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IN MEMORY OF NENAD MLADENOVIĆ (1951–2022)

Abstract. The special issue of Zbornik Radova is dedicated to the memory of Professor Nenad Mladenović, who left an exceptional legacy in the field of operations research. This introductory paper contains the most important details of his biography and short description of his main scientific achievements, followed by a complete bibliography.

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1. Biography

Nenad Mladenović was born on April 28, 1951 in Jagodina, Central Serbia. He earned his B.Sc. Degree in Mathematics and M.Sc. and Ph.D. Degrees in Operations Research from the University of Belgrade. He joined the Faculty of Organizational Sciences of Belgrade University in 1985 as a teaching assistant for *Decision Theory and Econometric Methods* and he was promoted to the position of an assistant professor for *Methods of Optimization* in 1988. In 1991, at the invitation of Professor Pierre Hansen, Mladenović went to the University of Montreal for scientific training. In Montreal, he worked as a researcher at one of the world's largest centre for operations research – the GERAD Institute, where he actively participated in helping students to prepare their master and doctoral theses, and gave lectures on Operations Research at McGill University. He was also involved in three industrial projects with leading Canadian companies which aimed to develop software to optimize some production processes. For the 1998/99 school year, he received the position of visiting professor at the Free University in Brussels.

Professor Mladenović got a position at the Mathematical Institute of Serbian Academy of Sciences and Arts (SASA) in 2000 as a senior research associate, and in 2002 he was elected a scientific advisor. From 2006–2016 he was a part-time professor at the Faculty of Organizational Sciences, teaching undergraduate and graduate courses *Location Theory*, *Nonlinear Programming*, *Combinatorial Optimization* and *Metaheuristics*. Professor Mladenović remained at the Mathematical Institute until his retirement in 2018. From 2018–2022 he held the position of *Professor of Industrial and Systems Engineering* at Khalifa University in Abu Dhabi, United Arab Emirates.

Professor Mladenović, was a visiting professor at several well-known world universities. From 2005–2013 he taught *Operations Research*, *Heuristic Optimization* and *Operations Management* at the University of Birmingham and Brunel University in London. From 2013–2016 he gave lectures on *Mathematical Optimization Methods* to doctoral students at the University of Valenciennes in France. From 2014–2017, he taught several courses to doctoral students at three Brazilian universities: Federal University of Rio Grande del Norte, Natal, University of Joao Pessoa, Paraiba and University of Ouro Preto, Minas Gerais. Professor Mladenović had many years of cooperation with the Department of Management of the Hong Kong Polytechnic University in Hong Kong, the School of Business Administration of the University of Prince Edwards Island in Canada, and the University of La Laguna in Tenerife, Spain. He also lectured at universities in Novosibirsk, Samara, Vladivostok, Kaiserslautern, Darmstadt, Madrid, Beijing, Lille, Alma Ata

and Kuwait. At the universities in Belgrade, Novi Sad, Tenerife, London, Birmingham and Alma-Ata, Professor Mladenović supervised the preparation of several doctoral and master dissertations in the field of operations research.

At the Mathematical Institute, Professor Mladenović managed scientific research projects *Mathematical Models and Methods of Optimization* and *Mathematical Models and Methods of Optimization of Large Systems* financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. He was a leader of two research projects in the UK: *Variable Neighborhood Search in Clustering and Data Mining* and *p-Centre Problem with Formulation Space Search*, as well as of the projects *Global Supply Chain* and *Constrained Vehicle Routing* in France and *Heuristic Optimization* in Russia. He also participated in numerous other scientific research projects in Canada, Spain, France, Russia, Kazakhstan, Brazil and China.

Professor Mladenović was a member of the Scientific Society of Serbia, the Academy of Nonlinear Sciences, as well as the European Academy of Sciences (Academia Europea). He was awarded the Charter for Merits in the Development of Operations Research in Serbia. In 2020 he was recognized as the #2 top scientist in the UAE according to the Guide2Research 2020 Top Computer Science and Electronics Scientists Ranking.

Professor Mladenović was a member of the program committee of numerous scientific conferences. He was a member of the program committee of the *Symposium on Operations Research SIM-OP-IS* (since 1990), and the *Balkan Conference on Operations Research* (since 2007). As one of the two authors of the world-renowned metaheuristics Variable Neighborhood Search (VNS), Professor Mladenović was appointed chairman of the program committee of two scientific conferences called *Mini EURO Conference on VNS*, held in Spain in 2005 and in Montenegro in 2012. Following a growing interest of the scientific community, international conferences dedicated to the Variable Neighborhood Search continued to be organized at a regular basis, where Mladenović participated in the organization of conferences in Tunisia (3^{rd} *International Conference on VNS*, 2014), Spain (4^{th} *International Conference on VNS*, 2016), Brazil (5^{th} *International Conference on VNS*, 2017), Greece (6^{th} *International Conference on VNS*, 2018), Morocco (7^{th} *International Conference on VNS*, 2019), United Arab Emirates (8^{th} *International Conference on VNS*, 2021). In addition to the above, Professor Mladenović was a member of the program committee of the *International Network Optimization Conference* (*INOC 2013*), *Metaheuristics International Conference* (*MIC 2013*), *Global Optimization Workshop* (2012), *SIAM International Conference on Data Mining* (*SDM 2008*), *Learning and Intelligent Optimization* (*LION II, III, IV*) (since 2007), *Matheuristics Workshop* (since 2007). He gave invited and introductory lectures at more than 40 international conferences and has chaired the European Working Group on Location Theory.

