Curriculum Vitae

Alexandre Salles da Cunha

Professor (Full)
Head of the Operations Research Lab
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Federal University of Minas Gerais
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December 29, 2024

PERSONAL

Marital Status: Single

Citizenship: Brazil

RESEARCH INTERESTS

Integer and Combinatorial Optimization, Stochastic Optimization, Network Design, Operations Research and Artificial Intelligence.

EDUCATION

2002 — 2006 **Ph.D.** in Computer Science and Systems Engineering
Federal University of Rio de Janeiro,
Graduate Program in Systems Engineering and Computer Science
Rio de Janeiro, Brazil
Thesis Advisor: Abilio Lucena Ph.D. Thesis: "Optimal Trees: Models, Algorithms and Applications"(in Portuguese)

2004 — 2005 **Visiting doctorate researcher** at CORE, Center for Operations Research and Econometrics, Catholic University of Louvain, Louvain-la-Neuve, Belgium.
Supervisor: Laurence Wolsey

2001 — 2002 **M.Sc.** in Mechanical Engineering
Federal University of Minas Gerais, Belo Horizonte, Brazil.

1990 — 1994 **Mechanical Engineer**, concentration in Heat Transfer and Fluid Mechanics
Federal University of Minas Gerais, Belo Horizonte, Brazil.

ACADEMIC AWARDS

2010 — now **Research Productivity Grant**, National Research Council (CNPq), Brazil.

2014 — 2015 **Sabbatical Year Fellowship**, sabbatical year spent at LIMOS - Laboratoire d'Informatique, de Modélisation et d'Optimisation des Systèmes, Université Blaise-Pascal, France. National Research Council (CNPq), Brazil.

2002 — 2006 **Ph.D. Fellowship**, National Research Council (CNPq), Brazil.

2004 — 2005 **Ph.D. Fellowship** for visiting CORE, Center for Operations Research and Econometrics, Catholic University of Louvain, Louvain-la-Neuve, Belgium. Brazilian Ministry of Education (CAPES), Brazil.

EXPERIENCE AND JOB HISTORY

2022 — now **Professor (Full)**, Computer Science Department, Federal University of Minas Gerais, Belo Horizonte, Brazil.

2014 — 2022 **Associate Professor**, Computer Science Department, Federal University of Minas Gerais, Belo Horizonte, Brazil.

2006 — 2014 **Adjunct Professor**, Computer Science Department, Federal University of Minas Gerais, Belo Horizonte, Brazil.

1999 — 2001 **Senior Financial Analyst**, TIM - Telecom Italia Mobile, Belo Horizonte, Brazil.

1998 — 1999 **Project Supervisor**, Unilever, Belo Horizonte, Brazil.

1997 — 1998 **Process Supervisor**, Cia de Cigarros Souza Cruz (brazilian subsidiary of BAT - British American Tobacoo), Uberlância, Brazil.

1995 — 1997 **Project Engineer**, Usiminas, Usinas Siderúrgicas de Minas Gerais (one of the leading flat steel producers in Brazil), Ipatinga, Brazil.

CONFERENCE AND WORKSHOP ORGANIZATION

2021/2022 **Joint ALIO/EURO International Conference on Applied Combinatorial Optimization (Program Committee member)**

2019 **X LAGOS - Latin American Algorithms, Graphs and Optimization Symposium (Program Committee member)**

2017 **SLIOIA - Simposio Latinoamericano de Investigación de Operaciones e Inteligencia Artificial (Program Committee member)**

2013 **Latin American Conference on Computation (Program Committee member)**

OTHER PROFESSIONAL ACTIVITIES

2007 — now **Referee for:** Annals of Operations Research, Computers & Operations Research, Discrete Applied Mathematics, Discrete Optimization, European J. of Operational Research, INFORMS J. on Computing, International Journal of Production Economics, International Transactions in Operational Research, Journal of Global Optimization, Journal of Heuristics, Mathematical Methods of Operations Research, Mathematical Programming, Networks, Optimization Letters, RAIRO - Recherche Opérationnelle.

