One Problem, Two Structures, Six Solvers, and Ten Years of Personnel Scheduling

Louis-Martin Rousseau

CIRRELT, École Polytechnique de Montréal, Montréal,
C.P. 6128, succ. Centre-ville, Montréal, H3C 3J7,Canada
louis-martin.rousseau@polymtl.ca

The shift-scheduling problem was originally introduced by Edie in 1954 [8] in the context of scheduling highway toll booth operators. It was solved a short time later, by Georges Dantzig [6], using a set covering formulation. However, the Multi-Activity Shift Scheduling (MASSP) version of that problem, where one not only needs to schedule when employees are working or resting, but more precisely, what activity they are performing, still remains a challenge. During this invited lecture, we will recall the turning points of this 60-year journey, focusing particularly on the efforts of the last decade to solve MASSPs.

The first breakthrough came from Constraint Programming (CP), with the introduction of the Regular Language Membership Constraint [13,1], which enabled us to specify shift regulations through Deterministic Finite Automata. Two years later, the Context-free Grammar Constraint [15,18] was introduced, shortly followed by both a decomposed formulation [16] and incremental filtering algorithm [11]. From these constraints it is possible to identify two network structures (paths in a layered directed acyclic graph for *Regular* and hyper-paths in a hyper-graph for *Grammar*).

Using these graph structures, Mixed Integer Programming (MIP) models were initially proposed [3] to address the MASSP. Thanks to Orbital Shrinking [9], a new MIP formulation [4], and hybrid CP-MIP branch and bound [17] were proposed which allowed us to solve these models more efficiently.

Dynamic Programming (DP) algorithms were also developed to optimize (find the shortest paths and hyper-paths) for both *Regular* and *Grammar* given that marginal costs are associated with performing certain activities at a given time. These costs can be estimated manually during a Large Neighbourhood Search (LNS) [14] or obtained through dual values in the context of a Branch-and-Price approach [7,5]. Finally Lazy-Clause Generation (LCG) within CP [10] has shown to produce very good results for a subset of the benchmark originally introduced in [7].

From a practical point of view, the concepts of [5] were implemented into commercial software (*Planora*), while the models using the decomposition of *Regular* were used in case studies involving a major fashion retailer [2] and Hydro Québec's large call center [12].

B. O'Sullivan (Ed.): CP 2014, LNCS 8656, pp. 4–5, 2014.

References

1. Beldiceanu, N., Carlsson, M., Petit, T.: Deriving filtering algorithms from constraint checkers. In: Wallace, M. (ed.) CP 2004. LNCS, vol. 3258, pp. 107–122. Springer, Heidelberg (2004)
2. Chapados, N., Joliveau, M., L'Ecuyer, P., Rousseau, L.M.: Retail Store Scheduling for Profit. European Journal of Operations Research (2014), doi:10.1016/j.ejor.2014.05.033
3. Côté, M.C., Gendron, B., Quimper, C.G., Rousseau, L.M.: Formal languages for integer programming modeling of shift scheduling problems. Constraints 16(1), 54–76 (2011)
4. Côté, M.C., Gendron, B., Rousseau, L.M.: Grammar-based integer programming models for multiactivity shift scheduling. Management Science 57(1), 151–163 (2011)
5. Côté, M.C., Gendron, B., Rousseau, L.M.: Grammar-based column generation for personalized multi-activity shift scheduling. INFORMS Journal on Computing 25(3), 461–474 (2013)
6. Dantzig, G.: A comment on Edie's traffic delay at toll booths. Journal of the Operations Research Society of America 2, 339–341 (1954)
7. Demassey, S., Pesant, G., Rousseau, L.M.: A cost-regular based hybrid column generation approach. Constraints 11(4), 315–333 (2006)
8. Edie, L.: Traffic delays at toll booths. Journal of the Operations Research Society of America 2, 107–138 (1954)
9. Fischetti, M., Liberti, L.: Orbital shrinking. In: Mahjoub, A.R., Markakis, V., Milis, I., Paschos, V.T. (eds.) ISCO 2012. LNCS, vol. 7422, pp. 48–58. Springer, Heidelberg (2012)
10. Gange, G., Stuckey, P.J., Van Hentenryck, P.: Explaining Propagators for Edge-Valued Decision Diagrams. In: Schulte, C. (ed.) CP 2013. LNCS, vol. 8124, pp. 340–355. Springer, Heidelberg (2013)
11. Kadioglu, S., Sellmann, M.: Grammar constraints. Constraints 15(1), 117–144 (2010)
12. Pelleau, M., Rousseau, L.-M., L'Ecuyer, P., Zegal, W., Delorme, L.: Scheduling of Agents from Forecasted Future Call Arrivals at Hydro-Québec' s Call Centers. In: Principles and Practice of Constraint Programming, CP 2013, Springer, Heidelberg (2014)
13. Pesant, G.: A regular language membership constraint for finite sequences of variables. In: Wallace, M. (ed.) CP 2004. LNCS, vol. 3258, pp. 482–495. Springer, Heidelberg (2004)
14. Quimper, C.G., Rousseau, L.M.: A large neighbourhood search approach to the multi-activity shift scheduling problem. Journal of Heuristics 16(3), 373–392 (2010)
15. Quimper, C.G., Walsh, T.: Global grammar constraints. In: Benhamou, F. (ed.) CP 2006. LNCS, vol. 4204, pp. 751–755. Springer, Heidelberg (2006)
16. Quimper, C.G., Walsh, T.: Decomposing global grammar constraints. In: Bessière, C. (ed.) CP 2007. LNCS, vol. 4741, pp. 590–604. Springer, Heidelberg (2007)
17. Salvagnin, D., Walsh, T.: A hybrid MIP/CP approach for multi-activity shift scheduling. In: Milano, M. (ed.) CP 2012. LNCS, vol. 7514, pp. 633–646. Springer, Heidelberg (2012)
18. Sellmann, M.: The theory of grammar constraints. In: Benhamou, F. (ed.) CP 2006. LNCS, vol. 4204, pp. 530–544. Springer, Heidelberg (2006)