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Scheduling through Group Decision Support with Adaptive Hypermedia

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Abstract— **This paper aims is to present an ongoing project which proposes a new methodology and architecture for Collaborative Scheduling through Adaptive Hypermedia and Group Decision Support. The approach to the problem is new in a sense that the techniques of User Modelling, Adaptive System and Group Decision Support will be used and adapted to the Scheduling Process in Manufacturing Environments. An Scheduling module outputs a set of candidate scheduling solutions, each generated based on specific criteria and/or by a particular method. 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. The selection of a scheduling solution is achieved through the interaction among scheduling actors which is supported by a Group Decision Support Module considering the different necessities and the diversity of information source of each group or individual user.**

I. Introduction

THE scheduling process involves many actors representing different manufacturing perspectives (e.g. management, customer-service, manufacturing, quality assurance and distribution). Scheduling is a multi-criteria decision problem; in practice different schedulers may agree on key objectives but differ greatly on their relative importance in any given situation [1]. Considering this fact the option to define and use an Adaptive Hypermedia Framework using the concept of Group Decision Support (GDS) plays an important role. The practical advantages are evidenced in better performance of managers responsible for production planning and control and the consequently increased efficiency and productivity of industrial systems.

It is widely accepted that manufacturing scheduling problems are generally difficult or hard to solve to optimality [23].

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 [3], [4], [27]. 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. 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 the 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.

The purpose of this project is to develop an Adaptive Collaborative Framework for Scheduling; based on product oriented and resource oriented heuristics to solve scheduling problems using the GDSS concept to support the scheduling process on manufacturing environments.

This paper is organized as follows. Sections II, III and IV provide a general approach to the Collaborative Scheduling, Group Decision Support and Adaptive Hypermedia. The architecture and interaction model to support Adaptive Decision Support in Collaborative Scheduling are presented in section V and VI. Finally section VII presents some conclusions.

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II. Collaborative Scheduling

For most real world problems, found in practice, manufacturing scheduling can be a very difficult and, many times, an impossible job. This is so because the number of variables tend to increase in relation to theoretical formulated problems, which are already hard and, additionally, because environment is predominantly dynamic and non-deterministic, which makes things even more difficult. This means that, in a given moment, an established schedule, even an optimum one, for some particular scheduling instance, soon becomes invalid and may have to be scraped or adapted. Therefore, methods for such uncertain environments and complex problems usually tend to be of heuristic nature, involving frequently simple mechanisms, designed for getting good or acceptable solutions, rarely optimum ones, in the short available time for taking decisions.

Furthermore, actual industrial environments are often geographically dispersed; in the scheduling environment unplanned events occurs frequently requiring scheduling decisions to be taken constantly. This type of scheduling can be identified as Distributed Dynamic Scheduling. It must incorporate on-line information, in real time, and it must allow the adjustment of data and schedules whenever necessary. So, there is the need of a diverse range of technical capabilities, usually representing different manufacturing perspectives to work together, sharing their knowledge through a collaboration process to arise to a global scheduling solution.

The determination of feasible and mutually-acceptable schedules can be a major challenge [20]. Moreover, automated scheduling methods, whatever their nature is, whether heuristic or rule-based, might not produce realistic schedules in environments where contextual information is inadequately represented. Where objectives are complex and unstated, and situations are dynamic and uncertain, domain experts can address these issues [26], [12], [31], [3]. So, under these circumstances, human schedulers bring to the scheduling process their inductive and pattern recognition abilities.

This problem evidenced the necessity to create collaborative scheduling systems, where a group of users and scheduling engines collaborate in plans generation, identifying candidate alternatives, and selection one of them, thus profiting the better of the two worlds. This form of collaboration provides a very powerful approach to multi-attribute, multi-criteria, decision support in complex manufacturing environments.

Collaborative scheduling occurs where different organizational units coordinate individual activities for joint benefit. Participants in this process deal with multi-attribute, multi-party, and multi-criteria decision-making and negotiation; in general this environment is characterized by distributed, uncertain, and conflicting contextual information. Typically this complexity can neither be adequately modelled mathematically nor sufficiently captured in information databases [29]. Hence, human schedulers are crucial in collaborative scheduling.

