A Real Time Web Integrated Scheduling Support System For A Multi Product Manufacturing Industry

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Abstract

This paper deals with the real time implementation of a web integrated scheduling support system for a multi-product manufacturing industry. The industry manufactures a wide variety of products ranging from steam turbines, gas turbines to compressors. The product assembly is quite complex, in particular a typical bill of material (BOM) has more than 50 levels. It is obvious that scheduling of these parts on the available resources and out sourcing is a gigantic task. Currently the task of planning and scheduling is being carried out manually and it is consuming several planning months to come up with a workable rather than an optimal/near-optimal solution. In this context, we have developed a computerized scheduling system that aids in computing the make span for complex job-shop. A priority based scheduling system was developed based on the priorities of the customer. The priority of the customer is fixed considering various factors like due dates, customer influence, and engineering design considerations. The system is developed in two phases. Phase – I involves the development of a stand-alone job-shop scheduling system with make-span minimization as the prime objective. Other objectives like minimizing the maximum lateness/tardiness were also explored. Phase – II involves making the system web enable, which allows the decision makers with the flexibility of distributed decision making.

1. Introduction

The scheduling activity in a manufacturing environment may be defined as the activity of allocating tasks, or jobs to resources over a time, for achieving certain objectives. One of the most popular models in scheduling theory is that of the job shop. Job shop is considered to be a good representation of the general domain, and has earned reputation of the most difficult to solve among NP-hard (Baker, 1974) set of scheduling problems.

In this paper, we focus on the job-shop that manufactures multiple products. Scheduling for a multi product manufacturing job-shop is quite complex due to the variations in the number of operations to be performed on each part, and their operation sequence besides recirculation, priorities and other host of real world considerations/constraints. The day wise scheduling of the jobs on to the machines is a gigantic task due to the presence of various uncertainties, like machine breakdowns and/or change in priority of customer orders, etc.

In this context, we propose for an intelligent scheduling system that caters to the problem of job-shop scheduling. We design a heuristic to solve the job-shop scheduling problem. Further the scheduling system should be capable of taking the inputs from various sources (that are geographically dispersed) in and around the multi-product manufacturing job-shop for effective decision making. We use a three tier web-based frame work to host the intelligent job-shop scheduling system to provide the capability of distributed and seamless decision making in a timely manner.

Our work is based on the requirements of a high scale turbine manufacturing industry based in India. The user industry has an objective of minimizing the make span while respecting the capacity constraints, work order priorities, etc. We have developed the scheduling system in two phases. Phase – I involved the development of a stand-alone job-shop scheduling system with make-span minimization as the prime objective. Other objectives like minimizing the maximum lateness/tardiness were also explored. Phase – I is developed in Visual Basic (VB 6.0. enterprise edition), and this uses turbine data present in standard oracle database.

Phase – II of this project was proposed in order to provide the decision makers with the flexibility of distributed decision making. We use Active Server Pages (ASP) in order to host the inputs/outputs from Phase-I on to a secure intra-enterprise network.

The job-shop scheduling discussed here is based on the priorities of the customers, i.e., a job with high priority is to be processed first, irrespective of the release/available date. The priority of the customer is fixed considering various factors like due dates, customer influence, and engineering design considerations. The integration of the scheduling system with the World Wide Web (WWW) particularly in an enterprise specific network is emphasized.

The rest of this paper is organized as follows: Section 2 reviews the extant literature that is relevant to the problem that we investigate. Section 3 defines the problem under consideration and also gives an insight into the complexity of the problem. In section 4, we discuss our heuristic for solving the scheduling problem and the assumptions made. Section 5 discusses the phases I and II of scheduling support system leading to the integration of the scheduling system with the web. We conclude with some directions for extending our current work in Section 6.

2. Relevant Literature

This research work integrates two strands of literature namely; job-shop scheduling and web integrated manufacturing/planning applications.

2.1 Job-shop Scheduling

In manufacturing and service industries, sequencing and scheduling play a crucial role in decision making. Bulk of the industrial and academic research has been devoted to this area over the past fifty or more years. We survey some relevant literature that has some connection with our current work, and hence this survey is not exhaustive.

