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A Hybrid Job-Shop Scheduling System

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Abstract

The intention of the scheduling system developed at the Fraunhofer-Institute for Material Flow and Logistics is the support of a scheduler working in a job-shop. Due to the existing requirements for a job-shop scheduling system the usage of flexible knowledge representation and processing techniques is necessary. Within this system the attempt was made to combine the advantages of symbolic AI-techniques with those of neural networks.

System structure

The scheduling system is situated below a MRP system giving the relevant data for the schedule generation. This data contains information about the orders, work plans and resources, the optimization goals and the strategies. Out of this data local, global and strategic constraints are generated.

The local constraints describe the strict requirements the schedule has to fullfil. These are the sequence of operations, the demand for resources, the capacity restriction of resources, and the due dates. Beside the strict requirements global optimization goals have to be considered within the schedule. An optimization goal consists of an optimization criterion whose value describes certain costs (throughput time, resource utilization, inventory, tardiness) and a goal description (minimization of throughput time, minimization of weighted resource utilization, ...). These global constraints represent the optimization goals as preferences. Strategies for building up and refining a schedule are formulated as strategic constraints. These strategic constraints contains a description about when certain strategies can be used, where the schedule can be made more detailled, how specific situations can be detected and what kind of actions have to take place, how the data of the schedule can be aggregated to make the detection of situations possible, and how specific requirements of the factory can be taken into account. All three type of constraints are used

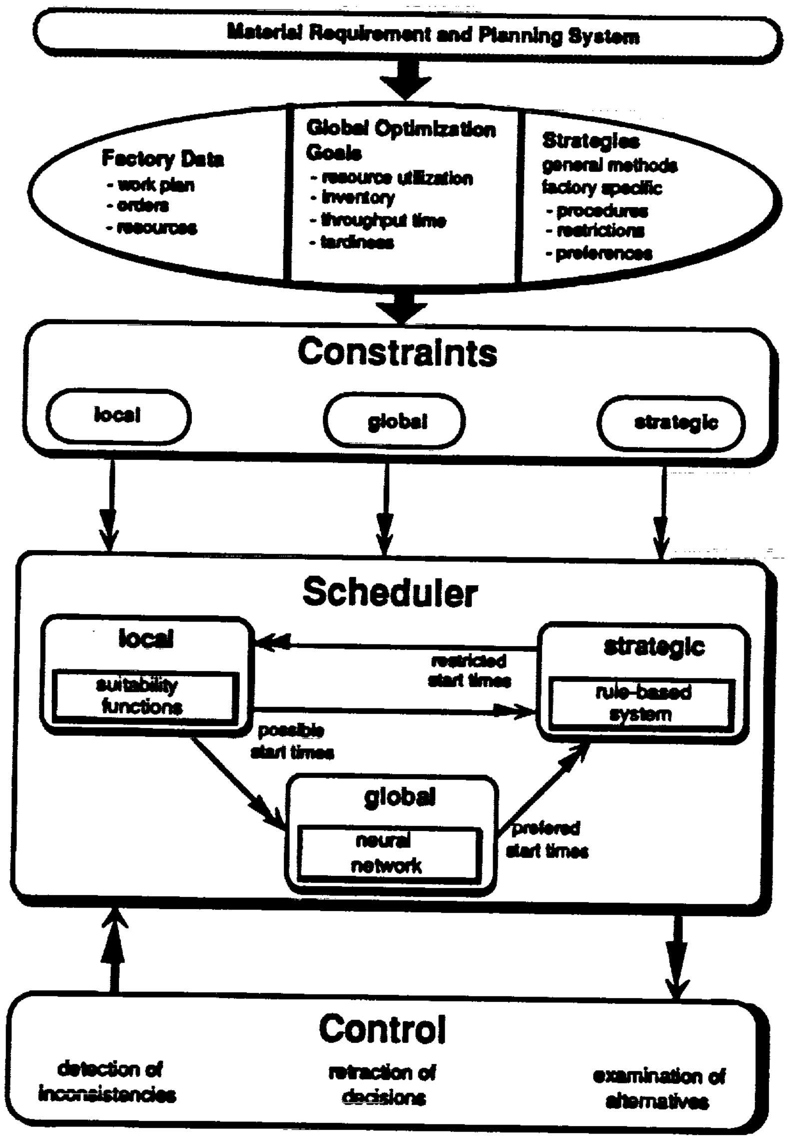

Fig. 1: Structure of the Scheduling System

by the different schedulers (local, global, strategic) to build up a schedule. The structure of the scheduling system is shown in Fig. 1.

Generation of the schedule

For the generation of the schedule all three schedulers work on it while the information between them is exchanged through the partially detailled schedule. The process of the schedule generation can be described as follows. In a first phase the local scheduler makes a preliminary analysis of the starting time for every operation. This analysis is done with respect to the strict requirements and preferences the schedule should fulfill. The possible starting times are determined through the propagation of the local constraints within so called suitability functions [JOHNSTON 89]. Suitability functions describe for every operation how desirable it is to start it at a certain time, so they can be described as functions over the time (Fig. 2). When the value of a suitability function for an operation is zero this operation cannot be started at that time. The local scheduler generates a schedule in which all times where an operation cannot start are excluded. The propagation of the local constraints are based onto Allen's time relations [ALLEN 83], the values of the constraints being suitability functions (Fig. 3).