There are some works on distributed, cooperative or collaborative scheduling. An example is the work developed by Kawamura and his colleagues [16] which is a distributed cooperative scheduling system, where several scheduling agents negotiate among them to realize schedule adjustments among busy departments. Another different approach is presented by Murthy and his colleagues [28] where autonomous agents work together to produce a set of candidate alternatives, and a human scheduler make the final decision interacting with the other agents. Chang et al. [10] developed a collaborative scheduling system for coordinating work schedules in construction industry. They introduce a dependency intelligent list and a mechanism for resolving concurrency problems, as collaborative features of the system. Cooperation and collaboration in their system can be interpreted as coordinated negotiations that are triggered by user intervention.

Our approach to collaborative scheduling considers the integration of multiple problem solving approaches to produce a set of solutions to a scheduling problem, and the interaction between a group of decision makers using different evaluation criteria to come to a single solution.

This kind of collaboration involves interaction between a group of humans of diverse departments, which are the decision makers and represent different manufacturing perspectives. In practice, different schedulers may agree as to the key objectives, but differ greatly as to their relative importance in any given situation. It thus requires substantial effort to define solutions that are feasible, efficient, and encompass multiple perspectives. We believe that our methodology is applicable to any scheduling problem where there are no dominant solution methods.

III. Group Decision Support Systems

According to Bedworth [5] "…common sense is the best way to scheduling when there is complex scenery". What seems really useful is a tool for supporting decisions to help operators to achieve and contribute for good scheduling. For this, a collaborative framework capable of integrate multi-criteria decisions, arising from the different actors involved in the manufacturing process, can be most adequate.

The term Group Decision Support System [14], [15], [21], [24], emerged effectively in the beginning of the eighty-decade. According to Hubber [15] 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 [30] and says that GDSSs are interactive computer-based environment which support concerted and coordinated team effort towards completion of joint tasks.

The GDSS aims to reduce the loss associated to group work and to maintain or improve the gain [13]. Nunamaker et al [30] identified the majors sources of gains associated to group work, some of them will be presented next:

- Sources of Gain: Group has greater knowledge than any individual participant;
- Participants' differing knowledge and processing skills allow results that could not be achieved individually;
- A group is better than an individual participant at detecting flaws in proposed ideas;
- People are more responsible for decisions in which they participate, which mean less likelihood to resist to implementation.

In general, the use of GDSS allows groups to integrate the knowledge of all members into better decision making but without adaptation to the profile of the user.

In the 80's most of the research in the GDSS area was focused in the synchronous/same-place dimension, several decision rooms were configured. In the last years, with the proliferation of Internet the research on GDSS has its focus on the different-time/different place dimension. Several web-based GDSS have been developed, and others like for instance GroupSystems, that initially were developed just to support configuration of decision room type, are now able to support remote decision making.

The scheduling process, involve the evaluation and selection of one alternative between a set of them. This are not trivial decisions, because they usually involve multiple and conflicting criteria. Actual organizations are dispersed around the world; in Portugal for instance, there are several textile industries that have the administrative section here in Portugal, but the production section is in China. In this case the agents involved in the scheduling process are in different countries, if it is intended that they discuss the possible alternatives for scheduling, is necessary a support infrastructure.

The aspect of collaboration is obvious in the decision making process, which frequently involves many people, experts on different aspects of the problem, revealing the importance of multi agent systems to hold up GDSS. Decision-making is about thinking of new situations and making choices among them. The decision process is about changing the current situation to a new situation. This aspect may be more important than the decision outcome itself. Decision makers need to be able to determine what they can change, why they want to make a change, and how it may be introduced.

IV. Adaptive Hypermedia Systems

The main objective of Adaptive Systems 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 [7], [11].

Adaptive Hypermedia Systems (AHS), as Adaptive Systems that are built and use an hyperlinked, internet based environment, are referred as being a crossroad in the research of Hypermedia and User Modelling (UM) [7], [8], [11].

