Micro-Boss: Dual-use ARPI scheduling technology helps improve manufacturing performance

In complex, large-scale domains such as military transportation or manufacturing, traditional scheduling technologies often prove inadequate because they rely on rigid and oversimplified models. These models cannot capture critical domain constraints, preferences, or objectives. They provide little or no support for dynamic schedule revisions necessary to react to contingencies (for example, changes in the tasks to perform or in resource availability) or to help users evaluate and compare alternative scheduling options (what-if analysis).

Over the past several years, researchers at Carnegie Mellon University have developed a family of scheduling procedures that attempts to fill this void. These procedures efficiently build and dynamically revise high-quality solutions to complex transportation and manufacturing scheduling problems.[3, 5] This work, supported by ARPI, advocates an opportunistic constraint-directed scheduling approach. This approach regularly monitors search and dynamically redirects the problem-solving toward the most critical decision points.

The Micro-Boss scheduler embodies this approach. In Micro-Boss, a micro-opportunistic search procedure tracks resource contention during schedule construction and revision. The system constantly focuses optimization on those groups of operations that cause the highest contention.[1]

By late 1993, Carnegie Mellon had carried out extensive experiments comparing Micro-Boss with a number of competing scheduling techniques on randomly generated just-in-time job-shop scheduling problems representative of a wide range of load conditions.[3, 2] This included comparisons with combinations of up to 39 dispatch-based scheduling techniques, and competing bottleneck-centered scheduling approaches. Micro-Boss significantly improved performance under all conditions considered in these studies. Improvements could be traced back to the flexibility of the Micro-Boss search procedure, the accuracy of its contention analysis, and the power of its bottleneck optimization heuristics.

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Further encouragement was also received from the excellent performance of the Knowledge-Based Logistics Planning Shell. Carnegie Group developed KBLPS to help US Army logisticians solve commodity distribution problems (for example, distribution of ammunition, fuel, and water). The system incorporates variations of the contention analysis and focus-of-attention mechanisms developed in Micro-Boss, and has now been deployed at multiple Army sites.[4]

The next step was to see how Micro-Boss would fare on an actual problem. The opportunity came when Raytheon approached ARPA about advanced technologies for scheduling production at its facilities. Stephen Cross of ARPA initiated joint meetings to introduce Raytheon to Carnegie Mellon's scheduling technology. The meetings identified an initial problem: scheduling production in the printed wiring assembly area at Raytheon's Andover facility. The selection of this problem was motivated by its strategic importance to Raytheon as well as the considerable technical challenges it presented. The problem requires scheduling an environment with 1,000 different part types, a volume of approximately 35,000 parts per month grouped in approximately 1,000 orders, process routings of approximately 30 operations per job, and 148 resources grouped in 23 workcenters. Additional difficulties include complex dynamic bottlenecks, variable batch sizes, overlapping between successive manufacturing steps, and a highly dynamic environment.

Customizing Micro-Boss for this problem took a little over six months. It included significant scale-up (the system had never solved problems with more than 1,000 operations). Carnegie Mellon also had to generalize the constraints for which the system can account. (One example is overlapping constraints, which let the system transfer jobs as small sublots between manufacturing stages, without waiting for the entire job to be processed.)

The resulting system is written in C++ and has an X/Motif interface. Comparison with the shop's existing practice, which combined family-based lead times with an earliest-due-date dispatch mechanism, was carried out using actual load conditions during the first half of 1994, as well as conditions obtained by artificially inflating the facility's load 10 and 20%. Under all three conditions, Micro-Boss significantly improved performance. It reduced lead times 55 to 60%. It significantly improved due-date performance. (It reduced average tardiness 14 to 16%, and over 50% when factoring out minimum tardiness inherited from earlier stages.) The system also reduced inventory 20 to 30%.

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