Yang and Wang (2000) present a constraint satisfaction adaptive neural network, together with several heuristics, to solve the generalized job-shop scheduling problem, one of NP-complete constraint satisfaction problems. The proposed neural network can be easily constructed and can adaptively adjust its weights of connections and biases of units based on the sequence and resource constraints of the job-shop scheduling problem during its processing. Several heuristics that can be combined with the neural network are also presented. Dorndorf et al (2001) describe a branch-and-bound algorithm for the open shop scheduling problem which performs better than other existing algorithms. They adopted this approach instead of analyzing and improving the search strategies for finding solutions, and they focused on constraint propagation based methods for reducing the search space. Chang and Lo (2001), proposed an integrated approach to model the job shop scheduling problems. Asano and Ohta (2002) developed a heuristic algorithm based on the tree search procedure for solving job shop scheduling problem to minimize the total weighted tardiness with job-specific due dates and delay penalties. A certain job shop scheduling to minimize the maximum tardiness subject to fixed sub-schedules is solved at each node of the search tree, and the successor nodes are generated, where the sub-schedules of the operations are fixed. Thus, a schedule is obtained at each node, and the sub-optimum solution is determined among the obtained schedules. Guilherme et al (2003), in their paper discuss a framework of strategies, policies, and methods for rescheduling of manufacturing systems. They also discuss how rescheduling affects the performance of a manufacturing system, and conclude with a discussion of how understanding rescheduling can bridge some aspects of scheduling theory and practice.

Chung et al (2005) proposes an algorithm for planning subcontract operations in a job shop environment. Viewing that the overloads are the results of insufficient capacities and poor scheduling decisions, the algorithm is designed to effectively decrease tardiness measures by rescheduling or subcontracting the operations on bottleneck machines. Liu et al (2005) analyze the characteristics of the dynamic shop scheduling problem when machine breakdown and new job arrivals occur, and present a framework to model the dynamic shop scheduling problem as a static group-shop-type scheduling problem. The problem of providing flexibility to solutions of two-machine shop scheduling problems was discussed by Esswein et al (2005). Nowicki and Smutnicki (2005) proposed a new approximate algorithm that is based on the big valley phenomenon, and uses some elements of so-called path relinking technique as well as new theoretical properties of neighbourhoods for solving job shop scheduling problem with the makespan criterion.

Ohta and Nakatani (2006) consider the job-shop scheduling problem of minimizing the total holding cost of completed and in-process products subject to no tardy jobs. A heuristic algorithm based on the shifting bottleneck procedure is proposed for solving the minimum total holding cost problem subject to no tardy jobs.

Zribi et al (2007), in their paper discuss the Job-shop with Multi-Purpose Machine scheduling problem with Availability Constraints (JMPMAC). Machines equipped with different tools are called multi-purpose machines. They propose a heuristic, based on priority rules to solve the assignment problem. A local search algorithm is then introduced to improve this assignment solution. Suwa (2007) proposes a new when-to-schedule policy in online scheduling, which considers timing of rescheduling based on the concept of a control limit policy and rolling schedules. Under the proposed policy, rescheduling is carried out based on a cumulative delay which can be a measure to determine suitable timing of rescheduling.

2.2 Web-based Manufacturing Planning

In our earlier works, (Krishna et al (2002)), we discussed the development of a rapidly reconfigurable web integrated inventory and dynamic machine scheduling decision support system. The paper discusses the implementation of multi-tiered architecture for the integrated decision support system. The integration of a scheduling support system for a multi-product manufacturing industry with the internet using Dynamic Hypertext Markup

Language, Visual Basic as front end tools and an Oracle database is presented by Krishna et al (2002). The present paper is an extension of the previous work using .NET technologies. Jia et al (2002) discuss the development of a Web-based Multi-functional Scheduling System for a Distributed Manufacturing Environment with the utilization of the latest Internet and World Wide Web (WWW) technology. The entire web-based scheduling system includes three layers, i.e., stand-alone application module, scheduling agent module, and e-scheduling module. They are implemented using Java Application and Applet Language. Huang and Mak (2001) in their paper focus on a number of major initiatives and projects recently completed or just launched on web-based product design and manufacture. Major issues emerged from these recent developments are then identified and discussed in the design and development of future web applications in product design and manufacture. The potentials and challenges of the web technology are also discussed.

