Ana Almeida, Goreti Marreiros, Constantino Martins
Knowledge Engineering and Decision Support Research Group - GECAD,
Computer Science Department
Institute of Engineering of Porto, Porto, PORTUGAL
{ana, goreti,const}@dei.isep.ipp.pt

Scheduling is a multi-criteria decision problem in practice, where different schedulers may agree on key objectives but differ greatly on their relative importance in a particular situation. This kind of problems can be tackled with Collaborative approaches, which is the aim of this work. Collaboration supports work being undertaken by dispersed entities allowing the sharing of final results and also the process of obtaining them. This involve a range of activities such as information exchanging, knowledge sharing, argumentation, problem solving strategies, role playing, group mediation, individual training and conflict resolution, among other. Here, we propose a Collaborative framework with an Adaptive behaviour to be used in Manufacturing Scheduling Environments.

1 INTRODUCTION

Today organizations pursue the global objectives of high resource utilization, fast order turnaround and outstanding costumer service. The latter relies on delivery accuracy, i.e., delivering goods on time, with quality and low costs. These are some critical factors of success of an organization, so one of the main aspects for competitiveness and success of an organization is the efficient production managing, particularly in production scheduling which is a complex problem when dealing with multiple criteria sometimes with conflicting goals in dynamic environments with high degree variation factors. This scenario is more problematic because it is known that in reality variables behaviour is not the same as planned, so there is a strong possibility to reformulate the existing plan and the need to change current schedule to adapt to emerging modifications.

Generally, we may say that the present business environment is characterized by the use of groups, working in distributed environments and dealing with uncertainty, ambiguous problem definitions, and rapidly changing information.

Scheduling decisions are often characterized by goals, roles, activities and resources that are dynamically changing, or uncertain. For improved competitiveness scheduling decisions should arise from the integration of different production functions where each participating actor collaborates in achieving a solution.

The purpose of this work is to develop an Adaptive Collaborative Framework that uses Group Decision Support (GDS) and Adaptation concepts to support the scheduling process on manufacturing environments.

This paper is organized as follows. Sections 2 presents a background research giving a general approach to Collaborative Scheduling, Group Decision Support and Adaptive Systems. The architecture and interaction model to support Adaptive Decision Support in Collaborative Scheduling are presented in section 3, and an

illustrative example is provided in section 4. Finally section 5 presents some conclusions.

2 BACKGROUND

An approach to avoid the gap between automatic scheduling and humans is the establishment of Adaptive Collaborative Scheduling Systems, where users and computers collaborate in plans generation, identifying candidate alternatives, thus profiting the better of the two worlds. The user provides intuition, a notion about goals and appropriate trade-off, and refined problem resolution strategies. The computer provides adaptation to user, skill to manage details, to assign and schedule resources and operations, and to analyze quantitatively the suggested choices. These forms of collaboration may provide a very powerful approach to multi-objective decision support in complex manufacturing environments.

2.1 Collaborative Scheduling

Collaborative scheduling integrates multiple problem solving approaches to produce a set of solutions to a single scheduling problem. A wide study on the diversity of scheduling methods can be found in literature (Almeida, 2002; Almeida et al., 2002; Morton and Pentico, 2003). Collaboration can mean interaction between humans, between scheduling methods and between humans and scheduling methods. Through complexity and fashion how production scheduling problems were tackled in the past, we can actually conclude that there is a gap between the way that scheduling systems solve problems and the way human resolves them. While automatic scheduling systems need complete specification of goals and scenario before beginning problem resolution, humans progressively learn with scenario and change their goals during planning and execution. Automatic scheduling quantitatively evaluates plans while persons evaluate them subjectively. While automatic systems focus on one solution at a time, persons compare options and alternatives before decision.

2.2 Group Decision Support

In Collaborative Network Organizations is mandatory to support collaborative work. Collaborative work presupposes that we will have a group of people that has as mission the completion of a specific task (e.g. making a decision) (Camarinha-Matos, 2003). The number of elements involved in the group may be variable, as well as the persistency of the group (permanent or temporary). The group members may be in different places, meet in an asynchronous way (different times), may belong to different organizations. Collaborative work has inherent advantages (e.g. greater pool of knowledge, different perspectives, increased acceptance) but has also disadvantages (e.g. social pressure, domination, goal displacement, groupthink).

