Integration of manufacturing information using open hypermedia

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Abstract

This paper discusses some of the benefits from using an open hypermedia system to deliver the diverse range of information found within the manufacturing environment. The open hypermedia approach to information management and delivery allows a single multimedia resource base to be used for a range of applications, and permits a user to have controlled access to the required information, in an easily accessible and structured manner. Our approach is illustrated by the presentation of a case study of a system delivering maintenance and process information on the factory floor, within a fully automated manufacturing plant. The development of the application is discussed, together with guidelines for the authoring and delivery of information. It is our contention that with the integration of open hypermedia, and knowledge based systems together with network technology giving access to external databases, the concept of industrial strength hypermedia can be realised.

Keywords: Open hypermedia; Information management; Manufacturing

1. Introduction

During the 1980s, the emphasis within manufacturing industry was on the integration of a number of systems within the confines of a single manufacturing plant. This was typified by the introduction of CAD/CAM, and its integration with the production and planning systems. The result was that each manufacturing facility, becomes an island of automation. Currently the emphasis on integration is moved towards the concept of the virtual factory through the use of supply chain management techniques, such as EDI (electronic data interchange), and JIT (just in time). Successful collaboration within, and between organisations is in principle achievable by sharing the wide range of engineering and commercial information produced, and used during all phases of the business cycle. This integration will enable manufacturing plants to operate as one cohesive unit regardless of location, giving an increase in supply flexibility and reduction of costs. Current network technology makes it possible for companies with dissimilar computer systems to exchange a wide range of information, for example about inventory levels, and delivery schedules. However for many companies the development of systems and business processes that allow total electronic collaboration remains elusive. Even highly sophisticated companies have found, and continue to find, that the task of creating a seamless electronic network of lean computer integrated manufacturing operations to be frustrating and difficult [7]. This results in managers of companies struggling to make their information systems more

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flexible, and are perplexed about why so much paper is still being shuffled around both the design office and the factory floor.

Integration on the scale proposed in this paper implies different goals too different manufacturing functions. To the manufacturing engineer, integrated manufacturing means the integration of CAD and CAM, while to the factory floor it implies a communication and system consolidation exercise. To senior management true integration is concerned with an enterprise wide information system in which all parts of the organisation base their operation on common and, and importantly, current data in a shared database. Shared data has been termed the glue that binds the enterprise together, and allows it to operate successfully as a unified system.

Stored common data will not by itself be sufficient, however, operators and management will need an increasing amount of intelligent support from computer based systems to manage the retrieval and interpretation of the relevant data, and to define the appropriate course of action. In the fields of manufacturing, intelligence will generally be given to individual manufacturing cells, to aid with production, quality, and maintenance. Database and information systems technology therefore have a crucial role to play in modern manufacturing management. Rigorous and consistent structuring of data that describes a product from design to final shipment will potentially allow anyone within the organisation to access the information for their decision making process. Currently most individual functions of a manufacturing organisation maintain their own private databases, resulting in islands of data, analogous to islands of automation.

Current engineering practice, particularly concerning the early design stage of the product, requires redefining to make full use of the rich diversity of available and emerging information technology. Such technology can address a wide range of activities included the capture of the requirement definitions, product modelling and the product’s complete documentation (including drawings, manufacturing procedures and the OEM’s information). Currently the basic components required for this strategy communication, including hypermedia, and network technology, are available to exchange information electronically. However the common services and methods used to exchange information over wide area networks, and to facilitate a range of supporting collaborative work is currently lacking. The information generated during the design process will form the core of the information required during the products life cycle. Engineering practice is evolving as companies are forced to increase their overall effectiveness, flexibility and response times to customers. To overcome these challenges the company must maximise the reuse of existing internal and external information, while forming virtual enterprises with firms who focus on their individual core competencies. A successful engineering information management strategy must be able to integrate this information, irrespective of format, from a large number of sources, and allow personnel easy, and controlled access to the information. In addition the integrity of the information must be maintained by the implementation of suitable change control, and associated security measures. Finally if documentation is to be changed, the required process must be error free, and procedures used must be capable of auditing by recognised quality procedures. This paper will address some of the aspects of information integration, with particular reference to manufacturing activities on the factory floor.

2. The application of open hypermedia within manufacturing

Computer-based systems for the presentation and distribution of text together with a limited range of graphical information, in a sequential fashion is no longer considered sufficient, for the complexities of modern production equipment. If the information available is expanded to include high quality graphics and video, and is provided with a retrieval system that permits the user to move easily between the different items of information in a structured fashion, then the management of the engineering data resource can be optimised. To fully justify this approach the problems with information retrieval from paper-based documentation need to be highlighted:

- The issuing of updates and modification notes may not be rigorously enforced or collated. The available documentation on the factory floor may
not be to the latest version, and the users may be unaware of any changes.