PATENTS

1. United States Patent 7,978,629, "*Method for network design to maximize difference of revenue and network cost*," (with Abilio Lucena, Nelson Maculan, and Mauricio G.C. Resende), issued on July 12, 2011.

TEN MOST CITED PAPERS – Google Scholar (December 4, 2022)

1. C.A. Valle, J.E. Beasley and A.S. da Cunha, "*Optimally solving the joint order batching and picker routing problem,*" **European Journal of Operational Research**, vol. 262(3), pp. 817–834, 2017 –

98 citations

2. F.A. Santos, G.R. Mateus and A.S. da Cunha, "*The pickup and delivery problem with cross-docking,*" **Computers & Operations Research**, vol. 40(4), pp. 1085–1093, 2013 – **87 citations**

3. F.A. Santos, G.R. Mateus and A.S. da Cunha, "*A branch-and-cut-and-price algorithm for the two-echelon capacitated vehicle routing problem,*" **Transportation Science**, vol. 49(2), pp. 355–368, 2015 – **74 Citations**

4. B. Gendron, A. Lucena, A.S. da Cunha and L. Simonetti, "*Benders decomposition, branch-and-cut, and hybrid algorithms for the minimum connected dominating set problem,*" **INFORMS Journal on Computing**, vol. 26 (4), pp. 645–657, 2014 – **71 citations**

5. A.S. da Cunha, A. Lucena, N. Maculan and M.G.C. Resende, "*A relax-and-cut algorithm for the prize-collecting Steiner problem in graphs,*" **Discrete Applied Mathematics**, vol. 157 (6), pp. 1198–1217, 353–361, 2009 – **66 citations**

6. F.A. Santos, A.S. da Cunha, and G.R. Mateus, "*Branch-and-price algorithms for the two-echelon capacitated vehicle routing problem,*" **Optimization Letters**, vol. 7 (7), pp. 1537–1547, 2013 – **63 citations**

7. F.A. Santos, G.R. Mateus and A.S. da Cunha, "*A branch-and-price algorithm for a vehicle routing problem with cross-docking,*" **Electronic Notes in Discrete Mathematics**, vol. 37, pp. 249–254, 2011 – **62 citations**

8. L. Simonetti, A.S. da Cunha, and A. Lucena, "*The minimum connected dominating set problem: Formulation, valid inequalities and a branch-and-cut algorithm,*" **International Conference on Network Optimization**, pp. 162–169, 2011 – **56 citations**

9. C.A. Valle, L.C. Martinez, A.S. da Cunha, and G.R. Mateus, "*Heuristic and exact algorithms for a min-max selective vehicle routing problem,*" **Computers & Operations Research**, vol. (38)(7), pp. 1054–1065, 2011 – **45 citations**

10. W.M. Aioffi, C.A. Valle, G.R. Mateus, and A.S. da Cunha, "*Balancing message delivery latency and network lifetime through an integrated model for clustering and routing in wireless sensor networks,*" **Computer Networks**, vol. (55)(13), pp. 2803–2820, 2011 – **43 citations**

RESEARCH PAPERS SUBMITTED TO PEER REVIEWED JOURNALS

1. "*The Profitable Single Truck and Trailer Routing Problem with Time Windows: Formulation, Valid Inequalities and Branch-and-cut algorithms*," (with Henrique Favarini) Submitted for publication, 2021.

RESEARCH PAPERS IN PEER REVIEWED JOURNALS, CONFERENCES AND BOOKS

54. "*Exact Solution Algorithms for the Chordless Cycle Problem*", (with D.S. Pereira, A. Lucena and L. Simonetti), **INFORMS Journal on Computing**, vol. 34, 2022.

53. "*Improved formulations and Branch-and-cut algorithms for the Angular Constrained Minimum Spanning Tree Problem*", **Journal of Combinatorial Optimization**, vol. 44, 2022.

52. "*The minimum area spanning tree problem: Formulations, Benders decomposition and branch-and-cut algorithms*," (with D.A. Guimarães), **Computational Geometry: Theory and Applications**, vol. 97, 2021.

