The Consensus Scheduling Model: Negotiation among Peers

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Abstract

The Consensus Scheduling Model (CSM) is introduced as a way to accommodate negotiation in over-constrained, distributed scheduling problems. The CSM is appropriate for negotiation among a group of peers and is also applicable to a manager that must balance conflicting views of its workers. The distributed scheduling algorithm that is used selects a candidate from the priority list of resource requests and inserts that candidate into the evolving timetable. Two protocols are required. The minimax protocol assures equitable power among the peers. The bumping protocol allows reactive scheduling by using a request's total worth to dictate when a new request can seize a previously assigned resource. A request's total worth is the sum of its priority value, its ordering value, and any bonus points received by previous negotiations. Three styles of negotiation are examined: unilateral, verbose, and periodic.

In cases where a problem is over-constrained, no solution is possible unless the system relaxes the constraints. Inclusion of negotiation within the communication protocol allows the system to adjust its constraints in an intelligent way. In a distributed environment these relaxation choices may be made by multiple users, and the users need to negotiate about relaxing some constraints.

The main goal of this work is to determine appropriate models for negotiation among peers. This goal generates the following criteria on which the design of CSM is based: (1) the schedule's evaluation and the decision to relax constraints are distributed; (2) the human peers are able to give their constraints and preferences to the system without being bound to the tedious communication and negotiation processes; (3) the system goal is to maximize the total worth of the system; (4) the implementation for scheduling has been modularized into four components: accumulation of resources, communication, scheduling, and negotiation; (5) the protocol is one form of equitable scheduling among peers; (6) variations in the calculations of a constraint's worth are provided; (7) the model can deal with multiple, independent schedules being constructed and negotiated simultaneously; and (8) only requests that require the shared resources are made public.

The CSM begins with a committee of peers and adds a Virtual Chair (VC). VC does not dictate to the committee members as is customary in a hierarchical structure, but acts as secretary of the committee by (1) performing all scheduling of the shared resources, (2) incorporating individual members' objections to proposed schedules, and (3) accommodating members' changing constraints and utilities. The collection of requirements and associated utilities that the committee members present to VC is the public knowledge.

Each request for a shared resource has a priority value assigned to it by the requestor. VC begins scheduling by randomly selecting one member after the other, with no repetitions, until each department has been selected once. VC holds a tab for each member as follows: when a resource with priority P is scheduled, add to the member's tab the cost P/(10N) where N is the total number of requests and P ≤ 10. Until all resources are assigned, repeat (a) use the minimax protocol to select the next member and assigned its highest rated, unassigned request, and (b) insert the resources into the schedule and adjust the member's tab; the bumping protocol may be required here.

The *minimax* protocol chooses the next member to schedule based on the minimal current tab and from that department's request list of unassigned resources, chooses the request with the maximum priority. The *bumping* protocol allows transference of an already-assigned resource to a later requestor and rescheduling of the original request. This transfer is bumping and can occur only if the request being added is worth more than the request being transferred. The worth of a request is the weighted sum of its priority value, its ordering value, and any bonus points received by previous negotiations.

In the *unilateral* negotiation style committee members agree that no negotiation will take place when the system is over-constrained. This style is also used in conjunction with other styles as a last resort after other styles of negotiation have failed to resolve a dispute. When negotiation between VC and the members begins in the middle of scheduling, all requests of lesser priority have to wait. This style of negotiation is *verbose*. Two different reward types are considered for verbose negotiation. The *group-rate* reward affects all unscheduled request of the rewarded member by changing its tab calculations. The *coupon* reward asks that a specific number of unscheduled courses be given bonus priority points. In *periodic* negotiations, VC fills as many request as possible, notes the unfilled requests, and continues constructing the schedule. The members are asked to help accommodate the unfilled requests after the current schedule and unfilled requests are presented. VC can reward a chosen compliant member by attempting to *upgrade* all of the compliant member's requests by adding points to each request's worth.

All styles have been implemented and tested using the Parallel Virtual Machine on a SUN network.

One possible expansion allows the requests to include constraints; a request may include priorities together with other constraints about time or location. Other styles of negotiation that look promising are either those based on timing or those based on structure. For example, another appropriate structure-based style of negotiation for large systems may be a *delay* style, which lies between the periodic and the verbose styles

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