- If the release of documentation needs to be controlled, monitoring of the audit trail needs to be rigorously enforced.
- The constant cross-referencing, between instructions, engineering drawings and parts lists can be both time consuming, and error prone.
- The quality of the documentation, particularly on the factory floor can be very poor.

One of the major problems experienced with paper documentation can be the physical size of the documentation sheet and its relationship to other sheets. This can be highlighted by current trend of presenting electrical circuit drawing on A4 sheets, while this keeps the individual paper pages conveniently sized, the cross-referencing becomes very difficult, as the somewhat arbitrary sectioning does not allow the user to see the complete picture. [8] As any engineer will testify, accurate tracing of a signal path even across a few A4 sheets, while on the factory floor can be considered very difficult. These, and a number of secondary problems contribute to low efficiency within the manufacturing enterprise, the problems with paper documentation are summarised in Fig. 1. In most organisations the formal information is supplemented by information gleaned by other engineers and operators, and is normally recorded in personal logbooks that is not easily accessible. Within a hypermedia system, the provision of integrating third party information is available, with minimum effort. It can easily be appreciated, that this information is not only of value to other engineers, but also to the equipment manufactures, as it will form a maintenance and operational history, allowing the manufacture to identify problem areas.

The use of hypermedia is particularly suited to engineering applications, as the information is normally organised into a large number of relatively small documents, incorporating a considerable amount of cross-referencing, while at any one time the user may only require a small fraction of information. For example, during the commissioning and maintenance of process equipment, an engineer will typically have to refer to test schedules, electrical circuit diagrams, mechanical drawings, list of parts, and perhaps a personal log book.

If hypermedia is to be accepted in industry, the delivery computer must be taken to the point of use, as opposed to the user leaving the factory floor to refer to a documentation on a remote desk-top computer. In the approach discussed in this paper, all the available information is accessed using a portable pen computer, allowing the maintenance engineer to selected the required information easily and quickly on the factory floor. With the provision of rigorous quality control systems, this concept will ensure that the correct documentation is used, and is presented in a clear and consistent format, hence reducing the possibility of errors. In the consideration of manufacturing information provision, the requirements go beyond the provision of equipment and process documentation either locally or remotely, and probably will include real time engineering data. This allows any process be continually monitored, and on the basis of this information the preventive maintenance tasks can be programmed, and the correct procedures being called up as required. In the case of a failure the system can be interrogated on-line, ensuring that the maintenance staff are directed to the correct area, ensuring that maintenance down time is minimised. With the use of the Internet and Intranets, it is possible for the user on the factory floor to have a range of functions, including access to stores for rapid part procurement, and the manufactures’ database to obtain updates and procedural changes.

In the development of an industrial hypermedia application, a number of questions need to be addressed, in particular those relating to the capture and subsequent authoring of the information resources for the application. Within manufacturing industry, operational and maintenance information is normally held on either paper or microfiche. The size of a set of documents ranging from a few hundred pages for a medium-sized industrial machine-tool, to thousands of individual manuals, with supporting engineering drawings, for a complete manufacturing plant. If the information provision not only includes production and maintenance information, but also incorporates design, quality, and standards, the stored documentation can become significant. With an industrial application it should be noted that the information capture and authoring is not an isolated event that freezes the information at a point of time, but is a continual process as modifications are incorpo-
rated, all of which must be correctly linked into the existing hypermedia system. As with paper documentation the maintenance of the application needs to be considered, it is hoped that with the tools we are developing this effort will be automated, with minimal cost. While the use of electronic media will reduce the authoring effort, the current reliance on electronic transmission of information, the capture and authoring of an application will prove to be a considerable problem. Experience has shown that electronic media generated by an individual (e.g., a memorandum detailing a minor change) may in all probability will not be formally entered into the document audit trail, unless a rigorous document management system is enforced. The collection and integration of documents produced and transmitted by individual (e.g., faxes and e-mail) will prove to be a significant challenge as the use of personal computers reaches all aspects of factory floor activity.
Within any manufacturing organisations, engineering personnel are highly skilled, and hence highly priced, therefore the percentage of their time spent on performing useful maintenance tasks must be maximised, in particular the time spent locating the correct information must be minimised. Estimates have shown that over half an engineer’s time is spent in searching for and retrieving information to undertake an activity [5]. It is the ability to integrate many forms of information, from a number of sources, and allowing the engineer to access them with ease, at a single point, that has led to the requirement for of computer based information retrieval system.