51. "*Dynamic intersection of multiple implicit Dantzig-Wolfe decompositions applied to the Adjacent Only Quadratic Minimum Spanning Tree Problem*," (with D.L. Pereira), **European Journal of Operational Research**, vol. 284, pp. 413–426, 2020.

50. "*Semidefinite programming lower bounds and Branch-and-bound algorithms for the Quadratic minimum spanning tree problem*," (with D.A. Guimarães and D.L. Pereira), **European Journal of Operational Research**, vol. 280, pp. 46–58, 2020.

49. "*Modeling and solving the angular constrained minimum spanning tree problem*," (with Abilio Lucena), **Computers & Operations Research**, vol. 112, pp. 104775, 2019.

48. "*Formulation and branch-and-cut algorithm for the minimum cardinality balanced and connected clustering problem*," **International Network Optimization Conference, Avignon, 2019**, **Proceedings of the 9th International Network Optimization Conference**, vol. 1, pp. 25–30, 2019.

47. "*Polyhedral Results, branch-and-cut and Lagrangian relaxation algorithms for the adjacent only quadratic minimum spanning tree problem*," (with D. L. Pereira), **Networks**, vol. 71, pp. 31-50, 2018.

46. "*Exact solution approaches for the Multi-period Degree Constrained Minimum Spanning Tree Problem*," (with R.J. Chagas and C.A. Valle), **European Journal of Operational Research**, vol. 271, pp. 57–71, 2018.

45. "*Reformulations and branch-and-price algorithm for the Minimum cost-hop-and-root constrained forest problem*," (with D.L. Pereira), **Computers & Operations Research**, vol. 98, pp. 38-55, 2018.

44. "*Optimally solving the joint order batching and picker routing problem*," (with C.A. Valle and J. Beasley), **European Journal of Operational Research**, vol. 262, pp. 871–834, 2017.

43. "*Branch-and-cut-and-price algorithms for the Degree Constrained Minimum Spanning Tree Problem*," (with L.H. Bicalho and Abilio Lucena), **Computational Optimization and Applications**, vol. 63, pp. 755–792, 2016.

42. "*A branch-and-cut-and-price algorithm for the Stackelberg minimum spanning tree problem*," (with V.W.C. de Moraes and P. Mahey), **International Network Optimization Conference, Warsaw, Poland, 2015**, **Electronic Notes in Discretete Mathematics**, vol. 52, pp. 309–316, 2016.

41. "*The Tree-Star Problem: A Formulation and a Branch-and-Cut Algorithm*," (with L. Simonetti and Abilio Lucena), **International Network Optimization Conference, Warsaw, Poland, 2015**, **Electronic Notes in Discretete Mathematics**, vol. 52, pp. 285–292, 2016.

40. "*A strong symmetric formulation for the Min-degree Constrained Minimum Spanning Tree Problem*," (with Abilio Lucena and L. Simonetti), **International Network Optimization Conference, Warsaw, Poland, 2015**, **Electronic Notes in Discretete Mathematics**, vol. 52, pp. 237–244, 2016.

39. "*Modeling and solving the joint order batching and picker routing problem in Inventories*," (with C.A. Valle and J. Beasley), **ISCO 2016 - International Symposium on Combinatorial Optimization, VietrI Sul Mare, Italy, 2016**, **Lecture Notes in Computer Science**, vol. 9849, pp. 81–97, 2016.

38. "*A branch-and-cut-and-price algorithm for the two-echelon capacitated vehicle routing problem,*"(with F.A. Santos and G.R. Mateus), **Transportation Science**, vol. 49(2), pp. 355–368, 2015.

37. "*Optimality cuts and a Branch-and-cut algorithm for the K-rooted Mini-Max Spanning Forest Problem*," (with Abilio Lucena and L. Simonetti), **European Journal of Operational Research**, vol. 246, pp. 392-399, 2015.

36. "*Formulations and exact solution approaches for the degree preserving spanning tree problem*," (with Abilio Lucena, L. Simonetti and B. Gendron), **Networks**, vol. 65, pp. 329-343, 2015.

