GLOBAL PRODUCTION MANAGEMENT IN GRAPHIC ARTS PRODUCTION — MODELS, EXPERIENCES AND DEVELOPMENT POTENTIAL

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Abstract: Production processes in the graphic arts industry, especially in newspapers, differ from other industrial manufacturing processes in many critical aspects. Enterprise-wide production management requires new methods and system solutions.

This paper presents a general model for global production management systems in the graphic arts industry. The model covers product structuring, standardization of intersystem communication, production tracking and scheduling, and resource allocation. Experiences from a prototype installation are reported.

The possibilities of future extensions to the model is discussed. Industry restructuring will require the management of networked virtual enterprise production processes. Increased information repurposing will require the management of parallel production of printed and digital products. The model can also be enhanced through the incorporation of additional product information, e.g., for color and quality management purposes. We show, that our model can be developed to include these features.

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INTRODUCTION

Production management in the graphic arts industry

Real time production management in the graphic arts industry has traditionally been limited to local monitoring and control of specific functions, e.g., printing press or newspaper mailroom operations [Nordqvist 1996, Karttunen 1993]. This may seem odd, since the production process is normally very complex with strict time constraints and a considerable interdependence between the different production steps. In addition to this the industry have been more and more focused on to producing specialized products in shorter production runs. It would seem that company-wide, i.e., global, computer based production management tools could significantly improve productivity, as it has done in, for instance, the manufacturing industry.

Graphic arts production, however, has a number of characteristics that have made difficult the application of global production management solutions common in other industries.

- Diverse, dynamic production elements and subassemblies. In the prepress activities of graphic arts production, the manufacturing components are information elements of various nature (text, line art, graphics). These content elements can, in contrast to manufacturing components in, e.g., mechanical industry, dynamically change shape and dimensions during the production.
- Element re-use and multichannel distribution. Content elements are not consumed as they are used, as in the assembly industry. The same element can be re-used in the same or in a different form in other products. Traditionally, all products have been print products, but increasingly, printers and publishers choose to disseminate their information using multiple parallel distribution channels, many of them digital, e.g. cd-rom and WWW.
- Strong concurrency in production. Much of the prepress production is carried out in parallel. Because of the dynamic nature of the production elements, changes that affect the entire product structure are often made very late in the production run. Especially in newspapers, product design and actual production are normally carried out concurrently. In contrast to this, press and postpress production processes are mostly linear and sequential.
- Distributed production. Significant portions of the production are often carried out by subcontractors, outside the control of the responsible contractor. There is also an increasing trend, especially in commercial printing, to distribute production in networked organizations and virtual companies.
- A heterogeneous production technology. Different functions in the production process are carried out with the aid of technical tools —

computer systems and mechanical equipment — that are often incompatible in an information exchange sense. Specialized systems from different vendors cannot normally exchange information about production status.

These and other characteristics have made difficult the application of modern production management techniques and tools in the graphic arts industry. The same characteristics, however, make the total production process difficult to monitor and control, with frequent unmanageable production disturbances as a consequence. Thus, the potential benefits of technical real time production management solutions are considerable.

Objectives

In a research and development project involving several printing and publishing companies we have developed a model for a global production management system for the graphic arts industry. We have tested and validated a prototype system in actual production at a newspaper company.

In this paper we present the general model and the prototype implementation. We also report on the experiences from the pilot installation which show that a global real time monitoring of graphic arts production is possible and valuable.

The prototype has only limited functionality. The general model presented, however, is powerful enough to allow several types of extended functionality. We discuss the possibilities of constructing more advanced production management solutions, based on the same conceptual model, that include the management of additional product types, enhanced product information, networked production processes and cross-media publishing.

A MODEL FOR GLOBAL PRODUCTION MANAGEMENT SYSTEMS

A general GPMS structure

The global production management system (GPMS) model described here has earlier been conceptualised and developed by Nordqvist [Nordqvist 1996]. We can identify three major steps in the development of the GPMS model: (1) the definition of a basic production management system (PMS) model, (2) the identification of local and global PMS:s, forming the basis for defining the concept of a GPMS, and (3) the extension of a GPMS to interact with actual processes, their resources and the products produced.