3. Open hypermedia systems

The application discussed in this paper, has been authored using Microcosm, the open hypermedia link service developed by the Multimedia Research Group at the University of Southampton, which permits the integration of a wide range of different applications into a single multimedia resource base [3]. Microcosm consists of a number of autonomous processes that communicate with each other by a message-passing system. No information about links is held in the document data files in the form of mark-up. Instead, all data files remain in the native format of the application that created them. All link information is held in link databases (linkbases), that hold details of the source anchor (if there is one), the destination anchor and any other attributes such as the link description. This model has the advantage that it is possible to have different sets of links for the same data, and it is possible to make link anchors in documents that are held on read only media, including CD-ROM and conventional electronic document management systems.

Microcosm allows a number of different actions to be taken on any selected item of interest, so use of the system involves more than simply clicking on buttons to follow links. In Microcosm the user selects the item of interest (for example a piece of text) and then chooses an action to take. A button in Microcosm is simply a binding of a specific selection and a particular action. The basic Microcosm processes are termed viewers and filters.

3.1. Viewers

Programs that allow the user to view a document in its native format. The task of the viewer is to allow the user to peruse the document, to make selections and to choose actions. Typical actions are follow link, start link and end link (where links may be to processes as well as to documents). The actions themselves are not carried out by the viewer. Instead, the viewer is responsible for passing the information to the filters where it can be processed. Viewers are inherently user interface components and, as such, will have to be controlled by any screen management process. A feature of Microcosm of particular relevant to engineering applications, is the use of viewers that permits the appropriate information to be used to initiate the link retrieval process. An example of this extended functionality, is the integration of Microcosm and the industry standard drawing package AutoCAD.

3.2. Filters

Processes that provide the functionality of the Microcosm system. Filters are responsible for receiving messages, taking any appropriate actions, and then handing the message on to the next filter in the chain. The actions that filters take are such as changing a message, or adding or removing messages. Filters may also have their own interfaces. These might be dialogue boxes such as the history list, or control panels such as the one provided by the mimic filter to control the guided tours. Filters may also have user interface components (for example, the history filter displays a list of viewed documents). The Microcosm filter architecture permits dynamic link creation, based on information retrieval and rule-based algorithms [4]. This facility can be used for the automatic generation of links in large resources bases, together with the development of ‘intelligent agents’ to guide users around the resource base, for example during fault-finding within industrial plant. Due to its open structure, Microcosm also allows the integration of data generated by suitable third party software, for example CAD packages, databases, and spreadsheets, into a single application. This feature enables users to access the full capabilities of these
software applications, whilst still having access to the multimedia resources containing information describing or enhancing the data being manipulated.

4. The case study

The main product of the Pirelli Cables building wire factory at Aberdare, South Wales, is the standard three-core United Kingdom building cable, a large proportion of which is sold in packs containing 100-m lengths. The manufacture of the cable consists of four main processes, metallurgy or the breaking down of copper bars into wire strands of the required size, followed by laying up, where the wires are bunched to form the conductors. The cable is then insulated in the extrusion process, before packaging; where the product is cut to length and boxed before dispatch. To form the packs, a number of packaging lines are used. In packing the cable, a cardboard carton is erected, while a measured length of cable is wound onto a mandrel. The coil of cable is dropped into the open carton, the packaging line then assembles a reel round the cable. Finally the box is sealed, and labelled before dispatch. One aspect of Aberdare’s current management practice that needs to be considered when considering maintenance provision, is the flexibility of the labour force, where line operators are permitted to undertaking minor fault-finding on the machine, before maintenance is called. In addition each operator is expected to be familiar with a number of separate processes, to giving flexibility of labour. The development of the Aberdare site, and the background to its industrial relations policy has been reported elsewhere [2]. The mobility of labour and the fact that the packaging line is by its very nature, complex, made it an ideal candidate for use with a hypermedia maintenance resource.

As noted earlier the biggest obstacle to the successful implementation of a hypermedia application is the authoring effort required. This requires significant effort in several areas, including the collection and formatting of the data, construction and validation of the linkbase, and subsequent maintenance of the system. Collection and formatting the documentation is the biggest element and can vary depending the available source material. At one end of the spectrum the documentation to be used may only be available in a paper form, and therefore need to be converted into electronic format before loaded into the system. On the other end of the scale, all the documentation will be available in electronic form, therefore inputting the information will be a relatively easy task. If the source material is largely paper-based, we have estimated that up to 80% of the time required to develop a new hypermedia application is taken in converting the information into a suitable format. The information of the Aberdare packaging line is self contained, and including the engineering drawings, location drawings, test schedules and list of parts is contained on over 500 separate sheets of A4, all of which had to be converted.