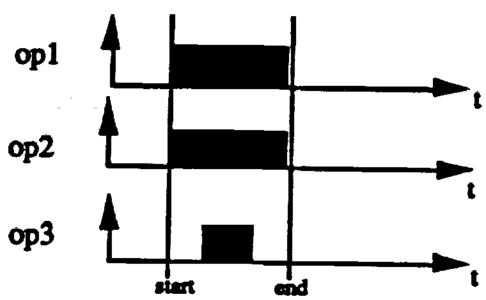

Fig. 2: Example of suitability function before propagation

Each time relation is expressed by a utility function (Fig. 4). This type of function represents a relative measure for the preference of the starting time of an operation. In an extention of the time relations static constraints for the first possible start time, the least possible end time, and the capacity of a resource are built.

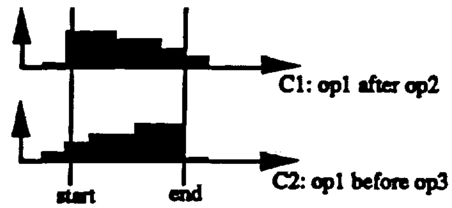

Fig. 3: Constraints as utility functions

In each propagation step an operation is chosen and for each constraint to another operation a sub-suitability function is being built. The result is a suitability that shows the possible starting times of this operation under a constraint.

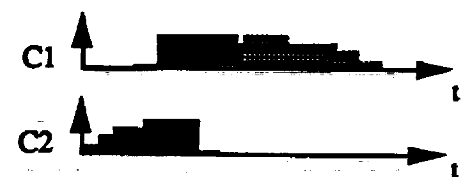

Fig. 4 : Resulting sub-suitability functions

At each propagation step the new suitability function is formed out of the product of all sub-suitabilites and the static suitabilities. Within this new suitability all constraints have been taken into account (Fig. 5). If the suitability function has changed all suitabilities of a constrained operation must be updated. When no suitability changes anymore the propagation ends. In the CSP - notation this propagation creates an arc consistent graph.

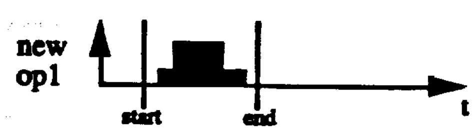

Fig. 5: Suitability Function after propagation

Besides the strict requirements the global optimization goals should also be considered within the schedule. This is done by the global scheduler which refines the possible starting times of every operation by using a neural network.

This neural network is built up based upon the possible starting times determined through the local scheduler. The neural network is a Guarded-Discrete-Stochastic Network (GDS) a special type of Hopfield net [JOHNSTON/ ADORF 89], [MINTON ET AL. 90], [HOPFIELD/ TANK 85], [HOPFIELD/TANK 86]. The main idea is a unit guarding a subset of normal units, so that it is guaranteed that one unit is active. In the scheduling domain it helps to generate schedules for all operations and resources and not for a subset what would only be possible with Hopfield-nets [JOHNSTON/ ADORF 89]. The net is divided into two parts, the operation net and the resource net. The weights between the units of the operation net are explicitly set by the goals of the optimization (minimization of throughput time, weighted resource utilization, tardiness and work in progress). All units have a bias which is based on the results of the local scheduler, thus representing the suitability functions. The activation of the units of the operation net corresponds to it's preferred start time interval while the activation of the resource units represent the remaining capacity in that time interval.

The net is arranged in a matrix-like manner. While the rows represent the operations and resources, the columns contain the time intervals in which the suitability functions of all operations are constant. The update of all units of both nets is done synchronically with the same probability and regarding the state of the guarding units. The convergence of GDS-networks is not guaranteed, and so we impose a restriction on the number of epochs [JOHNSTON/ADORF 89]. The result of a stable state of the neural network is an optimized schedule with respect to the different optimization goals.

The local and the global scheduler work on the schedule as a whole, i.e. changes in the schedule affect all operations. These changes are generally rather coarse. The strategic scheduler on the other hand selects one operation out of the schedule for which it does a detailled planning. The strategies the scheduler uses for this are described within the strategic constraints. Strategic constraints are formulated as rules on four levels of abstraction:

- metarules

  These rules describe which strategies are adequate at certain states of the schedule.

- strategies

  The strategies describe how to refine the schedule (e.g. scheduling the critical operations first) taking into account the state of all operations and resources.

- situation & action

  These rules are used to detect situations (e.g. when an operation is critical) and to suggest actions (e.g. scheduling an operation in it's preferred time interval). The view of these rules is local, looking at the actual state of an operation or resource within the schedule.

- transformation & reduction

  With these rules the actual state of the current schedule can be reduced to the relevant informations (e.g. the preferred time interval for starting an operation) used by the rules of the higher abstraction levels.

As a first step the strategic scheduler selects an adequate strategy by using the metarules. The strategies suggest detailled changes for the scheduling of a selected operation. This selection is done by the strategic constraints describing the situation & action and transformation & reduction. The suggestions are based upon the actual schedule containing the possible and the preferred starting times for each operation as a result of the local and the global scheduler. The suggestion which seems to have the most promising effects on the schedule is integrated into the schedule and the effects are propagated through the suitability functions using the local scheduler. This cycle (local – global – strategic scheduling) continues until all operations are scheduled. In the case that the decision of the strategic scheduler leads to an inconsistent schedule this decision and all it's effects have to be retracted and an alternative has to be chosen. This work is done by a control component. The work of the three schedulers can be seen as a stepwise refinement of the schedule. The possible starting times for each operation are repeatedly restricted until a sufficient exact starting point or a sufficient small interval for the starting time is determined.

At the moment the system described above is in the state of implementation. So a judgement about the quality of the scheduling system can't be done yet. But the parts implemented so far show promising results, so that we are rather hopeful about fulfilling the objectives the system should meet concerning the quality of the schedule.

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