Our focus here is to describe a model for a GPMS operating on an enterprise-wide level, i.e. over the entire manufacturing process, from sales and order taking to the delivery of the final product, including the design, production, packaging and distribution processes.

To implement a GPMS, or a PMS, real time information from the actual process is required, e.g. the status of the components and products being produced [Enlund et al 1995]. The process and the products have to be formalized in models of reality. The interaction between the GPMS and the process, its resources and the products are also important issues to be discussed. To achieve the necessary interaction, mechanisms are required for the transfer of data to and from the GPMS.

Our GPMS concept differs from the common definition of PMS in manufacturing science. A production management system, according to Viswanadham [Viswanadham et al 1992], regulates the manufacturing system at the operational level through its decisions regarding what to buy and make. The two main objectives of a PMS are the planning and control of a manufacturing operation. The approach presented in this paper is more specific and the functionality has been extended to cover the entire production process and surrounding systems which indirectly or directly affect the manufacturing process.

The GPMS model is shown in figure 1, an elaboration of the model presented in [Nordqvist 1996]. The GPMS is connected to the different local production processes through specific intersystems communication mechanisms which are discussed at the end of this chapter. The process, the resources and the products are described as models in the GPMS. The models are updated when there are changes in reality.

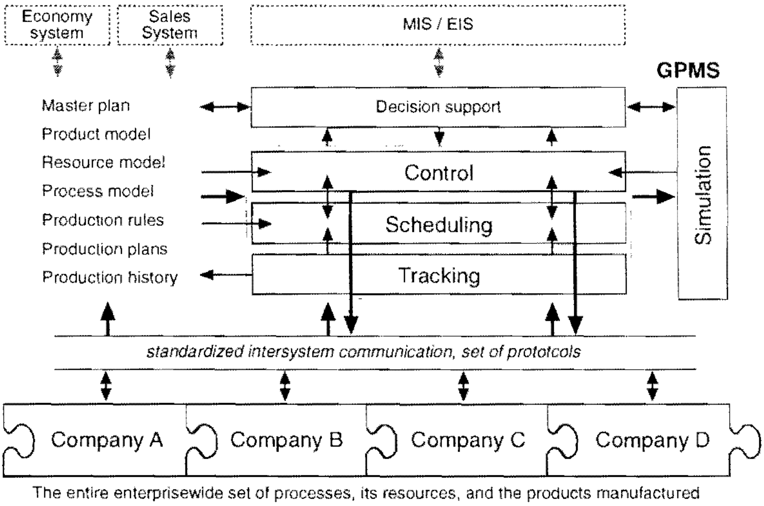

Figure 1: A general model of a global production management system.

In figure 1 it is indicated that a GPMS can serve a set of companies which are interconnected in an enterprise chain or network in order to manufacture a specific product. The enterprise A–D can be one or many companies and there can be one or many communicating GPMS:s. A GPMS can be used by a company as a means of integration with other companies with compatible GPMS:s.

Production management system functionality

The central functional components of the GPMS are tracking, scheduling, control, simulation, and decision support.

The actual production processes are monitored by the tracking module. Overall production plans are scheduled and coordinated by the scheduling module. The schedules are then communicated to the production process by the control module. Simulation can be used, for instance, when there is a production disturbance and it becomes necessary to replan or to perform a resource reallocation. Decision support can be obtained through the use of simulation, as described in [Nordqvist 1996]. The function can be handled by either an internal module or an external module, abstracting strategic information from the other GPMS modules. The GPMS should also support communication with business systems used in the company or by a group of companies which together produce the product ordered by a customer.

For active real time production control to be possible using a GPMS, the system requires on-line information on the products to be produced, the activities involved, the resources available and the production plans set. In a heterogeneous technical environment such as most graphic arts enterprises are, the process involves production systems from different manufacturers. The required information must be exchanged in a structured, standardized manner between the different local production management systems and the GPMS.

The decision support component has the function of gathering information from production data and statistics from the other components of the GPMS. This information can serve as a basis for long and short term strategic planning by corporate management and other concerned. The information can be presented or used in two different ways. The first alternative is to use an existing management information system (MIS) or an existing executive information systems (EIS) in the company and not try to re-invent the wheel. Thus GPMS data can be gathered and exported to the MIS/EIS, in real time and with a high degree of automation. The second alternative is to use the decision support component to present customized key figures based on the information within the GPMS. A client interface could be based on, for instance, a spreadsheet application or on intranet technology [Hedin et al 1997].