Professor Mladenović was a member of the editorial board of *Yugoslav Journal of Operations Research* (*YUJOR*) since its founding in 1990, and since 2010 one of the three editors-in-chief, while in 2022 he took over the position of the sole editor-in-chief. In addition to editing *YUJOR*, Professor Mladenović was a member of the

editorial board of 14 other scientific journals, of which we single out: *TOP* (Associate Editor, since 2012), *EURO Journal on Computational Optimization* (since 2012), *Journal on Optimization* (since 2009), *International Journal of Metaheuristics* (since 2008), *International Journal of Mathematics in Operational Research* (since 2008), *Computers and Operations Research* (since 2005) and *Computer Science and Information Systems* (*COMSIS*) (since 2003). He was a guest editor of special issues of the *European Journal of Operational Research*, *IMA Journal of Management Mathematics*, *Journal of Applied Mathematics*, *Journal of Global Optimization* and *Computers and Operations Research*. He reviewed papers for almost all leading journals in operations research.

Nenad passed away on May 7, 2022 at the Cleveland Clinic in Abu Dhabi and his funeral took place in Belgrade, Serbia, on May 17, 2022.

2. Research work

Professor Mladenović was a very productive researcher, who gained an enviable world reputation in the field of operations research, dealing with problems of decision-making and management in complex systems. He published about 200 papers in scientific journals, 70 papers in edited conference proceedings and 50 books and chapters in scientific monographs. His results have had a big impact on the scientific community. According to Google Scholar, at the time of writing this article, they have been cited more than 32.000 times with the h-index equal to 67.

The main research contribution of Professor Mladenović is the creation of the well-known Variable Neighborhood Search (VNS) metaheuristic. He proposed this methodology in 1995 and since then it has gained the status of one of the leading general heuristic methods. At that time, the standard practice in global optimization was the random multi-start local search, i.e. repeating local search starting from feasible and randomly selected points. The principal contribution of the VNS is to define a sequence of neighborhood structures to replace the random selection of a new starting point. A random point is selected in the first (smallest) neighborhood of the current solution (which is the best solution obtained up to this time) and the local search starts there. If a local optimum better than the current solution is obtained it becomes the new current solution; otherwise, a random point in the next (bigger) neighborhood of the current solution is selected to start the new local search, and so on. In this way the local search uses information of the current solution instead of starting anew from a completely random point. Empirical evidence shows that the VNS consistently outperforms random multi-start algorithms using the same local search. Furthermore, there is a large flexibility in defining neighborhood structures, which contributes to the efficiency of the new approach. Mladenović first independently, and then together with Professor Pierre Hansen, elaborated several variants of the VNS and showed their applicability to various optimization problems. Their seminal paper on VNS was published in Computers & Operations Research in 1997. Nowadays, several VNS schemes have been proposed, such as Reduced VNS (RVNS), Variable Neighborhood Descent (VND), General VNS (GVNS), Skewed VNS (SVNS), Variable Neighborhood Decomposition Search (VNDS), and others. The VNS methodology was applied for the solution of a large

number of optimization problems, such as exact solution of large-scale location problems by primal-dual VNS, generation of solutions to large mixed integer linear programs by hybridization of VNS and local branching, generation of solutions to very large mixed integer programs using VNS decomposition and exact solvers, finding a global optimum of nonlinear programming problems, etc. A good illustration of the big impact of the VNS methodology is the fact that in 2017, on the occasion of celebrating 40 years of the *European Journal of Operational Research*, the paper: P. Hansen, N. Mladenović, *Variable neighborhood search: Principles and applications*, European Journal of Operational Research **130**(3) (2001), 449–467 is included in the collection of 40 most influential articles published in the *European Journal of Operational Research* since its founding in 1977 and ranked eighth most cited.

Mladenović initiated and developed two more general heuristic methods, which confirms his originality and inventiveness over a longer period of time: Formulation Space Search (FSS) in 2005 and Less is More Approach (LIMA) in 2016. A special group of Mladenović's papers consists of theoretical contributions, which refer to the conditions for the existence of a degenerate solution of some continuous location problems and finding a formula for the dual gap of a simple location problem. Together with the co-authors, he proposed a new method for solving large asymmetric problems of vehicle routing and proved that the method is exact, i.e., finds optimal solutions. Another important characteristic of Mladenović's work is the great applicability of his scientific results to real problems of large dimensions, such as problems in the oil industry, urban planning, traffic, telecommunications, searching large data sets, etc. Examples of industrial use of Mladenović's results include Ultramar Canada, Hydro-Quebec Canada, berthing allocation in the Hong Kong harbour and the Petro-Brazilian over rig transportation.

From the bibliography of Nenad Mladenović, it can be seen that in less than 6 years, from 2017–2022, he has published 60 articles in scientific journals, which is almost a third of all articles he has published. This is the best illustration of the fact that death interrupted him in full creative momentum. But the Variable Neighborhood Search and its numerous applications cannot and will not be erased.

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