35. "*Branch-and-cut and Branch-and-cut-and-price algorithms for the adjacent only quadratic minimum spanning tree problem*," (with D.L. Pereira and M. Gendreau), **Networks**, vol. 65, pp. 367-379, 2015.

34. "*Benders Decomposition, Branch-and-Cut, and Hybrid Algorithms for the Minimum Connected Dominating Set Problem*," (with B. Gendron, Abilio Lucena and L. Simonetti), **INFORMS Journal on Computing**, vol. 26, pp. 645-657, 2014.

33. "*Finding totally independent spanning trees with linear integer programming*," (with F.S.H. Souza), **ISCO 2014 - International Symposium on Combinatorial Optimization, Lisbon, Portugal, 2014**, **Lecture Notes in Computer Science**, vol. 8596, pp. 149–160, 2014.

32. "*The Min-degree constrained minimum spanning tree problem: Formulations and branch-and-cut algorithm*," (with L.C. Martinez), **Discrete Applied Mathematics**, vol. 164 , pp. 210-224, 2014.

31. "*Polyhedral results and a Branch-and-cut algorithm for the k-cardinality tree problem*," (with L. Simonetti and Abilio Lucena), **Mathematical Programming**, vol. 142, pp. 511–538, 2013.

30. "*Branch-and-price algorithms for the two-echelon capacitated vehicle routing problem,*" (with F.A. Santos and G.R. Mateus), **Optimization Letters**, vol. 7 (7), pp. 1537–1547, 2013.

29. "*The pickup and delivery problem with cross-docking,*" (with F.A. Santos and G.R. Mateus), **Computers & Operations Research**, vol. 40(4), pp. 1085–1093, 2013.

28. "*A branch-and-price algorithm for the multi-vehicle covering tour problem*," (with R. Lopes and V.A.A. Souza), **VII Latin-American Algorithms, Graphs and Optimization Symposium (LAGOS) 2013, Playa del Carmen, Mexico**, **Electronic Notes in Discretete Mathematics**, vol. 44, pp. 61–66, 2013.

27. "*Formulating and Solving the Minimum Dominating Cycle Problem*," (with Abilio Lucena and L. Simonetti), **VII Latin-American Algorithms, Graphs and Optimization Symposium (LAGOS) 2013, Playa del Carmen, Mexico**, **Electronic Notes in Discretete Mathematics**, vol. 44, pp. 83–88, 2013.

26. "*Formulating and Solving the Minimum Dominating Cycle Problem*," (with Abilio Lucena and L. Simonetti), **International Network Optimization Conference, Tenerife, 2013**, **Electronic Notes in Discretete Mathematics**, vol. 41, pp. 423–430, 2013.

25. "*The Degree Preserving Spanning Tree Problem: Valid Inequalities and Branch-and-cut method*," (with B. Gendron, Abilio Lucena and L. Simonetti), **International Network Optimization Conference, Tenerife, 2013**, **Electronic Notes in Discretete Mathematics**, vol. 41, pp. 173–180, 2013.

24. "*Stronger lower bounds for the quadratic minimum spanning tree problem with adjacency costs*," (with D.L. Pereira and M. Gendreau), **International Network Optimization Conference, Tenerife, 2013**, **Electronic Notes in Discretete Mathematics**, vol. 41, pp. 229–236, 2013.

23. "*A parallel Lagrangian relaxation algorithm for the Min-degree constrained minimum spanning tree problem*," (with L.C. Martinez), **ISCO 2012 - International Symposium on Combinatorial Optimization, Athens, Greece, 2012**, **Lecture Notes in Computer Science**, vol. 7422, pp. 237–248, 2012.

22. "*Optimization in designing complex communication networks*," (with F.S.H. Souza and G. R. Mateus), **Handbook of Optimization in Complex Networks**, Springer, vol. 1, pp. 3–38, 2012.

21. "*Heuristic and exact algorithms for a min-max selective vehicle routing problem,*" (with C.A. Valle, L.C. Martinez, and G.R. Mateus), **Computers & Operations Research**, vol. (38)(7), pp. 1054–1065, 2011.