Product, process and resource models

The products manufactured in graphic arts production are traditionally paper based, e.g., books, magazines, and newspapers. In the graphic arts industry, there has been only limited interest in developing commonly accepted methods for specifying product models, as has been done in the manufacturing industry. However, attempts have been made to standardize the generic description of a newspaper product, for instance by IFRA [Enlund et al 1994, Thoyer 1995]. In this case, the product description is part of an object model used in the production tracking mechanism called IFRAtrack [Thoyer 1995]. IFRA proposes the use of a structured description of the product to be manufactured, its objects and their relationships. A product description is an instance of a product model that describes a newspaper product being manufactured. A newspaper product is manufactured in a rapid and evolving process with concurrent properties [Alasuvanto 1994]. This requires the use of a flexible product model that can be realised in the database structure of a real time GPMS. It is also important to use a standardized product model when products are exported and imported between different companies. The digital formats for packaging the raw material of the products are fairly standardized, for example in PostScript or TIFF, and in application formats such as QuarkXPress and PageMaker, but there are no accepted standards or mechanisms which support the exchange of product data — the information concerning the structure of the raw material and the products. A well defined and standardized product model could act as a universal job ticket for the product [Bäck et al 1994]. This is even more important to the commercial printing industry than to the newspaper industry, although newspaper companies also tend to handle increasing amounts of externally produced material.

A process can be seen as a set of specified activities. Depending on the level of detail studied, the level of granularity [Enlund et al 1994], each activity can be further described as a process consisting of other activities. In order to create a model for global production management systems it is necessary to identify and map the activities that affect the system. This mapping should be performed at a common, specified level of granularity for all included parts of the system. It is necessary to first define the entire process to be further described. This process can then be further broken down into activities, each activity being further described as a process containing other activities, and so on, in a hierarchical manner.

A resource model is a structured description of the resources available for executing the activities in the process model on the objects described in the product model. The resources can be persons, workgroups, machines, or combinations of these. With each resource is associated a set of primary and secondary capabilities of the resource, as well as information about the performance and cost of using the resource in different types of activities. In order to connect resources with activities in the early planning stages of the production, it is useful to use the concept of agents and roles as an intermediate layer [Nordqvist 1996].

Interfaces to the production process

There exists only a few structured mechanisms for communication of production management information that are designed for use in the graphic arts industry. The available mechanisms are mostly based on simple file transfer or on tags that accompany the material. A few mechanisms are relayed and co-ordinated through the use of database technology. Let us briefly mention two examples using different messaging techniques and aiming at solving different problems.

One promising evolving format is called CIP3 (Cooperation for integration of Prepress, Press and Postpress). It transfers the product information available in prepress production to the press and postpress stages. The format is based upon PostScript and includes information in tags joined to the actual prepress material. CIP3 is mainly intended for the commercial printing industry and can handle information such as product administration data, low resolution images, transfer curves, register marks, color and density measurement, cutting and folding information and private data [Daun et al 1996]. The format aims to reduce the duplication of data acquisitions and facilitate shorter production cycles

The IFRAtrack messaging mechanism makes it possible to create open and modular global production monitoring systems [Enlund et al 1995] which permit intercommunication between local and global production management systems. IFRAtrack is primarily aimed at monitoring the entire workflow but promising developments could extend IFRAtrack to include also process scheduling and the allocation of resources. The format is best utilized in a database environment where all information is collected and distributed by means of a database.

CIP3 and IFRAtrack use different messaging techniques and help to solve different problems in the graphic arts industry. Both can be used and implemented independent of each other and each is adding value for the user. There are other proposed messaging techniques. [NAA 1994] , e.g., describes a mechanism primarily suited for the exchange of newspaper mailroom process data. The EDIFRA mechanism can be used for the interchange of business information, especially for newspaper advertising sales data [Gottberg 1995].

AN IMPLEMENTATION FOR NEWSPAPER PRODUCTION

Technical solution

We have developed a prototype GPMS that has been installed at a medium-size Swedish newspaper with a six day circulation of 66.400 copies.