The whole product life cycle contains lots of data where product data management is crucial for making use of update information to facilitate collaborative product commerce. A product data exchange standard, product information markup language, which is composed a set of well defined XML schema, is introduced to provide a flexible way to encode structured data into a format. The implementation of a Web-based concurrent design using the product information markup language was discussed by Lee et al (2003). Yang and Xue (2003) have given a comprehensive review of extant research on developing web-based manufacturing systems. The authors focused on key issues in developing web-based manufacturing systems, including collaboration among product development partners, data modeling, system architecture design, and security management. Authors also present interesting research insights to address the above key issues in design and deployment of web-based manufacturing systems. Feryal et al. (2003) discuss the implementation of an Internet-based enterprise-wide decision support tool for a grocery retailer. The authors consider an objective of optimizing the 'total landed cost' across the functions of the enterprise planning system. This tool provides decision support to make purchasing (ordering) decisions across several stock keeping units (SKUs) on a daily basis, by optimizing the inbound logistics and inventory decisions at the retailer's distribution centers. The functioning of a multiple criteria decision support web-based system for facilities management was presented by Edmundas et al (2004). The authors created a web-based Multiple Criteria Decision Support System for Facilities Management (DSS-FM). DSS-FM differs from others in its use of new multiple criteria analysis methods. The developed System enables the user to analyse alternatives quantitatively and conceptually (i.e. the text, formula, schemes, etc.). Applying the DSS-FM may increase the efficiency of calculators, analysers, software, neural networks, expert and decision support systems and e-commerce. The database of a facilities management was developed and provides a comprehensive assessment of alternative versions from the economic, technical, technological, infrastructure, qualitative, legislative and other perspectives. Pappas et al (2006) describe the development of a web-based collaboration platform for manufacturing product and process design evaluation using virtual reality techniques. The Distributed Collaborative Design Evaluation (DiCoDEv) platform provides real-time collaboration of multiple users at different sites on the same project. The platform uses of virtual reality (VR) technology for the development of the working display environment that provides also navigation, immersion and interaction capabilities for all collaborative users in real time.

The new computer and Internet technologies, including computer languages such as C++, Java, Visual Basic and C#, script languages such as VBScript, JavaScript and Perl, Web mark-up languages such as HTML, Dynamic HTML (DHTML) and Extensible Markup Language (XML), Web-based client-server programming tools such as Active Server Pages (ASP) and Java Servlet, distributed object modeling methods such as Remote Method Invocation (RMI), Common Object Request Broker Architecture (CORBA) and .NET technologies have been employed for developing Web-based manufacturing systems.

2.3 Current Work

Our current work is different from the two strands of literature discussed earlier in this section. We emphasize the integration of job-shop scheduling system with the Internet. The user industry considered is a multi product industry manufacturing different products like steam turbines, gas turbines, switch gears, etc. For generating the schedule, the system should interact with huge database in real time. This involves large computational complexity because the system developed needs to take care of other dynamic conditions like machine break down, non availability of raw material and spare parts. The developed system is integrated with the internet which allows the system to be operated by different levels of users located at geographically different places. To the best of our knowledge, the proposed integration of such a real time complex job shop scheduling system with the internet is not discussed in extant literature on either JSP or web integration. Thus our current research contributes to the literature.

3 Problem Definition

We discuss the problem from the perspective of our user industry under investigation. It is a multi product manufacturing industry, manufacturing several types of products ranging from steam turbines, gas turbines, compressors to generators. The main task of the production planning and control (PPC) department is to determine the make span of a customer order considering several constraints like material availability, machine break down, and most importantly, the priority of the customer.

Each customer order is identified by a unique work order number (WONO). In turn, each work order consists of several subassemblies. Sub assemblies are identified by a unique number termed as product group main assembly (PGMA) and each product group consists of individual parts identified by part number (PARTNO). The operation sequence of each part is obtained by the operation number (OPNO), for example, OP_1. It should be noted that OPNO would be mapping of a part on to machine with a time component.

The process plan of all the work orders is available in the electronic data processing (EDP) section of the user industry in oracle database and it can be accessed (remotely) by the privileged decision maker of the company. We refer this as the master database. The master database maintains the history of process planning of all the work orders that were processed on the shop floor. The process plan of a work order is developed by retrieving the information of an equivalent work order from the master database. If the new work order has a different requirement, then the process plan of it must be added to the existing oracle database. Our scheduling heuristic interacts with this data to generate feasible schedules. The user industry executes 8 to 20 work orders for turbines per year.

The shop-floor has different machine shops like heavy machine shop, medium machine shop and light machine shop. Each machine shop consists of certain number of work centers (generally 15 to 25, identified by WCNO) and each work center consists of certain number of work places (machines) i.e., a group of similar machines of varying capacities. Work places are identified as work place number (WPNO). Figure 1 depicts a typical work centre in the user industry.

3.1 A Bird's Eye View of Problem Complexity

The complexity and magnitude of the scheduling problem can be better understood by considering a product like steam turbine. The steam turbine comprises 50 PGMAs and each PGMA has 50 parts on an average and each part undergoes 25 to 125 operations. For example, the outer casing, the exhaust hood and the valve chest are important sub-assemblies for any steam turbine. The number of operations for outer casing is around 125 operations, exhaust hood has around 45 operations, and valve chest has got 25 operations. The total processing time of the outer casing is also very high when compared with the other parts.