20. "*Balancing message delivery latency and network lifetime through an integrated model for clustering and routing in wireless sensor networks,*" (with W.M. Aioffi, C.A. Valle, and G.R. Mateus), **Computer Networks**, vol. (55)(13), pp. 2803–2820, 2011.

19. "*A Branch-and-price algorithm for a vehicle routing problem with cross-docking*," (with D.L. Pereira and G.R. Mateus), **LAGOS'11 - VI Latin-American Algorithms, Graphs and Optimization Symposium**, **Electronic Notes in Discretete Mathematics**, vol. 37, pp. 249–254, 2011.

18. "*Stronger column generation bounds for the minimum cost hop-and-root constrained forest problem*," (with D.L. Pereira and G.R. Mateus), **LAGOS'11 - VI Latin-American Algorithms, Graphs and Optimization Symposium**, **Electronic Notes in Discretete Mathematics**, vol. 37, pp. 315–320, 2011.

17. "*Relax-and-Cut as a Preprocessor and Warm Starter to Branch-and-Cut,*" (with Abilio Lucena and N. Maculan), in **Progress in Combinatorial Optimization**, A.R. Mahjoub (Ed.) Wiley, pp. 171–197, 2011.

16. "*The Minimum Connected Dominating Set Problem: Formulation, Valid Inequalities and a Branch-and-Cut Algorithm*," (with L. Simonetti and Abilio Lucena), **International Network Optimization Conference, Hamburg, 2011**, **Lecture Notes in Computer Science**, vol. 6701, pp. 162–169, 2011.

15. "*Formulations and Branch-and-Cut Algorithm for the K-rooted Mini-Max Spanning Forest Problem*," (with Abilio Lucena and L. Simonetti), **International Network Optimization Conference, Hamburg, 2011**, **Lecture Notes in Computer Science**, vol. 6701, pp. 43–50, 2011.

14. "*A novel column generation algorithm for the vehicle routing problem with cross-docking*," (with F.A. Santos and G.R. Mateus), **International Network Optimization Conference, Hamburg, 2011**, **Lecture Notes in Computer Science**, vol. 6701, pp. 412–425, 2011.

13. "*The k-Cardinality Tree Problem: Reformulations and Lagrangian Relaxation*," (with F.P. Quintão, Abilio Lucena and G.R. Mateus), **Discrete Applied Mathematics**, vol. 158, pp. 1305–1314, 2010.

12. "*A New Lagrangian Based Branch and Bound Algorithm for the 0-1 Knapsack Problem*," (with Abilio Lucena, L. Bahiense and C.C. de Souza), **ISCO 2010 - International Symposium on Combinatorial Optimization, Hammamet, Tunisia**, **Electronic Notes in Discretete Mathematics**, vol. 36, pp. 623–630, 2010.

11. "*On the design of complex networks through a branch-and-price algorithm*," (with F.S.H. Souza and G.R. Mateus), **2010 IEEE Globecom Workshops, Florida**, pp. 378–382, 2010.

10. "*A relax-and-cut algorithm for the prize-collecting Steiner problem in graphs*," (with Abilio Lucena, N. Maculan and M.G.C. Resende), **Discrete Applied Mathematics**, vol. 157, pp. 1198–1217, 2009.

9. "*The minimum cost hop-and-root constrained forest in wireless sensor networks*," (with C. Bechelane and G.R. Mateus), **LAGOS'09 - V Latin-American Algorithms, Graphs and Optimization Symposium**, **Electronic Notes in Discretete Mathematics**, vol. 35, pp. 139–144, 2009.

8. "*Exact algorithms for a selective vehicle routing problem*," (with C. Bechelane and G.R. Mateus), **LAGOS'09 - V Latin-American Algorithms, Graphs and Optimization Symposium**, **Electronic Notes in Discretete Mathematics**, vol. 35, pp. 133–138, 2009.

7. "*Optimal topology design of complex networks*," (with F.S.H. Souza and G.R. Mateus), **IEEE INFOCOM Workshops 2009, Rio de Janeiro**, pp. 1–6, 2009.