The system is based on the IFRAtrack object model [Thoyer 1995] with extensions for scheduling, resource handling and decision support. For storage of the production data we have chosen to use a standard Oracle relational database, even though an object-oriented database in some aspects would be a more natural choice since we are dealing with an object model. However, we found the benefits of a well established technology to be more important [Hedin et al 1997].

The database is completely encapsulated by an object cache that handles the translation between objects and database tables, and speeds up the data access (figure 2). All access to the database is done through an object-oriented services API (application programming interface).

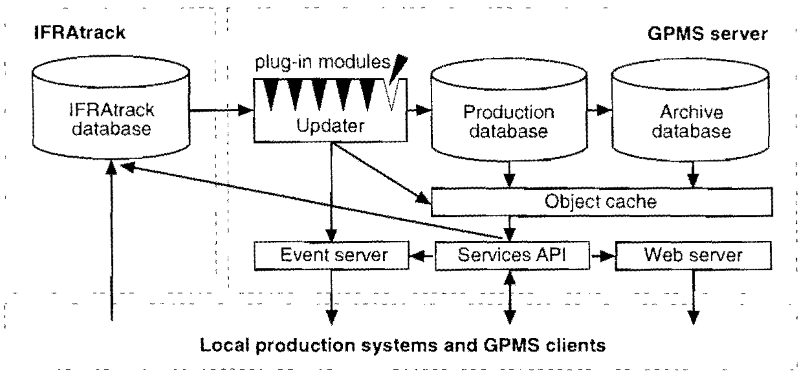

Figure 2: The GPMS prototype.

We have based the system on Internet and WWW technology — an intranet. A WWW server extracts information from the production database through the services API and displays it to the users through HTML pages and Java-applets. This means the system is platform independent, easy to install and easy to maintain, since no extra software, except a WWW browser, is needed on the client computers [Hedin et al 1997]. The WWW server also provides an easy accessible base for system information and documentation, on-line user manuals and user feedback through HTML pages and forms.

The communication with local production systems is handled through the IFRAtrack message mechanism [Thoyer 1995]. Messages conforming to the IFRA Message Format are inserted into a separate IFRAtrack database accessible to all systems. The messages are then collected and processed by the GPMS which updates the production database. This solution allows one system to be replaced by another without affecting the GPMS, as long as both systems can generate IFRAtrack messages.

A modular architecture allows extended functionality by the addition of plug-in server modules. These modules can handle, for example, decision support calculations, simulation, and the extraction of selected data from the production database to a separate archive database [Fällström et al 1997]. In addition, an event server allows a system to subscribe to certain events, such as when a deadline is passed. The system will then be notified immediately when one of these events occurs.

Modelling and implementation

We argue that a modular architecture is very important in a system like this. An extendible modular structure, easy to modify and specialize for certain purposes, is better than a general model that attempts to suit all possible cases. This is true not only for the internal structure of the system, but also for the interaction with local production systems. In IFRAtrack we have found the modular communication mechanism required. The overall modularity also makes the system prepared for future extensions of the functionality as discussed later in this paper.

In the prototype system we focus on prepress production, page output and printing. By monitoring and analyzing how different product structures affect the runnability in the press, we can predict delays in the distribution at an early stage.

We provide tools for planning of the prepress production by setting deadlines and by assigning pages to different page producers. Our model can handle tracking of separate elements on a page, but the prognosis calculations for decision support is based on pages only. We believe that this is sufficient for a good result.

An extension to the most common page layout program in the newspaper industry, QuarkXPress, handles the creation of page production events. At page output, we get event information automatically from the RIP:s and from the plate-line. In addition, a hand-held barcode reader is used at film output whenever a film is manually approved. The printing press control system sends information on number of printed copies, waste, and unplanned stops during printing. All events are sent to the GPMS using the IFRAtrack message mechanism.

We do not track the distribution operations at this point. The last measuring point is when a truck is fully loaded. However, a distribution model is included in the system, from which we can calculate a unique delay cost function for each truck. The distribution plan at the pilot prototype installation is usually determined from one day to another, but if the plan is changed, the delay cost functions will automatically be updated.

Using a GPMS involves a number of different types of information access which are handled by the system.