The adaptation capacity of these tools, considering the different necessities and the diversity of information source of each group or individual user will be necessary, namely to increase the adaptation efficiency to different environments.

De Bra indicates that these systems must present functionalities to change the content presentation, the structure of the links or the links annotation with the follow objectives [11]:

- To guide the user to the relevant information and keep him away from the irrelevant information or pages that he still would not be able to understand. This objective is generally known by link adaptation.
- Supply, in the content (page), additional or alternative information to certify that the most relevant information is shown. It is generally known by content adaptation.

User Modelling (UM) has increased relevance in AHS. The definition of an UM is relevant to allow the user reaches the objectives and goals. In addition, when the user reaches the objectives and goals the system must be able to readapt, for example, to his knowledge [7], [22].

In the next table we present some UM characteristics used in existing AHS:

Table 1 - Some UM characteristics of existing AHS

Characteristics	Some Systems
User Knowledge represented by layers, a net of concepts, thus forming a semantics net (Overlay Model)	INTERBOOK, KBS HYPERBOOK, INSPIRE, HYPADAPTER, AHA, HYPERFLEX, ISIS-TUTOR, KN-AHS, ELM-ARTII, ANATOM-TUTOR, METADOC, XAHM
Stereotypes of two classification dimensions	METADOC, AVANTI, C-BOOK
User Objectives	INSPIRE, HYPLAN, XAHM, HYPERCASE, HYPERFLEX, AVANTI, AHA, INTERBOOK, KBS HYPERBOOK
Pre-requisite and experience	AHA, ADAPTWEB, NETCOACH, INTERBOOK
Preferences	HYPERFLEX, HYPADAPTER, XAHM, INTERBOOK
User Interests	INSPIRE, AHA, ADAPTWEB, XAHM, NETCOACH, INTERBOOK, KBS HYPERBOOK
History	ADAPTWEB, NETCOACH, INTERBOOK

The architecture proposed, for example by Benyon [6] and De Bra [11], indicate that the AHS must have three essential parts:

- User Model, that describes the information, knowledge and preferences of the user. This model must express, supply and assign conclusions about the user characteristics.

- Domain Model, that represents concept hierarchies or maps and the related structure for the representation of the user knowledge level, either quantitative, qualitative or probabilistic.
- Interaction Model, represents and defines the interaction between the user and the application. Usually, this model is composed by some evaluation, adaptation and inference mechanisms.

V. COLLABORATIVE AND ADAPTIVE FRAMEWORK FOR SCHEDULING

A scheduling system should provide a user support, to assist him in build, change and revising processes of the scheduling plans and not deciding for him. The user has intelligence and knowledge acquired along the years that are not to underestimate. Nevertheless, a scheduling system could have autonomous capacity, suggesting alternatives according to some claimed criteria.

The user provides intuition, a notion about goals and appropriate trade-off, and refined problem resolution strategies. The computer provides skill to manage details, to assign and schedule resources and operations, and to analyze quantitatively the suggested choices.

Our proposal considers multiple scheduling objectives in a global multi-criteria collaborative framework. 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 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 and this is the objective of the concept of Adaptive Environments. This is especially important when we are dealing with Collaborative Decision Support Systems.

The first phase of our project was to identify and define the system architecture (Fig.1).

