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Multi-criteria satisficing for Supply-chain Management: a hierarchical approach

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Abstract

Supply-chain management of manufacturing systems poses new challenges to researchers who are still employing traditional methodologies to tackle them. What is needed is a brand new way of looking at the problem and using techniques at levels they work best to find the most optimum solutions.

In this paper, a hierarchical methodology, using prescriptive and analytical techniques, is proposed to tackle the multi-criteria, non-linear, stochastic nature of the problem that supply-chain management of manufacturing systems poses.

Problem Domain

Supply-chain management issues for manufacturing systems are characterized by a plethora of variables that define the problem space. These variables include the individual customer orders, raw material availability at individual factories, the equipment and the work-in-process in the factories, the operating policies on the shop-floor, and so on.

These issues also require satisfying a multitude of performance criteria, which include, but are not limited to, meeting customer due-dates, keeping the inventory low, and maintaining high throughputs at all the factories in the enterprise.

These problems have so far been approached using either purely analytical (mathematical programming, queuing) techniques, or the simulation-based techniques, which employ artificial intelligence and simulation in unison. We refer to the simulation-based techniques as prescriptive simulation techniques.

Manufacturing systems can be treated as discrete-valued, non-linear, stochastic systems and optimization techniques for them have been developed. But when multiple objectives need to be satisfied, these techniques fail to treat them satisfactorily.

Prescriptive approaches, as contrasted with optimization approaches, not only require the domain knowledge to narrow the search space, but also sometimes stop short of finding the optimum system configuration, as was realized during the development of APSS (Piplani, 1995).

APSS was compared with SIMICOM (Azadivar and Lee, 1988) which used an optimization approach for discrete-valued stochastic systems. SIMICOM, given the reduced set of variables, was able to do a better job of focusing on the target levels, even though it took quite a few extra iterations to achieve that. Without the knowledge of the domain, however, it was at a disadvantage, and attempted to use many more permutations of the variables and their levels to find the optimal combination.

Problem formulation

The problem described above can be formulated (analytically) as a stochastic root finding problem, where the objective is to solve equation $g(x) = \gamma$, where g can only be estimated with some error by an estimator $Y(x)$. γ is the desired system performance, x is the value of the design variable, $g(x)$ is the corresponding performance, and $Y(x)$ is the estimated system performance obtained from simulation experiment. x, g, and γ can be vectors.

A hierarchical approach

In the current research on optimization for supply-chain management of manufacturing systems, we are harnessing the strength of the two approaches and using them at the level they work best. In a two-level system, the prescriptive system is used at the upper level, and using the domain knowledge narrows down the set of variables affecting the performance criteria of interest. At the lower level, domain-independent (blind) search is used to explore the search space (defined by the set of decision variables narrowed down at the upper level). Starting with a reduced and manageable set of decision variables, the blind search technique has a better chance of finding the optimum levels that meet the performance criteria. Without the benefit of the domain knowledge (incorporated at the upper level), blind search methods alone need too many iterations to exhaustively explore the search space defined by the system variables, and that can be prohibitive in case of realistic and large systems. The problem with using the prescriptive methods alone is (as mentioned above) that they sometimes fail to meet the target levels, and stop short. So far the results have been encouraging, and in the near future we hope to produce more concrete examples to support our thesis.

In our current methodology, the domain-independent search takes over where the heuristic search stops. And working with the set of variables already narrowed down by using the domain knowledge, the blind search is able to explore the narrow space thoroughly.

References

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