Mixed Analytical / DEVS Approach to ARGESIM Comparison C14 “Supply Chain Management” using Xpress-MP and AnyLogic

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Programs. Xpress-MP MP is the standard LP Solver of Dash Optimization (www.dashoptimization.com). AnyLogic (www.xjtek.com) is a general-purpose simulator for discrete but also for continuous and hybrid application. The modelling technology of AnyLogic is based on Java so that building simulation models using AnyLogic should be easy for experienced programmers.

Model. Based on the Comparison 14 we want to demonstrate a possible connection between a discrete-event simulation and exact optimization. We developed a LP model which is aligned with the definition of the simulation model described in Comparison 14. Some parameters of the original definition have been changed slightly in order to apply optimization and to meet the requirements of the LP model.

We assumed a time horizon of 10 days (240 hours). Within our model factories 1 and 3 supply products 1 to 6, and factories 2 and 4 supply products 7 to 12. The amounts of products supplied at each factory have been generated randomly according to the definition of Comparison 14. Furthermore, we included inventory costs at the factories and the transportation costs are linearly depending on the number of products ordered.

The objective function consists of the inventory costs at the factories, the inventory costs of the distributors and the transportation costs between factories and distributors. To prohibit a solution where no product is delivered at all, the objective function of the optimization model is augmented by penalty costs, occurring if an order of one of the wholesalers is not fulfilled.

Without taken into account any stochastics, the goal of this experiment was to find the optimal solution for the whole network. Both the factories and the distributors are provided with an initial inventory level for each product. The inventory level costs are calculated based on the inventory level in the periods before ordering. The constraints of the LP model ensure that the products are sent through valid routes. Furthermore, the objective function is subject to several inventory balance and flow equations. The model was implemented in XPress-MP.

We also considered the possibility to develop a binary model minimizing the ordering costs, in order to have an exact representation of the assumptions given in the definition of Comparison 14. Due to the complexity of this problem (about 480 binary decision variables), the effort needed to optimize this model exceeded a reasonable amount of time.

Furthermore, we took the solution of the Comparison 14 provided by Michael Gyimesi and Johannes Kropf (SNE, Issues 35/36, December 2002, p.85) and adapted it according to the changes assumed for the LP model. The inventory costs for the factories and for the distributors have been assumed to be nonlinear. The distributors order the products following an ordering plan, which is at first determined in the optimization model using linearised cost functions. After a simulation run, the average inventory costs at each factory and at each distributor are computed and in turn are used for the next optimization run. We performed three iterations of this ping-pong game until the simulation model provided the same average inventory costs as in the previous round.

Results: For one of the test instances we assumed piecewise linear cost functions. Three iterations of the ping-pong game had to be performed, until the simulation model provided the same average inventory costs as in the previous round. Table 1 shows the changes of the inventory costs at factories (F) and at distributors (D) during the experiment.

	F1/F2/F3/F4	D1/D2/D3/D4
1st run	1,5/1,5/1,5/1,5	2,5/2,5/2,5/2,5
2nd run	3,44/3,29/3,23/3,19	1,0/1,03/1,02/1,01
3rd run	3,39/3,11/3,04/2,92	1,04/1,04/1,06/1,04

Table 1: Change of linearised inventory costs

We tested also other scenarios with logarithmic and piecewise constant cost functions. In the logarithmic case three iterations were necessary to get the same results for the simulation and the optimization model, whereas in the case of piecewise constant cost functions we got trapped in a cycle. Although we can gain convergence in the first and second example, we do not know if we are trapped in a local minimum or if we have found the global optimum. Especially if we consider more complex networks with different types of nonlinearities, it will be very difficult to find some general conditions under which we can guarantee convergence and to find an optimal solution.

C14 Classification: Mixed Analytical / DEVS Appr.

Simulator: Xpress-MP Rel. 2003, AnyLogic 5.1