several domains ranging from theory and methodology to application-oriented works namely in the energy, telecommunication and urban and regional planning domains. A representative sample of the more recent papers follows:

1. Almeida, L. A., J. Coutinho-Rodrigues, J. Current, "A Multiobjective Modeling Approach to Locating Incinerators", Socio-Economic Planning Sciences, 2009.

2. Almeida, L. A.; L. Tralhão, L. Santos, J. Coutinho-Rodrigues, "A Multiobjective Approach to Locate Emergencying Shelters and Identify Evacuation Routes for Emergencies in Urban Area", Geographical Analysis, special issue in memory of C. ReVelle, 2009.

3. Alves, M .J., J. Clímaco, C. H. Antunes, H. Jorge, A. G. Martins, "Stability analysis of efficient solutions in multiobjective integer programming: a case study in load management", Computers and Operations Research, vol. 35, 186 – 197, 2008.

4. Alves, M. J., J. P. Costa. "An Exact Method for Computing the Nadir Values in Multiple Objective Linear Programming". European Journal of Operational Research, 2009.

5. Antunes, C. H., C. Barrico, A. Gomes, D. F. Pires, A. G. Martins, "An evolutionary algorithm for reactive power compensation in radial distribution networks". Applied Energy, 2009.

6. Captivo M.E., J. Clímaco, M.Pascoal. "A mixed integer linear formulation for the minimum label spanning tree problem", Computers and Operations Research, 2009.

7. Clímaco, J., M. Pascoal. "Finding Non-Dominated Bicriteria Shortest Pairs of Disjoint Simple Paths", Computers & Operations Research, 2009.

8. Costa, J. P., M. J. Alves. "A reference point technique to compute non-dominated solutions in MOLFP". Journal of Mathematical Sciences, 2009.

9. Costa, M. G.; M. E. Captivo, J. Clímaco. "Capacitated Single Allocation Hub Location Problems: A Bicriteria Approach". Computers and Operations Research, Vol. 35, Issue 11, 3671-3695, 2008.

10. Craveirinha, J., R. Girão-Silva, J. Clímaco, "A Meta-Model for Multiobjective Routing in MPLS Networks", Central European Journal of Operations Research, vol. 16, no. 1, 79-105, 2008.

11. Dias, J., M. E. Captivo, J. Clímaco. "A Memetic Algorithm for Multi-objective Dynamic Location Problems. Journal of Global Optimization, Vol. 42, No. 2, 221-253, 2008.

12. Girão-Silva, R., J. Craveirinha, J. Clímaco, "Hierarchical Multiobjective Routing in MPLS Networks with Two Service Classes – A Heuristic Solution", International Transactions in Operational Research, 2009.

13. Gomes da Silva, C., J. Clímaco, J. Figueira, "Core Problems in Bi-Criteria 0-1 knapsack Problems". Computers and Operations Research, vol. 35, Issue 7, 2292-2306, 2008.

14. Gomes, A., C. H. Antunes, A. Martins. "Design of an Adaptive Mutation Operator in an Electrical Load Management Case Study". Computers and Operations Research, vol. 35, 2925 – 2936, 2008.

15. Gomes, T., J. Craveirinha, J. Clímaco, C. Simões. "A bicriteria routing model for multi-fibre WDM networks". Photonic Network Communications, 2009.

16. Gouveia, M. C., L. C. Dias, C. Henggeler Antunes. "Additive DEA based on MCDA with imprecise information ". Journal of the Operational Research Society, vol. 59 54-63, 2008.

17. Madlener, C. H. Antunes, L. Dias. "Assessing the performance of biogas plants with multi-criteria and data envelopment analysis". European Journal of Operational Research, 2009.

18. Neves, L., A. G. Martins, C. H. Antunes, L. Dias. "A multi-criteria decision approach to sorting actions for promoting energy efficiency". Energy Policy, vol. 36, issue 7, 2351-2363, 2008.

19. Neves, L., L. Dias, A. G. Martins, C. H. Antunes "Building a decision model to appraise energy efficiency initiatives". European Journal of Operational Research, 2009.

20. Oliveira, C., C. H. Antunes. "An interactive method to tackle uncertainty in interval multiple objective linear programming". Journal of Mathematical Sciences, 2009.

21. Rocha, C., L. C. Dias. "An algorithm for ordinal sorting based on ELECTRE with categories defined by examples". Journal of Global Optimization, Vol. 42, No. 2, 255-277, 2008.

22. Santos, L., J. Coutinho-Rodrigues, J. Current. "Implementing a multi-vehicle multi-route spatial decision support system for efficient trash collection in Portugal", Transportation Research Part A: Policy and Practice, Vol. 42, Issue 6, 922-934, 2008.

23. Sarabando, P., L. C. Dias, "Multi-attribute choice with ordinal information: a comparison of different decision rules", IEEE Transactions on Systems, Man, and Cybernetics, Part A, 2009.

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INESC Coimbra publishes since 2002 a series of Research Reports and Documents (see www.inescc.pt/ingles/pubinter.php). The number of research reports downloads amounted to about 7000 in 2008.

Ongoing PhD Theses in which MOO and MCA play a key role

There are currently underway about 30 PhD thesis supervised by INESC Coimbra' researchers, about half of them explicitly involving MCDA models and methods, including the following topics:

- A multi-criteria approach to the routing problem in WDM networks
- Planning and operation problems in electrical distribution networks using multi-objective meta-heuristics
- Decision support in integrated urban energy planning
- Decision support in urban rehabilitation planning
- Adaptive operators and hybridization in population-based meta-heuristics in MOO
- Group decision support
- Integrated use of MCDA and DEA models
- Multi-criteria sorting based on examples
- Multi-criteria design and project of networks
- Methods and software with ordinal information for problems of performance evaluation, selection and ranking of alternatives.
- Multi-criteria routing models for IP/MPLS networks
- Multi-criteria location
- Multi-objective models for electricity dispersed generation expansion planning