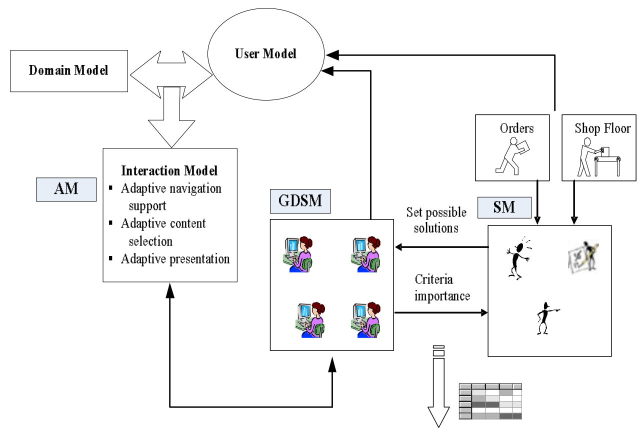

Figure 1 - Framework solution

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

1. The Scheduling Module (SM) consists of multiple problem-solving methods (called agents) working at the same time on a common problem, so it does not represent any single method or heuristic, but is rather an attempt to use multiple techniques by encapsulating individual algorithms as autonomous agents.
2. The Group Decision Support Module (GDSM) 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 choice the "best" solution from the set of scheduling solutions proposed by the SM.
3. The Adaptation Model (AM):
   a. The User Model based on the Stereotype Model, which describes the information, knowledge and preferences of the user.
   b. The Domain Model that represents concept hierarchies or maps and the related structure for the representation of the user objective and knowledge level.
   c. The Interaction Model represents and defines the adaptation between the user and the application.

A. Scheduling Module

The Scheduling Module (SM) consists of multiple problem-solving methods (called agents) working at the same time on a common problem, so it does not represent any single method or heuristic, but is rather an attempt to use multiple techniques by encapsulating individual algorithms as autonomous agents. So the SM module includes different autonomous agents: Information agent, scheduling agents, and setting agents as it can be observed in Figure 2.

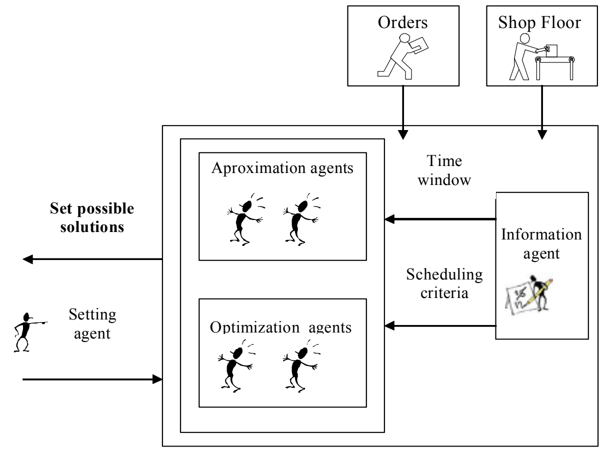

Figure 2 - SM architecture

Agents are typically knowledge representation entities characterized by independence and autonomy. The software agents are entities that have the ability to plan, to establish their actions ahead of time, to develop appropriated problems solving strategies, to communicate, or to share resources.

In our approach agents have the possibility to follow events as they occur in the environment, interpreting and sharing knowledge or data.

1) Scheduling Agents

The scheduling agents are different autonomous agents each one of them embodying a particular scheduling algorithm, as it was referred previously. According the scheduling criteria or objective, there is a broad range and variety of scheduling methods.

We can distinguish between optimization methods, mainly for small dimension problems, approximation methods namely priority dispatching rules which are a very popular technique due to their ease of implementation and their substantially reduced computational requirement, and heuristics. One can either apply an approximate method that delivers a good solution in acceptable time or an optimization procedure that yields a globally optimal solution, but requires a very high computing time.

We can also refer the origin of the scheduling method, Operational Research (OR) and Artificial Intelligence (AI). A wide study on the diversity of scheduling methods can be found in literature [3], [27].

2) Information Agent

In our approach the information agent, in accordance with the type of scheduling problem, sets a time window for the generation of the several scheduling alternatives. Also some criteria are settled; this way only the agents embodying algorithms respecting the established criteria will be triggered. Only the alternatives generated within the settled time window are considered for analyze and discussion by the GDSS module.

3) Setting Agent

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

B. Group Decision Support Module

One approach to tackle multi-criteria decision problems involves assigning weights to different criteria, aiming to come to a unique decision depending upon the assigned weights. In a collaborative decision making process, which frequently involves many people, experts on different aspects of the problem, all the relationships arising from the different departments representing the diverse manufacturing perspectives must be considered, so a set of weighted criteria seems to be the most adequate. For instance, from the manager point of view the most important criteria should be the profit and from a quality control department the most important criteria is product quality. But as economic conditions change, the relative importance of different criteria may change. This requires users to modify these weighting factors periodically, by changing the relative importance of each criterion.