The term Group Decision Support System (Huber, 1982; Kull, 1982; Lewis, 1982; Huber, 1984) emerged effectively in the beginning of the eighty-decade. According to Huber (1984) a GDSS consists of a set of software, hardware, languages components and procedures that support a group of people engaged in a decision related meeting. A more recent definition is from Nunamaker et. al (1997)

defining GDSSs as interactive computer-based environment which supports concerted and coordinated team effort towards completion of joint tasks.

2.3 Adaptive Systems

Adaptive behavior focuses on each particular member profile, providing him with appropriate information presented in the most suitable manner. This can limit information requirements and exchanging, and also the number and duration of interactions with the framework, therefore, reduce interaction time and improve transactions' quality and efficiency, enhancing individual members' contribution to the process. This, of course, leads to a significant gain of the collaboration process. In fact adaptation/personalization is becoming one of the main requirements of any system in different application areas, such as manufacturing, education and services. The main objective of Adaptive Systems (AS) is to adequate its relation with the user (content presentation, navigation, interface, etc.) according to a predefined but updatable model of the user that reflects his/her objectives, preferences, knowledge and competences (Brusilovsky, 2001; De Bra, 2004).

The architecture proposed, for example by Benyon (1993) and De Bra (2004), indicate that the AS must have three essential parts: Domain Model (DM), Interaction Model (IM) and User Model (UM).

2.3.1 Adaptive collaborative framework for scheduling

Our proposal considers multiple scheduling objectives in a global multi-criteria collaborative framework (Almeida & Marreiros, 2006). It generates several scheduling alternatives by using autonomous agents which encapsulates different scheduling algorithms. Each scheduling alternative represents a solution regarding an objective such as, accomplishment of deadlines, minimizing throughput times, maximizing profitability, product quality, and minimizing manufacturing disruptions.

This Adaptive Collaborative Decision Support Framework provides decision support considering the negotiation process of a group of users, each one of them with a different perception of the problem, effectively acting as a team to achieve a common and unique solution.

Our framework is an interactive system in which human scheduler's knowledge of organization, customer, and manufacturing issues play the role of an agent in developing a final scheduling solution.

Over many years, customer service and sales personnel have come to know and understand the special requirements of their customers, suppliers, and distributors, but this knowledge is not usually shared with the manufacturing service. A scheduling decision, must take into account the knowledge and experience of different individuals, with different points of view, allowing the consideration of broad issues of the company.

It is impractical to capture too many of the individual special constraints and considerations within the scheduling system itself. Such systems tend to be less efficient, and more brittle. Using the interface, the human, like all agents, decides what to work on, by selecting candidate solutions evaluated according to several important criteria.

To support effective cooperation between the group of humans' decision makers and agents, the scheduling system have an intuitive user-interface allowing the users to manipulate schedules down to the smallest detail.

A better interaction between the human being and the systems is necessary; we intend to achieve this through the construction of Adaptive Environments. This is especially important when we are dealing with Collaborative Decision Support Systems.

The architecture of the system has three essential parts as it can be observed on Figure 1.

Figure 1- Approach to collaborative scheduling through group decision support

Scheduling module

The Scheduling Module (SM) aims at generate a set of possible solutions for a specific scheduling problem. The SM is composed by several agents, namely:

Scheduling agents that are different autonomous agents each one of them embodying a particular scheduling algorithm;

Information agent, which, in accordance with the type of scheduling problem, sets a time window for the generation of the several scheduling alternatives;

Setting agent which settle on the criteria importance according with the global preferences of the GDS members, in order to cover all the relationships arising from the different departments.

2.4 Group Decision Support Module

One way of enhancing collaboration between agents and humans is to produce not one but many candidate solutions, evaluated with respect to multiple criteria. This allows users to gain important insights into the tradeoffs between multiple

competing objectives. They express their preferences by imposing weighting factors for different criteria. The GDMS will support the members of a scheduling meeting and the facilitator. This last one prepares the meeting and invites a group of people to participate, and to exchange different points of view, expertise and information, in order to choose the “best” solution from the set of scheduling solutions proposed by the SM.