The hierarchy of scheduling structure is depicted in Figure 2. The key task of the PPC department of the user industry is to schedule the low level hierarchical operations on the machines available on the shop floor, respecting the capacity constraints, materialb availability, and most importantly the priority of work orders.

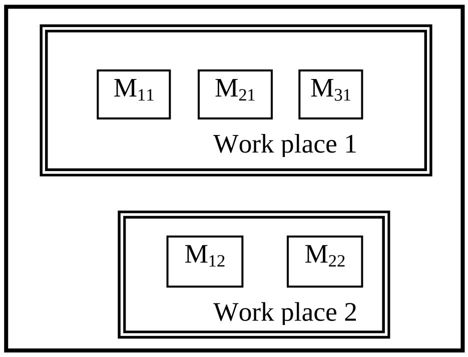
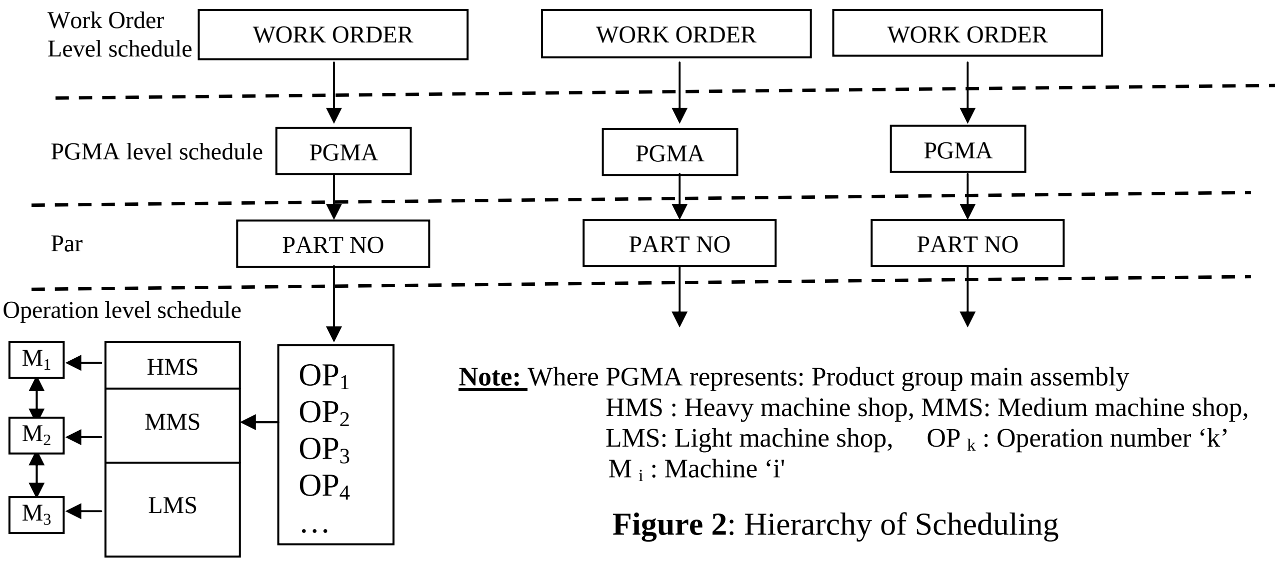


Figure 1: Layout of typical work centre

<u>Note</u>:

M_{ij}: represents machine 'i' in work place 'j'

Where i = 1 to m and
j = 1 to n
m = number of machines in a work place and
n = number of work places



<u>Note:</u> Where PGMA represents: Product group main assembly
HMS : Heavy machine shop, MMS: Medium machine shop,
LMS: Light machine shop, OP_k : Operation number 'k'
M_i : Machine 'i'

Figure 2: Hierarchy of Scheduling

The user industry has a number of plants at various places in India. The scheduling system is web enabled so that these geographically dispersed plants can be integrated through WWW to form a global system for scheduling. In this way, the capabilities of each work center of the connected system are utilized to the maximum extent possible.

4. Proposed Scheduling Heuristic – Phase - I

In job shop scheduling, a number of heuristic procedures are employed to resolve the choice of selecting a job from a set of available jobs waiting to be processed on the same machine at a given point of time. Some of them are earliest due date (EDD), least work remaining (LWKR), most work remaining (MWKR), ratio of shortest processing time to total time (SPT/TOT), shortest processing time (SPT), longest processing time (LPT). In the EDD rule, the priority is given to the job with the earliest due date. According to the LWKR rule, priority is given to the job with the least amount of total processing remaining to be done, while as per the MWKR rule priority is given to the job having the most work remaining to be processed. The SPT/TOT rule selects the part with least ratio of processing time to the total processing time of the part. According to the SPT rule, priority is given to the job with the shortest processing time on the machine under consideration, while as per the LPT rule priority is given to the job with the longest processing time on the machine under consideration.