Architectures that enable collaboration are useful when it is not efficient or possible to perform a task by a single agent or human. They provide mechanisms which allow several users to contribute with their knowledge to the system, participating on an equal basis in the selection of candidate alternatives.

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. Group Decision Support can provide a very powerful approach to multi-criteria decision support and optimization in complex manufacturing environments.

The GDSM 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 choice the “best” solution from the set of scheduling solutions proposed by the SM.

The GDSM is composed by the following components: Setup, Management, Argumentation, Multi-criteria and

Voting [26], as it can be observed in Figure 3.

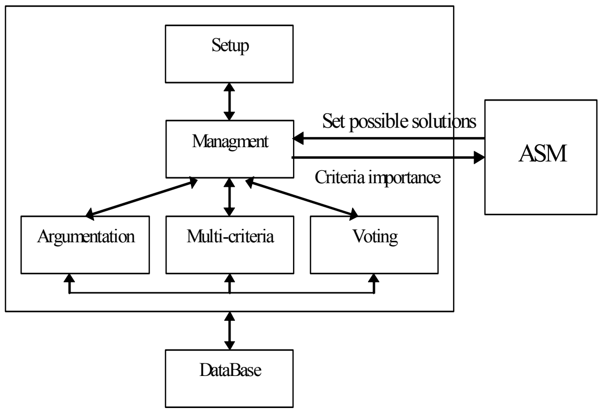

Figure 3 - GDSM architecture

1) Setup component

The Setup component will be operated by the facilitator during the pre-meeting phase. This involves several configuration and parameterization activities, such as:

- General schedule meeting configuration
- Selection of participants (from the database of expertise), invitation sending, confirmation of reception and participant replacement, if necessary.
- Definition of decision rules.

2) Management component

This component 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.

3) Multi-criteria component

This module is used by the facilitator to introduce a possible set of criteria; an example could be for instance, delivery time, quality, price, etc. The group members will, individually, assign weights to this set of criteria. The result of this process will be several sets of criteria weights, one for each group member. The group is composed by *k* elements.

$$W^T = (w_1, w_2, ..., w_j, ..., w_n) \quad (1)$$

$$\sum_{j=1}^{n} w_j = 1, w_j \geq 0 \quad (2)$$

Where *n* is the number of criteria and *wj* is the weight of criterion *j*. The sum of the criteria weight should be equal to one, and all the criteria should have a weight greater or equal to one.

At this moment there is not yet a set of alternatives just sets of criteria weights, and the system can have two different behaviours: Perform the mathematical aggregation of the individual's preferences, in order to have a unique set of criteria weights or the group members could use the argumentation and voting tools to select a unique set of criteria weights.

The first one is certainly less time consumer, but for other side the second one is more consensual.

After the SM module identifies the set of candidate alternatives, the group members will use this module to individually choice the preferred alternative. At this moment the group member could use two distinct methods both based on the Multi-attribute value function theory with compensatory option to rank the alternatives. The TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) [27] algorithm and a simple additive function, like the one in (3).

$$f(a_i) = \sum_{j=1}^{n} W_j * V_j(a_i) \quad (3)$$

Where a_i is the alternative number *i*, *Wj* is the weight of the criterion *j* and $Vj(a_i)$ is the value of alternative a_i in criterion *j*.

The process of establishing preferences is evolutive and, as time goes on, members can change the relative importance of each criterion and consequently express changes in their individual preferences. This component will help the individual scheduler agent to ranking the several scheduling alternatives. This component may also help the user to define the criteria importance.

4) Voting Component

The voting component is responsible for the emission of "vote bulletins", and for the publication of results (intermediate and final). These activities are performed according to the decision rules that have previously been defined by the facilitator in the pre-meeting phase.

5) Argumentation component

After establishing individual preferences the participants are expected to "defend" those preferences. Each participant will therefore argue for the most interesting alternatives or against the worst alternatives, according to his/her preferences. By expressing their arguments, participants expect to influence the others' opinions and make them change their choices. This component will structure the discussion between group members.

C. The Adaptation Model

The interface is an Adaptive Web based tool, designed to allow the user to assess the GDSM.