6. "*Integer programming formulations for the k-cardinality tree problem*," (with F. Quintão and G.R. Mateus), **Electronic Notes in Discretete Mathematics**, vol. 30, pp. 225–230, 2008.

5. "*Stronger upper and lower bounds for a hard batching problem to feed assembly lines*," (with M.C. de Souza), **Electronic Notes in Discretete Mathematics**, vol. 30, pp. 159–164, 2008.

4. "*Algorithms for improving the quality of service in wireless sensor networks with multiple mobile sinks*," (with C.A. Valle, W.M. Aioffi and G.R. Mateus), **MSWIM'08: Proceedings of the 11th International symposium on Modeling, analysis and simulation of wireless and mobile systems, Vancouver, Canada**, pp. 239–243, 2008.

3. "*Lower and upper bounds for the degree constrained minimum spanning tree problem*," (with Abilio Lucena), **Networks**, vol. 50, pp. 55–66, 2007.

2. "*Algorithms for the degree-constrained minimum spanning tree problem*," (with Abilio Lucena), **Proceedings of GRACO 2005, Angra dos Reis, Brazil, 2005**, **Electronic Notes in Discretete Mathematics**, vol. 19, pp. 403–409, 2005.

1. "*Two dimensional transient finite volume diffusional approach to transport equations*," (with W. Romero), **TEMA - Tendências em Matemática Aplicada e Computacional**, vol. 1, pp. 91–100, 2002.

PH.D. SUPERVISION (concluded)

3. Dilson Guimarães, **"Combinatorial Optimization Problems with Non-separable Objective Function"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, April 2021.

2. Dilson Lucas Pereira, **"Formulations and Algorithms Based on Linear Integer Programming for the Quadratic Minimum Spanning Tree Problem"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, March 2014.

1. Fernando Afonso Santos, **"Models and Algorithms for Integrated Routing and Distribution Problems"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, June 2012. (co-supervised by G.R. Mateus)

PH.D. SUPERVISION (ongoing)

1. Vitor Notini Pontes, **"Multi-period Stochastic Network Design Problems"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Rio de Janeiro, Brazil, expected conclusion date, 2023.

M.Sc. SUPERVISION (concluded)

10. Henrique Favarini Alves da Cruz, **"The Profitable Single Truck and Trailer Problem with Time Windows"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2020.

9. Dilson de Almeida Guimarães, **"Valid Inequalities for Split Disjunctions"**, Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2016.

8. Luis Henrique Costa Bicalho, **"Branch-and-cut-and-price algorithms for the Degree Constrained Minimum Spanning Tree Problem"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2014.

7. Leonardo Conegundes Martinez, **"The Min-degree Constrained Minimum Spanning Tree Problem: Formulations, Sequential and Parallel Algorithms'** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2012.

6. Rafael Santos Coelho, **"The Generalized Minimum Two Connected Subgraph Problem: Algorithms and Formulations"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2012.

5. Ramon Lopes Pereira, **"Exact and Heuristic Algorithms for Selective Vehicle Routing Problems with Covering Constraints"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2012.

4. Iuri Bueno Drummond de Andrade, **"Integrating Density Control, Covering and Routing in Wireless Sensor Networks: Mathematical Models, Algorithms, Simulation and Optimization Algorithms"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2011.

3. Cristiano Arbex Valle, **"Optimizing Routing and Clustering in Wireless Sensor Networks with Mobile Sinks"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2009.

2. Carla Oliveira Bechelane, **"An Approach for Mininizing Energy Consumption in Wireless Sensor Networks With Mobile Sinks"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2009.

1. Frederico Paiva Quintão, **"The k-cardinality Miniminum Cost Tree Problem: Reformulations and Lagrangian Heuristics"** (in Portuguese), Graduate Program in Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, 2008.

M.Sc. SUPERVISION (ongoing)

1. Victor Deluca, **"Algorithms for Rainbow Spanning Forest Problems"**, Graduate Program Computer Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, expected conclusion date, June 2023.