In this section we discuss the heuristic adopted for solving the large-scale complex job-shop scheduling problem of the user industry. The developed heuristic addresses the scheduling problems of the job shop. The scheduling of work orders is based on the priorities decided by the user industry using a priority index number. The heuristic procedure resolves the contention for the processing on the same machine by parts of different work orders by loading the part of a work order having highest priority index number first as on that date. The schedule generated is further refined by applying the three heuristics: *least work remaining* (LWKR), *most work remaining* (MWKR) and *ratio of shortest processing time to total time* (SPT/TOT). Here it may be noted that although user industry is interested in determining the make span, we have used the above heuristics to identify the amount of time spent by the parts on the shop floor, and to estimate cycle time for each product for expected date of shipment.

The following assumptions are made for the heuristic procedure adopted.

4.1 Assumptions

1. The sequence of operations of a part of a work order is fixed. (i.e. for example operation 10 cannot start until and unless operation 9 is finished, this is universally extensible for all parts, PGMA's and work orders to be scheduled).
2. The number of operations for each part is different from those of the other parts.
3. The priority of a work order is not fixed and may vary with time i.e. a work order with priority 1(high) can be shifted to low priority as per the user's choice.
4. The efficiency of the work place varies dynamically with time and the efficiency of workplace as on a given date is to be specified by the user.
5. In case of any break down of a machine (work place), the processing of the interrupted job is continued from the point of break down.
6. The part once loaded on a facility is not removed until and unless the

processing is complete, irrespective of the priority of the work order.

It should be pointed out that the above assumptions are quite generic for any job shop scheduling environment and more so for the user industry which we have considered for investigation.

4.2 Proposed Heuristic

The flow of our proposed heuristic is given below.

Step 1: The new work order details, like start date, priority index number, efficiency of work place, material availability date, and customer name are added.

Step 2: The process plan of new work order to the current database is added by selecting an equivalent work order from the master database.

Step3: The work place where there is a contention for processing of parts is identified.

Step 4: The clash between the parts waiting to be processed on the same work place is resolved initially based on the priority index number of work orders.

Step 5: The schedule generated is further improved by applying heuristics like LWKR, MWKR and SPT/TOT, to the existing schedules generated based on the priority index number i.e. if parts with same priority are contending for the same work place then they are loaded on to the work place based on these heuristics.

Step 6: Any changes in material availability dates, efficiencies of work places, break down of a work place and priorities are subjected to rescheduling (Step 3 is followed for rescheduling).

The output schedule for 8 work orders applying the above heuristic procedure is shown in Table 1.

Table 1: Output schedule for 8 work orders

WONO	Make Span (in days)		
	Priority with MWKR	**Priority with LWKR**	**Priority with SPT / TOT**
1	310	276	295
2	186	125	204
3	188	130	205
4	220	185	235
5	188	142	206
6	237	203	242
7	254	219	259
8	271	236	277

4.3 An Overview of Computational Complexity

It is a well known fact that Job-shop scheduling problems are NP-Hard. In other words, it is difficult to expect a globally optimal solution in polynomial time. We give an example here to emphasize on the complexity of current problem.

Consider generation of an initial schedule comprising 8 work orders that takes not more than 6 hours. It should be noted that the number of operations for each part varies from 25 to 125. A typical work order has an average of 800 parts. After this, for any changes opted by the user like material availability date, efficiency of work place(s) and priority of customer, the reschedule generation time is less because the changes will be implemented from the corresponding part of the schedule in the master database. It was found that it took only 5 minutes if the changes are made at the later stages than in the initial stages of the generated schedule. The program is executed on a P-IV system with 256 MB RAM, 1.17 GHz speed.

5. Web Integration – Phase – II

5.1 Background for the Deployment on WWW

The main advantage of web deployment/integration of any planning solution is its inheritance of client server architecture for distributed decision making (computing is a bit risky to use here). The rapid progress of web technologies in the recent past has made it possible for implementing the web-based systems for the design and manufacturing planning.

Most of the web-based applications lack a systematic approach, and mostly rely on the knowledge and experience of individual (myopic) decision makers. This is due to the fact that web has been regarded as an information medium rather than as an application platform.

The web technology is playing a crucial role to develop virtually many types of decision support systems in product design and manufacture. These decision support systems help decision makers to plan better in a host of activities in the product supply chain, typically starting from the customer requirement, to product deployment (order fulfillment).