The Adaptation Model 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, the adaptive system tries to adapt the interface of the GDSM to the skills of the scheduler expert, reorganizing the sequence of the content presentation according to the interaction he provides

The adaptation is in accordance with predefined but updatable model of user that reflects his/her objectives, preferences, knowledge and competences (Figure 4).

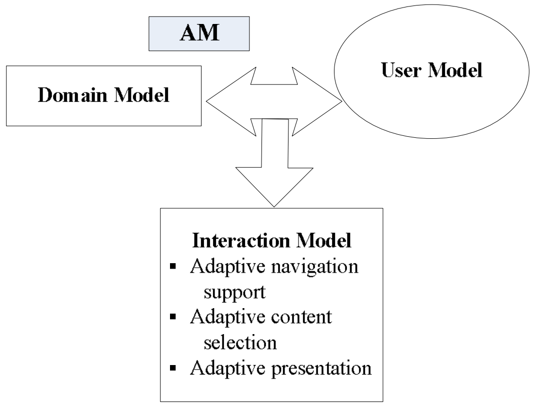

Figure 4 - Adaptation Model

1) User Model

The approach to build the User Model (UM) is the Stereotype Model. The representation of the stereotype is hierarchical. First, user subgroup is identified, then the recognition of key characteristics (each one identifying user-subgroup members) and finally the representation in hierarchical ordered stereotypes with inheritance. Stereotype for user groups with different knowledge have been used to adapt information, interface, scenario, goals and plans [17]. The user stereotypes, or the establishment of typical characteristics groups, where each user fits (the creation of stereotypes is a simple form to implement UM), was applied in the definition of the User Model was take in consideration the granularity degree wanted [25].

The User plan is a sequence of user actions to achieve a certain goal [18]. The system observes user actions and try to infer all possible user plans. This goal is possible because the system possess a library of all possible user actions and the preconditions of those actions [17]. The systems architecture and the Model include information referring to the specific knowledge that the system judges the user possesses on the Knowledge domain [17].

The Behavioural adaptation is implemented using Overlay methods [17]. This method creates the relation between levels of user knowledge with the objectives / competences that he intends to reach [17].

2) Domain Model

The Domain Model is represented by concept hierarchies or maps and the related structure for the representation user knowledge level (quantitative, qualitative or probabilistic value). A concept is used for this representation and route to be used in the graph defined by the interaction with the user.

3) Interaction Model

For the Interaction Model, the system presents the functionalities to change the content presentation, the links structure or annotation with the follow objectives [11]:

- Guide the user to the relevant information and keep him away from the irrelevant information that he still would not be able to understand, this technique is generally known by link adaptation (Hiding, disabling, removal, etc.).
- Supply, in the content, additional or alternative information to certify that the most relevant information is shown. The technique used for this task it is generally known by content adaptation.
- Also, the interaction model use multimedia adaptation technologies to choose the type of the content more appropriated according to the profile of the user (for example, according with some user disability).

To improve content understanding by providing adaptive narration, the adaptation techniques using Natural Language Adaptation (NGL) is using [8]. The natural language of the user also is taken in account.

VI. CONCLUSION

The attention to the individual needs of each customer is a driving force behind many changes taking place in every industry sectors, so a scheduling decision, must take into account the knowledge and experience of different points of view, allowing the consideration of broad issues of the company rather than focusing on scheduling tasks for a single process.

This project 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 concept of Group Decision Support (GDS) 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 [2].

This project will demonstrate that the approach of the problem is new way in a sense that the techniques using in Adaptive System and Group Decision Support will be the best solution to use and adapt to the Scheduling Process in Manufacturing Environments.

We expect a successful deployment of our system resulting in significant savings, new approach and improved customer satisfaction. These positive results arose from improved schedule quality and improvements in the business process that our adaptive collaborative decision-support approach has fostered.

The application of different adaptive technologies in an integrated way for the development of 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.

The capacity of the adaptation of these tools, considering the different necessities and the diversity of information source of each group or individual user will be necessary, namely to increase scheduling efficiency on manufacturing environments.

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