The GDMS is composed by the following components (Marreiros et al., 2004):

- Setup, operated by the facilitator during the pre-meeting phase, in several configuration and parameterization activities;
- Management, which supports the meeting in all its phases, sending “notifications” (by e-mail) to the facilitator or to the group members will be also responsible for the communications with the SM;
- Multi-criteria, used by the facilitator to introduce a possible set of criteria;
- Voting, responsible for the emission of “vote bulletins”, and for the publication of results;
- Argumentation, where participants argue for the most interesting alternatives or against the worst alternatives, according to his/her preferences.

2.5 Adaptation Module

The Adaptation Module (AM) is defined as a system that monitors user behaviour and adapts its presentation accordingly. User behaviour is mostly defined upon its interaction with the system itself. In our case, system tries to adapt the GDMS interface to the skills of scheduler expert, reorganizing the sequence of content presentation according to the interaction provided. It is composed by three components:

- User Model (UM), that describes user information, knowledge and preferences. This model express, supply and assign conclusions about user characteristics;
- Domain Model that represents concept hierarchies or maps and the related structure for user objective and knowledge level representation, either quantitative, qualitative or probabilistic;
- Interaction Model (IM), represents and defines the interaction between user and application. Usually, this model is composed by some evaluation, adaptation and inference mechanisms.

3 EXAMPLE

To illustrate the proposed framework, we can consider the example of a job shop 5x10, where each job has different routes, due dates and processing times. Applying the SM some criteria are settled and the heuristics respecting those criteria are triggered. The obtained results can be observed on Table 1.

Table 1 – Results from SM

Heuristic	Criteria						
	C_{max}	T_{max}	$\sum U_j$	$\sum C_j$	$\sum T_j$	$\sum w_j C_j$	$\sum w_j T_j$
EDD	406	94	7	2968	301	5329	672
FCFS	347	127	4	2808	219	4666	261
General SB	419	63	7	2819	341	4343	445
Local Serach/ C_{max}	306	67	4	2699	169	4575	224
Local Serach/sum(wT)	346	12	2	2679	22	4672	46
SB/ sum(wT)	317	97	1	2610	97	4360	97
SB/ T_{max}	364	12	4	2782	30	4856	66
SPT	422	136	3	2312	392	3688	528
WSPT	422	136	3	2312	392	3688	528

At this stage, there are many candidate solutions which must be evaluated with respect to multiple criteria so, experts will reunite to discuss and weigh up results according their preferences, in order to come to a single solution. For instance from the Sales/Costumer service point of view the number of late jobs ($\sum U_j$) and total tardiness ($\sum T_j$) are the most significant criteria, and from the factory floor perspective makespan (C_{max}) and total flow time ($\sum C_j$) have higher importance.

The role of the GDMS is to facilitate this process supporting the members of the scheduling meeting and the facilitator. During the pre-meeting phase the facilitator has several configuration and parameterization activities.

Figure 2 - Decision rules for meeting MG11

On Figure 2 we can observe the definition of decision rules for the meeting, namely voting rules, rules for argumentation, single or multiple alternative selection; visualisation (or not) of alternatives values after normalisation, as well as the goal of the meeting.

Figure 3 - Initial view of the argumentation forum

On Figure 3 it can be observed the argumentation forum, where each participant will argue for the most interesting alternatives or against the worst alternatives, according to his/her preferences. This component structures the discussion between group members.

As it can be observed on Table 1 EDD is the worst case when referring to the number of late jobs $\sum U_j$, while SB/ sum(wT) presents the best result, This is an argumentation from the Sales/Customer service which valorise the number of late jobs ($\sum U_j$)

4 CONCLUSIONS

This work addresses the interaction between the scheduling actors through the integration of the different kinds of knowledge in a global view of the system and the potential synergy in association with the collaborative activity of those actors taking in account multiple criteria which can improve the scheduling process. Considering this fact the option for a collaborative model using the concepts of Group Decision Support (GDS) and Adaptive Systems (AS) plays an important role. The practical advantages are evidenced in better performance of managers responsible for production planning, control, adaptability and the consequently increased efficiency and productivity of industrial systems.

We expect a successful deployment of our system resulting in significant savings, new approach and improved customer satisfaction. These positive results arise from improved schedule quality resulting in a global business process improvement.

The application of different adaptive technologies in an integrated way for the development of Adaptive Collaborative Framework for Scheduling will be not only an important alternative, but also a new solution/innovation to support the scheduling process on manufacturing environments.

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