UNIVERSITE CATHOLIQUE DE LOUVAIN

ECOLE POLYTECHNIQUE DE LOUVAIN

Study and Analysis of Networks Flows

Supervisor: YVES DEVILLE
Readers: FRANÇOIS AUBRY
JEAN-CHARLES DELVENNE

Thesis submitted for the Master's degree
in computer science and engineering
options: Artificial Intelligence
by DENIS GENON & VICTOR VELGHE

Abstract

Acknowledgment

Contents

Chapter 1

The Maximum Flow Problem

Chapter 2

Existing Algorithms

2.1 Augmenting path algorithms

2.1.1 Introduction

The idea behind the augmenting path algorithms is as follows : As long as there is a path from the source to the sink, we send flow along this path. And so on until there is no more path from the source to the sink.

An available path from the source to the sink is called *augmenting path* and to find it, we use the *residual graph*. A *residual graph* is a double oriented graph with the available capacities. For instance here is a graph with its *residual graph*:
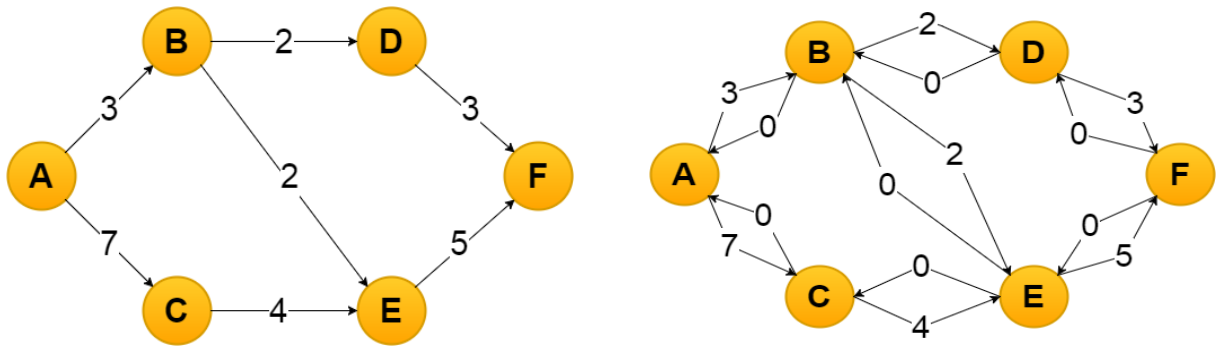

Figure 2.1: Graph with its residual graph

When an *augmenting path* is found, we send a flow equivalent to the minimum capacity of the edges of this path. We update the *residual graph* and then we look for a new augmenting path.

Here is the *residual graph* after sending 4 units of flow through the *augmenting path* A-C-E-F :
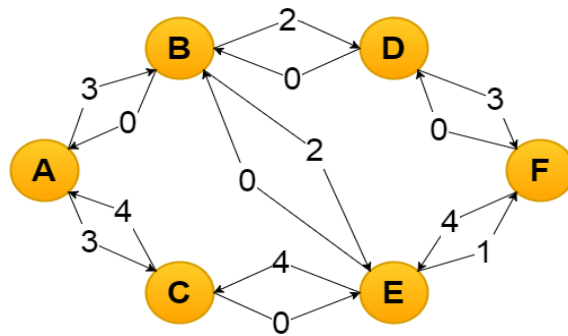
Figure 2.2: Residual graph

The pseudo-code of the augmenting path algorithm is given here :

```
Look for an augmenting path;
while There is an augmenting path do
    Send flow through this path;
    Update the residual graph;
    Look for an new augmenting path;
end
```

2.1.2 Ford-Fulkerson vs Edmonds-Karp

Je cause de la différence entre FF et EK

2.1.3 Complexities

Petite intro pour dire que c'est polynomial

Ford-Fulkerson

Edmonds-Karp

Il faut démontrer que la complexité grand O est pas possible?

2.2 Pre-flow 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.

24

List of Figures

List of Tables