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UNIVERSITE CATHOLIQUE DE LOUVAIN

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# Study and Analysis of Networks Flows

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## Abstract



## Acknowledgment



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## Chapter 1

# The Maximum Flow Problem



## Chapter 2

# Existing Algorithms



## Chapter 3

# Data Structures



## Chapter 4

# Improvements of Existing Algorithms





## Chapter 5

# Implementation



## Chapter 6

# Experimental Analysis



## Chapter 7

## Conclusion



# Bibliography

- [1] O. Rossi-Doria, M. Sampels, M. Birattari, M. Chiarandini, M. Dorigo, L. M. Gambardella, J. Knowles, M. Manfrin, M. Mastrolilli, B. Paechter, *et al.*, “A comparison of the performance of different metaheuristics on the timetabling problem,” *Practice and Theory of Automated Timetabling IV*, pp. 329–351, 2003.
- [2] M. Manfrin, M. Birattari, T. Stützle, and M. Dorigo, “Parallel ant colony optimization for the traveling salesman problem,” *Ant Colony Optimization and Swarm Intelligence*, pp. 224–234, 2006.
- [3] M. Dorigo and T. Stützle, “Ant colony optimization: overview and recent advances,” *Handbook of metaheuristics*, pp. 227–263, 2010.
- [4] T. Stützle and M. Dorigo, “Aco algorithms for the traveling salesman problem,” *Evolutionary Algorithms in Engineering and Computer Science*, pp. 163–183, 1999.
- [5] M. Dorigo, M. Birattari, and T. Stutzle, “Ant colony optimization,” *Computational Intelligence Magazine, IEEE*, vol. 1, no. 4, pp. 28–39, 2006.
- [6] M. Dorigo, V. Maniezzo, and A. Colorni, “The ant system: An autocatalytic optimizing process,” -, 1991.
- [7] M. Dorigo and T. Stutzle, *Ant colony optimization*. MIT Press, 2004.
- [8] L. M. Gambardella and M. Dorigo, “An ant colony system hybridized with a new local search for the sequential ordering problem,” *INFORMS Journal on Computing*, vol. 12, no. 3, pp. 237–255, 2000.
- [9] P. Toth and D. Vigo, *The vehicle routing problem*. Siam, 2001.
- [10] M. Dorigo and L. M. Gambardella, “Ant colonies for the travelling salesman problem,” *BioSystems*, vol. 43, no. 2, pp. 73–81, 1997.
- [11] M. Dorigo and L. M. Gambardella, “Ant colony system: a cooperative learning approach to the traveling salesman problem,” *Evolutionary Computation, IEEE Transactions on*, vol. 1, no. 1, pp. 53–66, 1997.
- [12] B. Bullnheimer, R. F. Hartl, and C. Strauss, “Applying the ant system to the vehicle routing problem,” in *Meta-Heuristics*, pp. 285–296, Springer, 1999.

- [13] L. M. Gambardella, É. Taillard, and G. Agazzi, “Macs-vrptw: A multiple colony system for vehicle routing problems with time windows,” in *New ideas in optimization*, Citeseer, 1999.
- [14] T. Stützle and H. H. Hoos, “Max–min ant system,” *Future generation computer systems*, vol. 16, no. 8, pp. 889–914, 2000.
- [15] C. Blum, “Aco applied to group shop scheduling: A case study on intensification and diversification,” in *Ant algorithms*, pp. 14–27, Springer, 2002.
- [16] C. Blum and M. J. Blesa, “New metaheuristic approaches for the edge-weighted k-cardinality tree problem,” *Computers & Operations Research*, vol. 32, no. 6, pp. 1355–1377, 2005.
- [17] R. Michel and M. Middendorf, “An aco algorithm for the shortest common supersequence problem,” 1999.
- [18] G. N. Varela and M. C. Sinclair, “Ant colony optimisation for virtual-wavelength-path routing and wavelength allocation,” in *Evolutionary Computation, 1999. CEC 99. Proceedings of the 1999 Congress on*, vol. 3, IEEE, 1999.
- [19] G. Reinelt, “TspLib - a traveling salesman problem library,” *ORSA journal on computing*, vol. 3, no. 4, pp. 376–384, 1991.
- [20] M. M. Solomon, “Benchmark problems and solutions.” <http://w.cba.neu.edu/~msolomon/problems.htm>, 2005. [Online; accessed 01-february-2014].
- [21] Z. C. S. S. Hlaing and M. A. Khine, “An ant colony optimization algorithm for solving traveling salesman problem,” in *International Conference on Information Communication and Management, Singapore, IPCSIT*, vol. 16, 2011.
- [22] J. E. Bell and P. R. McMullen, “Ant colony optimization techniques for the vehicle routing problem,” *Advanced Engineering Informatics*, vol. 18, no. 1, pp. 41–48, 2004.
- [23] B. Yu, Z.-Z. Yang, and B. Yao, “An improved ant colony optimization for vehicle routing problem,” *European journal of operational research*, vol. 196, no. 1, pp. 171–176, 2009.
- [24] W. F. Tan, L. S. Lee, Z. Majid, and H. V. Seow, “Ant colony optimization for capacitated vehicle routing problem,” *Journal of Computer Science*, vol. 8, no. 6, 2012.
- [25] F. Massen, *Optimization Approaches for Vehicle Routing Problems with Black Box Feasibility*. Universite Catholique de Louvain, 2013.
- [26] M. Dorigo, G. Di Caro, and L. M. Gambardella, “Ant algorithms for discrete optimization,” *Artificial life*, vol. 5, no. 2, pp. 137–172, 1999.
- [27] D. Corne, M. Dorigo, and F. Glover, “The ant colony optimization meta-heuristic,” *New Ideas in Optimization*. McGraw Hill, New York, 1999.



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