An integrated scheduling system consists of several intelligent hybrid systems (IHS) shown in Figure 3. Each IHS is located in an individual site with the function of planning the schedule for the tasks assigned to the site. Generally each client node is to be referred as a site where there is a provision for the authorized access to the HIS. The operator at each of the site is supposed to download the schedule on that work center with the proposed date of loading the job on to the work place.

These individual systems are then integrated through WWW, forming a global system for the scheduling .In this way; the capabilities of each work center of the operations on the work places to be carried out as per the schedule.

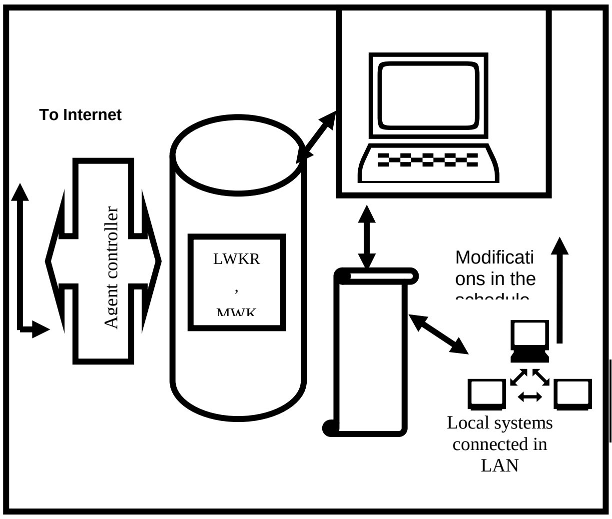


Figure 3: Intelligent hybrid system

Within an individual site, a site controller controls all activities and communicates with other sites via a web server through the network interfaces. Individual intelligent hybrid systems are located inside the industry, each of which is responsible for the integrated scheduling and planning in a specified work area. The agent controller (supervisor) is the in charge of the resources (databases, equipment and software tools, users etc).

The functional aspects of this system were originally developed by the authors (at NIT Warangal) using visual basic and oracle as database with common gate interface (CGI). The software in the host site is made available to be run by several clients. This allows the other plants of the user industry located at geographically dispersed places in INDIA to interact with the system.

A combination of DHTML, CGI and VBScript programming is used to run the software by several clients. The DHTML pages contain all the necessary graphical user interfaces (GUI's) between the client and the server. It allows authorized users to select the desired parameters for the scheduling viz., entering the details of a new work order, changing the material availability and generating schedule of a particular work order on a particular date. The selected parameters are then sent to the remote server, where the actual database exists, and it would be accessible by the CGI-files. The CGI program located on the server is initiated by the DHTML code .The CGI program passes the data and invokes the multi product scheduler (MPS) software (i.e. Visual Basic executable program) located on the remote server. When the execution is completed, the results are then sent back to the client, but it may take a considerable amount of time depending on the processing capabilities of the server machine. However, if the client computer sends a request to view the results like project schedule and work place loading, then it may be directly downloaded to the client's machine. This method of executing a large program and transmitting the results over the Internet to several clients has been proved to be the safest approach as the program is neither downloaded on to the client's machine nor the client has access to the source code. A foolproof arrangement to hide the Internet connectivity details between several clients and the remote server is achieved by using firewalls so that the unauthorized access to the main database is ceased. The development of a multi-user environment avoids the conflict that arises if more than one user encounters the application program.

5.2 Connection of Remote Database to the Web-Based Multi Product Scheduler

In the design of the multi product scheduler, the relational data base management system (RDBMS) oracle is used. The database is linked to the multi product scheduler executable program through the open database connectivity (ODBC). The CGI programs for linking have been developed in C++ language.

The two different methods namely, *GET* and *POST* are used to send the data to the server. The *GET* method sends the data as command line input, i.e. as one long string assigned to an environment variable, whereas the *POST* method sends all data values as one line of the text to a standard input device which must be read within the program .The amount of the data that can be retrieved from a *GET* is considerably smaller than that from a *POST*. As the amount of data to be retrieved is more in the present work, the *POST* method is being adapted.

5.3 The Structure – Implementing the Three Tier Methodology

The method adopted in this work is based on the client /server approach with the three tier architecture. The CGI program in the server receives the request for the data from the client in the form of one long string that needs to be parsed first. Subsequently the CGI program processes the data and sends the result back to the client, in the form of an DHTML page. Figure 4 shows the structure of the method, which would enable the user to run the multi product scheduler package and obtain the results from a remote location.

The first tier includes the multi product scheduler application clients. When the user browses the web, they become the multi product scheduler clients and these clients are not a part of the web-based multi product scheduler. The web application is designed for multiple clients.