- Real-time monitoring during production. Allowing all users to get an overview of the overall production state.
- Notification of events. The ability of a user to subscribe to certain types of events, such as when a deadline is passed. An event can then trigger different types of automatic warnings, such as displaying a message on a screen, sending an e-mail, or sending a message to a cellular phone.
- Structured postproduction reports. Provide reports of the production at different levels of detail automatically by e-mail every morning or through a GPMS client tool.

Experiences

Installing a GPMS system at a newspaper can be a controversial task. There may be a strong opinion not to accept any intrusion into personal integrity. The detailed tracking of the production made possible by the system can, and to some extent unavoidably will, do this. But more important, we believe, real time information about the overall production status, when spread to all staff involved, will make the production easier to survey and control to the benefit of both users and publishers.

The pilot system has been in operation only for a short period of time but interviews with the users indicate that the acceptance of the system has increased. The planning tools for prepress production have been well accepted, with requests for extended functionality, and the page output now feels more controlled. We also have clear indications of reduced delays in the prepress production.

The production reports automatically sent by e-mail each morning are appreciated by the decision makers, giving them quick and accurate information including the economical outcome of the production.

We did underestimate the problem of getting other vendors' systems to provide the GPMS with production data. Even though the IFRAtrack message mechanism makes it an easy task for a local production system to connect and deliver messages, this has taken an unexpectedly long period of time, due to non-technical reasons.

Discussion

Since 1995, there has been several other pilot newspapers using IFRAtrack based production management system prototypes — *Het Belang van Limburg* in Belgium, *Die Abendzeitung* in Germany [Manning 1996], *Göteborgs-Posten* and *Östgöta Correspondenten* in Sweden. Attempts are also being made to use and extend IFRAtrack for catalogue production by the company IKEA. In this case, it is necessary to create a process model for the catalogue production process, but many of the defined objects will be similar to those in newspaper production. We also know of a joint project among eight commercial printing companies in Sweden aiming at implementing production management systems using standardized and open formats such as IFRAtrack and CIP3.

It is still too early to assess the effects of company-wide production management systems. It is clear, however, that platform independent GPMS:s can be designed and implemented for different types of graphic arts production. The IFRAtrack production status message mechanism is a powerful and flexible basis for such systems. The open design of IFRAtrack makes it possible to extend the proposed standard in various ways.

EXTENDING THE GPMS MODEL

Cross media publishing

A generalized method for specifying the workflows, the processes and the resources (people, skills, software, hardware) required for producing specific media products can be described. This method can then be used to describe the actual processes and resources. Such a model will make it feasible to assign and dynamically reassign resources to the production of specific media products.

Today, without these models and tools, there is a very time and labour intensive process to manufacture media products for parallel publishing in different channels. The collection and preparation of media elements is often done in parallel and the elements are packaged separately for different distribution methods.

True cross media publishing would store the content elements in a distribution channel independent form. The collecting could be done separately for different type of information but the elements stored in a common manner. Packaging and repackaging could then use different versions or combinations of media elements.

It is important to define a common product model that enables a media independent product description. This description format could then easily be added to the existing tools for design, manufacturing and distribution of media in different channels.

To achieve this we also need to define a modular and extensible framework for producing and managing the entire process of parallel publishing and multichannel distribution.

New product types and enhanced element information

Media products are formed out of instances of media objects stored in a media database. Different elements can be used and reused in different ways in different products. Some products will be persistent (print, cd-rom), some will be volatile (WWW). The logic of combining different uses of media elements in different types of products can be described in a generalized model of media products. Each distinct media product can then be described with the aid of a structured product model.

In a GPMS intended for a modern graphic arts enterprise, the product model must cover both traditional product models for paper based products and extended models for digitally distributed products, e.g., cd-rom and WWW, and include also time dependent contents elements such as audio and video. There have been attempts to create general media product models that can handle cross media, multichannel publishing [Saarela et al 1997]. Such models have to be carefully defined to allow great flexibility in product and workflow design while having strong descriptive power.

Structured product models can be designed for most product types common in the graphic arts industry in the same manner as for newspapers in the GPMS prototype described earlier. By including such product models, together with adequate process and resource models, the GPMS can be adapted to monitoring and controlling also these production processes.

