



FINAL REPORT FOR ONR GRANT N000140610607:  
ADAPTIVE AND ROBUST  
RESOURCE ALLOCATION AND SCHEDULING

This grant has explored the design and implementation of adaptive and robust resource allocation and scheduling. It was motivated by the widespread dissemination of telecommunication technologies which enables enterprises and organizations to track their operations in real-time using technologies such as GPS, RFIDs, sensors, and high-performance networks. The ubiquity of telecommunication technologies led to a paradigm shift in business processes producing integrated supply-chains, sense-and-reponse logistics, and lean manufacturing to name a few. It is also producing a fundamental transformation in optimization and decision-support systems. Indeed, organizations can now exploit a wealth of historical and real-time data available, moving their traditional focus from a priori planning to real-time decision-making under uncertainty.

This grant has studied how to realize this paradigm shift. It has studied a wide variety of algorithms for decision making under uncertainty, large-scale optimization, and finding high-quality solutions to complex problems quickly. The main contributions have been

- The framework of online stochastic combinatorial optimization algorithms, i.e., the idea of making decisions during operations, sampling the distributions of the uncertainty, optimizing the obtained scenarios, and aggregating their optimal solutions into a robust solutions across all scenarios.
- The design and analysis of one-step anticipatory algorithms and their applications to a variety of routing, scheduling, and resource allocation problems.
- The design and analysis of multi-step anticipatory algorithms and their applications to resource allocation problems.
- The implementation of decomposition techniques for large-scale logistics applications and, in particular, the use of these techniques to find high-quality solutions quickly.

## Publications

- [1] P. Van Hentenryck and R. Bent. *Online Stochastic Combinatorial Optimization*. MIT Press, 2009. (Paperback version of [5]).
- [2] P. Van Hentenryck and R. Bent. *Online Stochastic Combinatorial Optimization*. Prentice Hall/India, 2007. (Reprint of [5]).
- [3] P. Van Hentenryck and R. Bent. *Online Stochastic Combinatorial Optimization*. The MIT Press, Cambridge, MA, 2006.

- [4] L. Michel, E. Sonderegger, P. Van Hentenryck and A. Shvarstman Optimal Deployment of Eventually-Serializable Data Services. *Annals of Operations Research*, (to appear).
- [5] P. Van Hentenryck, R. Bent, and E. Upfal. Online Stochastic Optimization under Time Constraints. *Annals of Operations Research*, (Published online on September, 18, 2009).
- [6] L. Michel, A. See, and P. Van Hentenryck. Transparent Parallelization of Constraint Programming. *INFORMS Journal on Computing*, 21(3), 363–382, Summer 2009.
- [7] L. Michel, A. See, and P. Van Hentenryck. Parallel and Distributed Local Search in Comet. *Computers and Operations Research*, 36(8), August 2009.
- [8] P. Van Hentenryck, R. Bent, L. Mercier, and Y. Vergados. Online Stochastic Reservation Systems. *Annals of Operations Research*, 171(1), 101–126, 2009.
- [9] L. Mercier and P. Van Hentenryck. Edge Finding for Cumulative Scheduling. *INFORMS Journal on Computing*, 20(1), 2008.
- [10] L. Mercier and P. Van Hentenryck. Strong Polynomiality of Resource Constraint Propagation. *Discrete Optimization*, 4, 288–314, 2007.
- [11] P. Van Hentenryck, R. Bent, and C. Coffrin. Strategic Planing for Disaster Recovery with Stochastic Last Mile Distribution. In *Proceedings of the Sixth International Conference on the Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR'10)*, Bologna, Italy, 2010.
- [12] L. Michel, M. Moraal, A. Shvartsman, E. Sonderegger, and P. Van Hentenryck. Online Selection of Quorum Systems for RAMBO Reconfiguration. In the Proceedings of the 15th International Conference on the Principles and Practice of Constraint Programming (CP-2009), 88–103, Lisbon, Portugal, September 20-24, 2009.
- [13] J.N. Monette, Y. Deville, and P. Van Hentenryck. Just-In-Time Scheduling with Constraint Programming. In the Proceedings of the 19th International Conference on Automated Planning and Scheduling (ICAPS09), Thessaloniki, Greece, September 2009.
- [14] C. Coffrin and L. Michel and A. Shvartsman and E. Sonderegger and P. Van Hentenryck Optimizing Network Deployment of Formally-Specified Distributed Systems. In the 18th International Conference on Software Engineering and Data Engineering (SEDE'09), Las Vegas, June 2009.
- [15] L. Michel and M. Moraal and A. Shvartsman and E. Sonderegger and P. Van Hentenryck. Bandwidth-Limited Optimal Deployment of Eventually-Serializable Data Services. In *CP-AI-OR'09*, Pittsburgh, May 2009.

- [16] G. Dooms and P. Van Hentenryck. Gap Reduction Techniques for Online Stochastic Project Scheduling. In *Proceedings of the Fourth International Conference on the Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR'08)*, Paris, France, May 2008.
- [17] L. Mercier and P. Van Hentenryck. Amsaa: A Multistep Anticipatory Algorithm for Multistage Stochastic Combinatorial Optimization. In *Proceedings of the Fourth International Conference on the Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR'08)*, Paris, France, May 2008.
- [18] L. Michel, E. Sonderegger, P. Van Hentenryck and A. Shvarstman Optimal Deployment of Eventually-Serializable Data Services. In *Proceedings of the Fourth International Conference on the Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR'08)*, Paris, France, May 2008.
- [19] R. Bent and P. Van Hentenryck. Randomized Adaptive Spatial Decoupling For Large-Scale Vehicle Routing with Time Windows. *Proceedings of the Twenty-Second Conference on Artificial Intelligence, Vancouver, Canada. (AAAI'07)*.
- [20] L. Mercier and P. Van Hentenryck. Performance Analysis of Online Anticipatory Algorithms for Large Multistage Stochastic Programs In *Proceedings of the 20th International Joint Conference on Artificial Intelligence, (IJCAI'07)*, Hyderabad, India, January, 2007. (Distinguished Paper (3 out of 1353)).
- [21] R. Bent and P. Van Hentenryck. Waiting and Relocation Strategies in Online Stochastic Vehicle Routing In *Proceedings of the 20th International Joint Conference on Artificial Intelligence, (IJCAI'07)*, Hyderabad, India, January, 2007.
- [22] P. Van Hentenryck, R. Bent, and Y. Vergados. Online Stochastic Reservation Systems. In *Proceedings of the Second International Conference on the Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR'06)*, Cork, Ireland, May 2006.

## Patents

1. Brown ID No.: BU2008-15.

PCT Application No.: PCT/US2009/001450 filed March 5, 2009.

Priority claimed from: U.S. provisional application no. 61/068,282 filed March 5, 2008.

Title: Gap reductions techniques for stochastic algorithms

Formerly known as: Improving scheduling and reservation systems one-step anticipatory algorithms

2. Brown ID No.: BU2008-16.

PCT Application No.: PCT/US2009/001449 filed March 5, 2009.

Priority claimed from: U.S. provisional application no. 61/068,327 filed March 5, 2008.

Title: Improved techniques for stochastic combinatorial optimization.

Formerly known as: AMSAA: A multistep anticipatory algorithm  
for online stochastic combinatorial optimization.