The middle tier consists of two layers. One layer is the multi product scheduler web server (MPSWS) and the other layer is the multi product scheduler application server (MPSAS). The MPSWS includes a number of web pages consisting of various functional components attached to the home page. The MPSAS layer includes the multi product scheduler application software developed and deployed with responsibilities, like dealing with the multi product scheduler main database.

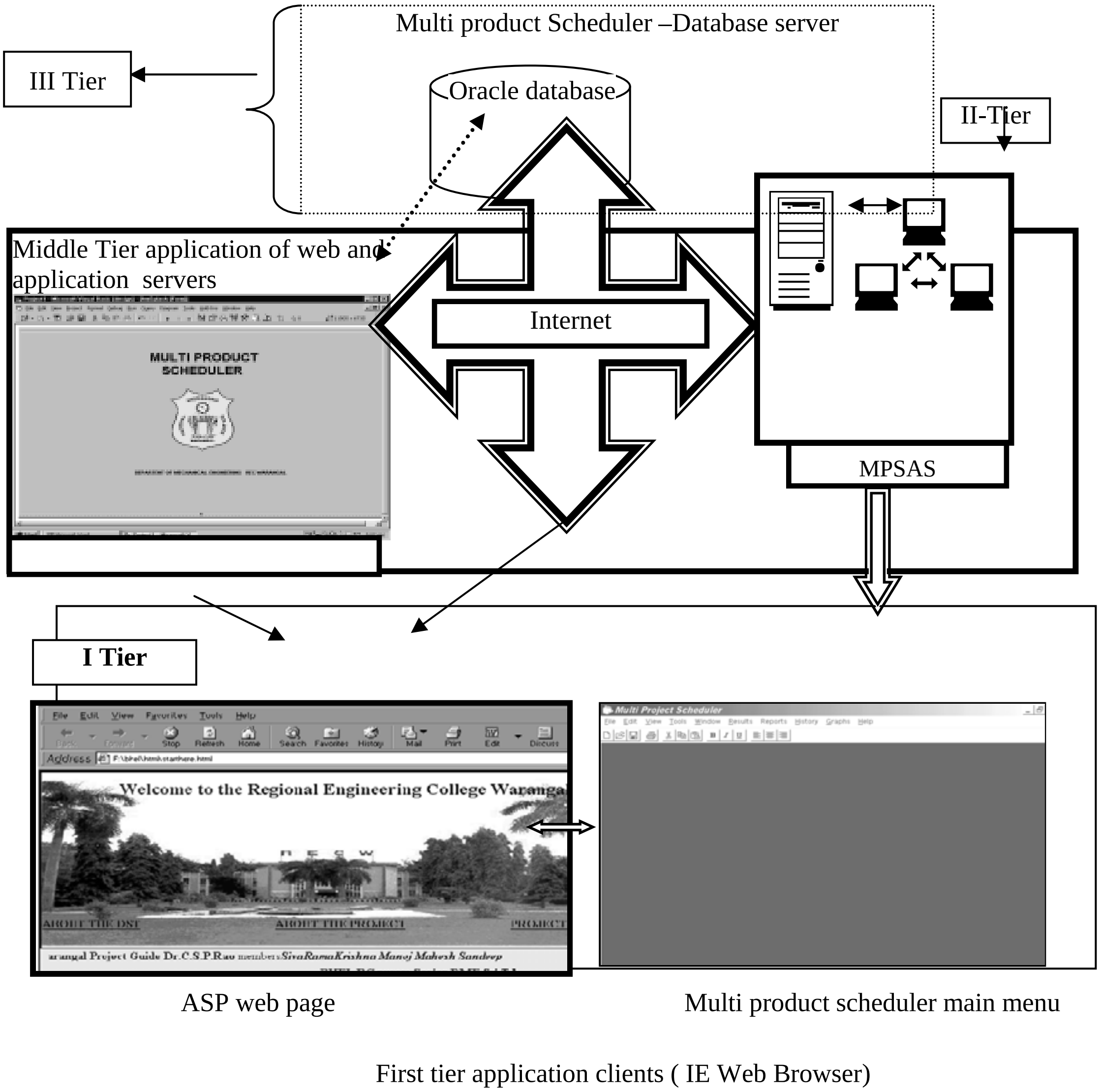


Figure 4: Three tier architecture of web integrated multi product scheduler

The third tier is the multi product scheduler database server. A multi product scheduler database server manages the relevant multi product scheduler data. In this package, the entire database is remotely deployed on a computer that is physically different and separate from the web server and application server.

The relationship between the middle tier and the third tier is more straightforward than that between the first tier and the middle tier. This is because the database operations are relatively standardized with the relational database management system (RDBMS). In the present design, emphasis is made on the implementation of a synchronized scheduling tool. It is found that a well designed and implemented application server is essential to support simultaneous use of the same scheduling tool among the geographically dispersed planners. The change remotely made by any one of the clients is captured by the application server that in turn informs all the other current clients connected on line about the change instantly.