For the paper-based legacy material, the most effective technique required documents to be first scanned at either 256 or 16 colour resolution depending on the amount of detail required. After scanning, some manual, and automatic, touching-up was required to lose the most obvious effects of distortion introduced by the process. At this stage the opportunity was also taken to reduce the number of colours or grey shades in the image from 24 bit to either 8 bit or 4 bit, whichever gave the most readable image. As some diagrams need retouching, and the occasional replacement of the text and the graphics to give a clear and concise view of the circuit, this process can be time consuming. To speed the processing of text based material use is made of optical character recognition software. We currently have not found an effective technique that can scan a detailed engineering drawing, and convert the image reliable to vector graphics for use with the DXF viewer.

During the development of this application, at times it was considered quicker to redraw, or re-enter the information in the correct format, than converting the documents to the required electronic format. This process does have implications on the processing of legacy information, and the maintenance of a satisfactory audit trail. In the future development of a hypermedia documentation for a new system, should not incur significant additional cost over a paper version, as the source media for either approach nowadays will be in electronic format due to the widespread use of word processors and CAD packages. However considerable care needs to be taken
with CAD drawings, if they were not drawn with hypermedia authoring in mind. It is all too easy to treat CAD as an electronic equivalent of a conventional drawing board, producing drawing where the embedded information is conflicting and leads to authoring problems where automatic link generation techniques are used.

Once the data had been collected, it was arranged in a suitable structure to form the resource base. A rigid pedagogical structure was followed, to ensure that the resource base can be easily maintained in the future. Following the development of the resource base, the link base can be constructed. Microcosm is supplied with a set of tools that ensure authoring is an efficient process. During the authoring process the start points of the links are identified and defined as buttons. At the same time the type of link is selected using the available authoring tools. In the case of engineering drawings it is considered more efficient to define links to part locations as generic links using the name of the part, this has the advantage in that the part location can then be accessed wherever the part name is used without any extra authoring effort. On completion the Pirelli, Aberdare, application contained over 800 documents, and 10,000 links, this clearly demonstrates the requirements for using an automatic link generation feature. It should be noted that this example is considered to be a relatively small, easily maintained, electronic manual. We are currently exploring the quality implications of very large application, while the hypermedia technology will largely be conventional, the quality control and maintenance of the individual documents audit trail will prove to be a significant challenge. One of the

Fig. 2. The cable-laying process explained using the system developed for Pirelli Cables' Aberdare.
The main differences between traditional documentation and hypermedia, is the ability to use temporal data such as sound and video. This will have a considerable impact on the presentation of dynamic information to engineers. Within the Pirelli application video was used to illustrate the coil winding process and the erection of a box. Feedback from the factory floor indicated, that the selective use of video was highly beneficial.

As part of the authoring effort for the Pirelli application we have made extensive use of 3D graphics. Our work has shown that in the factory floor environment the use of computer generated graphics are far more acceptable that a photograph. The application uses graphics not only to provide information, but also to act as a menu as part of the user interface. In the Pirelli application the images were generated using AutoCAD and 3D studio. Due to the separation of the links from the information, the same graphic can be used for a number of different tasks.

Figs. 2 and 3 show some of the applications features.

Fig. 2 shows the information required to set the cable laying part of the process. From the 3D representation of the machine (top left), the laying information is requested via a selection on the cable laying element of the line. This directly leads to the text, and if required to a photograph or video showing the adjustment required.

If required the user can directly select an electrical part, without the examination of the circuit diagram, Fig. 3. This is of particular relevance if the user only has a part number or other identifier, and needs to find more information.

5. Delivery of information

The introduction of hypermedia into manufacturing industry is to a large extent governed by its wide spread acceptance by factory floor personnel, this in particular, requires the user interface to be carefully designed. Most of the constraints are centred on finding an acceptable system, which will allow the maintenance engineers to use the hypermedia system with ease on the factory floor, and have required storage and display capabilities. At present, the standard interface for Windows based systems, such as Microcosm is the mouse used as a pointing device, this has been shown to inappropriate to the factory floor environment due to dirt and the lack of convenient flat surfaces. We have reviewed a number of options, including tracker balls and touch screens, and have conclude that the pen computer currently provides the most acceptable approach. The application discussed in the paper is running on a Compaq Concerto pen computer. The experience on-site of the pen interface has been favourable, with the user experiencing little difficulty with its use.

