

#### UMI LAFMIA 3175 CNRS at CINVESTAV-IPN

# **Bio-Inspired Metaheuristics Group**

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#### **Metaheuristics**



 Metaheuristics are high-level search procedures that apply some form of rule or set of rules based on some source of knowledge in order to explore the search space in a more efficient way.

#### **Metaheuristics**

Metaheuristics cannot guarantee (in general) convergence to the global optimum, but normally provide reasonably good approximations of it in a reasonable CPU time.

Due to their flexibility and ease of use, metaheuristics have become increasingly popular in the last 20 years.

#### **Bio-Inspired Metaheuristics**



One particular class of metaheuristics that has become quite popular in the last few years is that inspired on biological concepts such as evolution, ants' movements, birds' flight patterns, etc. These approaches are collectivelly known as bio-inspired metaheuristics.

### **Bio-Inspired Metaheuristics**

- Bio-Inspired Metaheuristics include (among others) to the following approaches:
  - Evolutionary Algorithms (genetic algorithms, evolution strategies, genetic programming, etc.)
  - Particle Swarm Optimization
  - Artificial Immune Systems
  - Cultural Algorithms
  - Ant Colony Optimization



The main research interests of this group are the following:

 <u>Multi-Objective Optimization</u>: We have developed new multi-objective evolutionary algorithms (MOEAs), archiving techniques, applications, etc.

- <u>Hybridization:</u> We hybridize metaheuristics with mathematical programming techniques (e.g., an evolutionary algorithm with gradient-based methods) with the aim to combine their advantages.
- <u>Constraint-handling techniques</u>: We have developed new constraint-handling techniques for evolutionary algorithms.

- Scalability: We have developed schemes to relax the Pareto dominance relation so that it can properly deal with problems having many objectives (more than four). We also study scalability in decision variable space.
- <u>Theory:</u> We are interested in developing archiving techniques for MOEAs that can guarantee convergence, under certain assumptions.



 <u>Applications:</u> We are interested in developing tools for solving engineering optimization problems with very costly objective functions (e.g., in aeronautical engineering).

The research group on bio-inspired metaheuristics at the UMI LAFMIA 3175 currently involves the participation of 3 researchers from CINVESTAV-IPN, 1 postdoctoral researcher, 5 PhD and 7 MSc students at CINVESTAV-IPN.

- In the period 2008-2011, this group has had 4 postdocs:
  - Julio Barrera (sponsored by CONACyT) (now at the Universidad Michoacana) (SNI-C)
  - Guillermo Leguizamón (sponsored by the UMI for 1 year) (now at the Universidad Nacional de San Luis, in Argentina)
  - Antonin Ponsich (sponsored by CONACyT) (now at UAM-Azcapotzalco) (SNI-1)
  - Antonio López Jaimes (sponsored by the UMI during 3 months) (now still at CINVESTAV-IPN)

- We currently have 5 PhD students associated to this group (all of them receive scholarships from CONACyT):
  - Adriana Lara
  - Saúl Zapotecas
  - Alfredo Arias
  - Eduardo Vázquez
  - Adriana Menchaca

Additionally, 4 PhD students have graduated since 2008 (including 2 students in Argentina)



□ The researchers are:

- Carlos A. Coello Coello (SNI 3) (leader)
- Oliver Schütze (SNI 1)
- Luis Gerardo de la Fraga (SNI 1)



This group also collaborates with the cryptography and computer security group (which consists of 3 researchers), particularly regarding the use of metaheuristics for solving combinatorial optimization problems arising in cryptography.



Archiving strategies that produce gap-free Pareto front approximations with guaranteed convergence using MOEAs. Reported at:

 Oliver Schuetze, Marco Laumanns, Emilia Tantar, Carlos A. Coello Coello and El-Ghazali Talbi, "Computing gap-free Pareto front approximations with stochastic search algorithms", *Evolutionary Computation*, Vol. 18, No. 1, pp. 65-96, Spring 2010.



- A novel point-wise iterative search procedure, for performing local search within a MOEA, which uses the geometry of the directional cones of the problem and works with or without gradient information. Reported at:
  - Adriana Lara, Gustavo Sanchez, Carlos A. Coello Coello and Oliver Schütze, "HCS: A New Local Search Strategy for Memetic Multi -Objective Evolutionary Algorithms", *IEEE Transactions on Evolutionary Computation*, Vol. 14, No. 1, pp. 112-132, February 2010.



#### A new particle swarm optimizer for solving economic dispatch problems. Reported at:

 Leticia Cecilia Cagnina, Susana Cecilia Esquivel and Carlos A. Coello Coello, "A Fast Particle Swarm Algorithm For Solving Smooth and Non-smooth Economic Dispatch Problems", *Engineering Optimization*, Vol. 43, No. 5, pp. 485--505, May 2011.



- A new MOEA that hybridizes differential evolution and rough sets, and which performs a very low number of objective function evaluations. Reported at:
  - Luis V. Santana-Quintero, Alfredo G. Hernández-Díaz, Julián Molina, Carlos A. Coello Coello and Rafael Caballero, "DEMORS: A hybrid Multi-Objective Optimization Algorithm using Differential Evolution and Rough Sets for Constrained Problems", Computers & Operations Research, Vol. 37, No. 3, pp. 470-480, March 2010.