5.4 User Interfaces for Distributed Decision Making

The web-based multi product scheduler has user friendly graphic interfaces which help the user in decision making. Some of them are discussed below.

Home Page

The home page is a login page consisting of user name and password. The Home page has three types of authorization levels. The first level allows to send request for the order and get back the delivery date. This level is generally allowed for a sales person or customer working off-site. The next level allows with full browsing capability into the manufacturing model and shop capacity, but no change capability. At this level, someone can play around to schedule and reprioritize orders, but cannot make an actual change to the shop plan. This level is generally allowed for middle level management. The third level, generally used by the top-level management, gives them full authority to revamp the schedule as required. Figure 5 represents the home page.

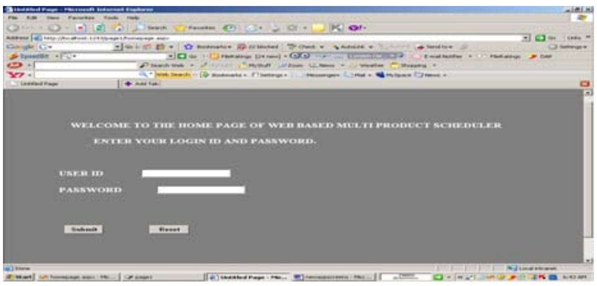


Figure 5: Home Page of Web-based Multiproduct Scheduler

Once the user logs on to the system, several other user interfaces appear, some of them are *New Work Order details*, *Project Schedule* and *Workcenter and Workplace loading*.

New Workorder Details**:** This GUI allows the user to add any new customer order by giving the priority and start date for any customer order, the software runs the schedule program and predicts the expected delivery date of the workorder. Figure 6 illustrates the new workorder details web page.

Figure 6: New workorder details web page.

*Project Schedule***:** This screen allows the user to see the schedule of a given part belonging to a PGMA and WONO. The accessibility of this GUI is given to both customer and the middle level management. The Project schedule web page is shown in Figure 7 below.

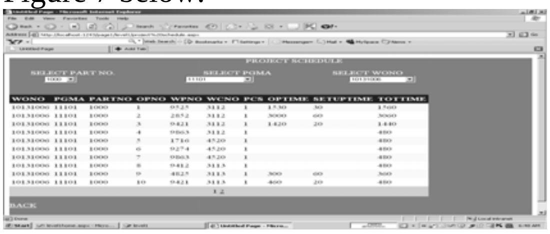


Figure 7: Project schedule web page

*Workcenter and Workplace loading***:** This GUI allows the user to know the loading of a particular machine on the shop floor for a given time bucket. The accessibility of this screen is given to only middle and top level management. The Workcenter and Workplace loading page is shown in Figure 8.

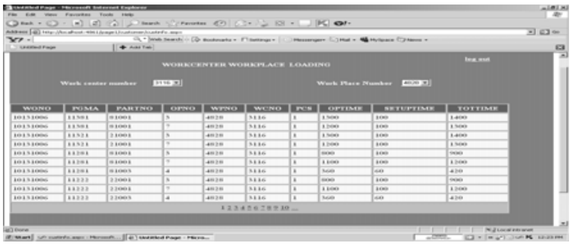


Figure 8: Workcenter work place loading web page.

6. Conclusions

In this paper we discuss a real time design and implementation of a web integrated scheduling support system for a turbine manufacturing job-shop. In particular, this system is developed in two phases, phase- I for stand-alone master run and phase-II for web deployment for facilitating distributed decision making. The scheduling module determines the make span of a work order based on priority index in conjunction with host of scheduling heuristics such as, the *least working rule*(LWKR), *most work remaining* (MWKR) and ratio of shortest processing time to total time(SPT/TOT) for refining the schedule generated earlier. It was found that priority with *least work remaining rule* performs better in comparison with the other heuristics. The scope of our work extends to integrating the web-based scheduling module with a remote inventory planning module.

Acknowledgements

The authors would like to extend their thanks to the Department of Science and Technology (DST), New Delhi – INDIA, for supporting this research project through the grant number: III.5(86)/97.ET (PRU). The authors also express their gratitude to the personnel of the user industry, in particular Mr. Ravichander and Mr. Mangapathi Rao managers of BHEL who have provided us with the necessary data for carrying out this work. The authors would also like to thank Mr.V.Mahesh, Associate Professor, S.R Engineering College, Warangal for his valuable suggestions during the development of the project.

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