The major disadvantage of any form of portable computer is that it is a one- or (more probably) two-handed operation, as with paper documentation it is not a ‘hand free’ operation. As a solution to this we are currently investigating the use of the true wearable computer. These systems, such as Rockwell’s Trekker, [1], have a head mounted display, with a computer and battery pack worn on the belt, and is designed to be voice operated. The combination of a voice operated system and head mounted display provides considerable advantages for the user when operating within the confines of a machine.
5.1. User interface issues

The industrial environment brings together users with different and varying computer skills, all of whom need to be supported. It is well known that effective screen management is a key to efficient human–computer interaction. Modern Graphical User Interfaces such as Microsoft Windows allow users to have a number of pieces of information displayed concurrently on the screen with each piece of information being displayed in a separate window that can be moved and sized independently of the others. For some users, the conventional Windows interface will be far too unstructured, it is very easy to hide inadvertently a piece of information with another window. To manage the screen resource within Windows it is necessary for the user to be reasonably comfortable with skills such as moving and sizing windows. Not all users want this ability as the focus should be on accessing the desired information. Because of this, interfaces are often developed, using fixed windows that cannot be moved or sized. The system takes responsibility for stopping information from being obscured by fixing the windows and restricting the flexibility of the interface. For a novice user this might be quite suitable. For an expert user however the restrictions might affect their ability to access the information they desire. They may not be able to compare two diagrams for instance since the system could restrict them to only one image on the screen at a time.

These problems suggest important features that will need to be considered with any proposed solution to screen management:

- The screen management should be able to be tailored to meet the needs of individual users.
- The screen management should be centralised to allow the interaction between interface components to be controlled as well as the individual appearance of interface components.

We have therefore been developing processes that provide a number of different screen management functions. The openness of the system allows the screen management functionality to be determined by the users’ requirements. Furthermore, as new screen management tools are developed they can be plugged straight into the system without the need to alter all the modules that contain interface components. In addition, the modular architecture allows screen management features to be added and removed as required. A wide range of screen management tools are being developed using this approach, in particular providing control to prevent inadvertent loss of a windows contents during minimisation or moving to the edge of the display area, particularly by an inexperienced user.

6. Discussion

In their paper, Malcolm et al. [6] argued for the development of industrial strength hypermedia. In which systems must evolve beyond the stand alone status to become a technology that integrates resource over the complete engineering enterprise. In this paper we have discussed the use of open hypermedia systems within the industrial environment, and demonstrated our approach with a resource-based approach to the provision of electronic information systems for the support of maintenance operations in a large-scale industrial plant. The advantages of the open system approach are in the maintainability of the resource-base, the automatic generation of links and the consequent reduction in authoring effort, and the ability to integrate the resource base with other application packages and the general computing environment. The case study described is now undergo a full evaluation at the Pirelli site in Aberdare, but our initial trials have already clearly demonstrated the advantages of the system, and its widespread acceptance.

As the result of our work, we believe that the advantages of using open hypermedia for the provision of engineering information with in manufacturing, can be summarised as follows:

- The ability to integrate data from a number of applications, with the ability to have controlled access to this data, will greatly enhance the effectiveness of personnel throughout the organisation.
- The facility to introduce an audit and change control system, to manage the documentation.
- The easy to use interface to the system permits easy access to the data, and ensures that the correct procedures are followed.
The ease of construction of the resource bases and subsequent authoring.

The ability of the user to place additional information and notes into the system, within constraints determined by the system manager. The notes can be retrieved at any time by future users.

The separation of links from data permits the same database to be used for other related activities, for example an interactive training programme.

The perceived benefits of open hypermedia are summarised in Fig. 4.

The use of open hypermedia with in the industrial environment has highlighted some of the common problems associated with screen management, when inexperienced users are working along side experienced users on a system. The solution indicated gives the designers of hypermedia applications flexibility when creating interfaces for users of differing ability. The openness of the system also allows

Fig. 4. Summary of the benefits of open hypermedia for information management within manufacturing.
future developments in screen management tools to be incorporated into the system without the widespread recompilation of existing software.

With an interface to a factory based local area network is available, we have highlighted a number of significant possibilities arise. In particular the breakdown maintenance process can be significantly enhanced, both in time and effort, by the implementation of intelligent filters, using information both from the database and from the failed system obtained through the network. A direct result of this approach is that when a fault occurs, the resource base is entered at the appropriate point (for example giving the location of a component and its functionality), as identified by the intelligent filtering process. Once this is achieved the hypermedia information system will form an integral part of the computer integrated manufacturing system. This interconnection will allow predictive and preventative maintenance procedures to be optimised by using the same resource base but with a different linking strategy. The advantage of the integration of a multimedia package hypermedia package with a network can not be under-emphasised.

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References

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