The product models described by Nordqvist [Nordqvist 1996] and by Bäck et al [Bäck et al 1994] can easily be extended to include additional semantic product information. Additional elements and their attributes can be added to the product model to facilitate element re-use and multichannel distribution. Media content elements are not consumed as they are used, as in, for instance, the assembly industry. The same element can be re-used in the same or in a different form in other products. Traditionally, all graphic arts industry products have been print products but, increasingly, printers and publishers choose to disseminate their information using multiple parallel distribution channels, many of them digital, e.g. cd-rom and WWW.

In a digital, possibly multichannel publishing situation, the content elements must be described in a rich format enabling the inclusion of, e.g.:

- Technical element descriptions (product data). The format should be able to handle physical form descriptions and full color information as described in, for instance, CIP3.
- Meta-information containing semantic information about the contents of the elements. This can enable automatic product assembly for different distribution channels.
- Element event history logs with information on in which products and in which manner an element has been included/published. This is important for multichannel production management [Nordqvist 1996].
- Administrative data, e.g., creator, owner, storage medium. This is necessary when importing and exporting elements between separate companies

With the move to digital technology, we have transferred almost all processing from manual work with film and paper to computer based design and manufacturing. Digital material has been handled primarily using de facto format standards. With the breakthrough of CTP technology we have completed the digitalization of the entire chain of manufacturing print originals. One effect of this is that traditional methods of transferring administrative and product information have been lost, since the digital formats contain only the actual material.

It is important for the industry to agree on a set of open and general product information exchange formats to be able to address the above needs. One possible general solution would be to combine the technical element description in CIP3 with the product structure information in IFRAtrack, using the IFRA Message Format as a basis for platform independent communication. Our experience shows that the IFRAtrack format can be extended to handle the required information.

Networked production

Digital technology allows the industry to operate within new business structures. Networked, or virtual, organizations are new ways of flexibly handling graphic arts and media production. Within these organizations, product data and element information must be exchanged digitally and reliably. Today, material is transported digitally but information about the material is often exchanged on paper or in a digital paper-like form. In order to efficiently and flexibly utilize a constellation of different companies making up a complete process chain from customer to customer we need standardized and powerful exchange mechanisms for product and element information.

The GPMS system described earlier can be extended to cover the management of production in networked, distributed organizations. Data exchange can be based on Internet technology and be implemented as intranets or combined to form so called extranets tying a group of companies together.

Such an extension of the GPMS concepts requires:

- Global element naming mechanisms where the industry either agrees on terminology and naming conventions or accepts possible emerging de facto standard.
- General interfaces and protocols for exchanging product and production status information between systems and applications.
- Agreed methods for the management of administrative and quality information shared by several companies.

A networked GPMS implementation could, in addition to improving production control, generate an improved customer service, e.g., allow direct customer monitoring of the progress of a product regardless of which company in the virtual business groups is doing the actual processing at the moment. This is currently being done by, for example, Federal Express and DHL, both networked global delivery companies.

CONCLUSIONS

The GPMS described in the paper is designed for newspaper publishing. At a commercial printer, the system would have to be modified to focus on the specific gamut of operations and products. To directly apply a newspaper GPMS in the commercial printing industry would be difficult, as a newspaper can be seen as a collection of different company types. In a newspaper operation, content creation and design is carried out by the editorial and advertising departments. Layout and prepress manufacturing is similar to the operations at prepress houses. Printing is, aside from scale factors, identical operations in commercial and in newspaper companies. Postpress operations differ mainly in speed and volume. If a group of commercial graphic arts companies would come together in a virtual organization, the similarities to a newspaper company would be striking. Such a business could easily use the GPMS concepts and tools developed for the newspaper industry.

The graphic arts industry is diversifying into cross media and multimedia publishing. This requires the management of new media element types and new types of production workflows. Ideally, all this should be integrated into a common management structure. The GPMS model here used in newspaper production can be extended to include the monitoring and planning of manufacturing for several media types and distribution channels.

We believe that the practical construction of viable global production management systems for multichannel publishing is rapidly becoming possible. Global production management systems in cross media publishing will make possible better control, added flexibility, improved customer service, and increased productivity.

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