- An approach that generates not only an approximation of the true Pareto optimal set, but also neighboring solutions. The approach was applied to multi-objective space mission design problems. Reported at:
  - Oliver Schütze, Massimiliano Vasile and Carlos A. Coello Coello, "Computing the Set of epsilon-efficient Solutions in Multi-Objective Space Mission Design", *Journal of Aerospace Computing, Information, and Communication*, Vol. 8, No. 3, pp. 53--70, March 2011.



- An approach based on differential evolution for solving constrained process engineering problems. Reported at:
  - Antonin Ponsich and Carlos A. Coello Coello, "Differential Evolution performances for the solution of mixed integer constrained Process Engineering problems", *Applied Soft Computing*, Vol. 11, No. 1, pp. 399--409, January 2011.



This group has collaborations with Shinshu University (in Japan), the University of Dortmund (in Germany), the University of Essex (in UK), the Universities Pablo de Olavide and of Málaga (in Spain), CIMAT, the Indian Statistical Institute (in India), UAM and the University of Sinaloa (in México).



The University of Nantes has an International MSc in Computer Science with emphasis on optimization. One student of this program (Thomas Pierrard) stayed several months at CINVESTAV-IPN (with some support from the UMI) working on the development of a multi -objective artificial immune system based on hypervolume.

#### Mobilité et stages étudiants ORO 2010-2011



M2R

- This collaboration, allowed us to write a grant proposal for the ANR-CONACyT call, entitled "Calcul de solution pareto en robotique". This proposal involved the participation of:
  - CINVESTAV-IPN
  - Laboratoire d'Informatique de Nantes Atlantique, UMR CNRS 6241 -Université de Nantes and Ecole des Mines de Nantes.
  - Institut de Recherche en Communications et Cybernétique de Nantes which is a joint research unit (UMR 6597) of CNRS "Centre National de la Recherche Scientifique".
  - Laboratoire d' Informatique de l'X, UMR CNRS 7161 Ecole Polytechnique.

This proposal will be submitted in 2012.



We have also collaborated with El -Ghazali Talbi, Clarisse Dhaenens and Laetitia Jourdan, from LIFL/CNRS /Polytech'Lille/INRIA, but informally, until now (joint publications).



#### Scientific production (2008-2011):

- 3 edited books
- 21 book chapters
- 37 journal papers (including papers at the two most prestigious journals in the field).
- 57 conference papers (including papers at the most prestigious conferences in the field).



#### Other activities:

 Involvement of the organization of several international conferences: EVOLVE 2011 (Luxembourg), IEEE MCDM 2011 (Paris, France), CEC'2013 (Cancún, México), SON 2010 (Mexico City, Mexico), CCE'2011 (Mérida, México), CCE'2010 (Tuxtla Gutiérrez, México), IEEE MCDM 2009 (Nashville, USA), CCE'2009 (Toluca, México).

#### Other activities:

- Invitations to members of the group to act as keynote speakers in Italy, Canada, USA, India, Brazil, China, Uruguay, Colombia, Chile, England, Spain and several parts of Mexico.
- A bilateral project with India (sponsored by CONACyT). Approx. \$21,200 US dollars (1 year). Similar funding has been approved for the second year of this project.

**Other activities:** 

- A basic research project (on evolutionary multi-objective optimization) from CONACyT for approximately \$44,600 US dollars (3 years).
- A SNI 1's project (on image processing using evolutionary algorithms) from CONACyT for approximately \$10,000 US dollars (1 year).

Other activities:

- A bilateral project with Chile (Universidad de Valparaíso) sponsored by CONACyT (about \$20,000 US for the first year).
- A bilateral project with Germany (University of Dormund) sponsored by CONACyT (about \$20,000 US for the first year).
- An FP7 project with Israel, England, Canada and Brazil (total funding is still unknown).

#### Other activities:

 Participation of members of the group in the editorial board of several international journals (e.g., IEEE Transactions on **Evolutionary Computation, Evolutionary** Computation, Engineering Optimization, Soft Computing, Computational **Optimization and Applications, Pattern** Analysis and Applications, Journal of Heuristics, Memetic Computing, etc.).

Participation in committees:

- SNI's evaluation committee (area VII).
- IEEE Computational Intelligence Society Awards.
- Evolutionary Computation Technical Committee of the IEEE Computational Intelligence Society.
- Refereeing of project proposals submitted to the European Research Council.

#### **Some Achievements**



Best Paper Award 2008 Genetic and Evolutionary Computation Conference,



Medal to the Scientific Merit 2009



Arturo Rosenblueth Award 2009 (best PhD thesis in engineering)



Best Paper Award, Graduate Student Workshop (GECCO'2010)



Best Paper Award AE'2009, France



IEEE Fellow plaque (New Orleans, USA)

#### **Some Achievements**

Best Paper Award at the Graduate Student Workshop of the 2010 Genetic and Evolutionary Computation Conference (GECCO 2010) held in Portland, USA.

Medal to the Scientific Merit 2009 (granted by Mexico City's congress).

Over 5,400 citations to the total publications of the group (half of these citations are reported in the ISI Web of Science).

#### **Future Perspectives**

- Formalize collaborations with France (with Xavier Gandibleux and also possibly with Marc Schoenauer and/or with EI-Ghazali Talbi).
- More algorithmic developments (hybrids, many-objective optimization) and more applications (e.g., in aeronautical engineering, bioinformatics).
- We are about to sign an agreement with the University of Nantes that will facilitate the exchange of students and other forms of collaboration.