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REAL TIME RAPID PRODUCT DEVELOPMENT PROCESS DATA AND INFORMATION MANAGEMENT FOR SMALLER ENTERPRISES

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Abstract

Research into the use of technologies such as Product Data Management (PDM) systems to support Rapid Product Development in Smaller Enterprises (SE's) has been largely ignored by the research community, yet these systems have been shown to be of benefit in reducing the time to market of manufactured products. Smaller Enterprises uptake of newer technologies such as PDM systems may be low due to lack of resources and unsuitability of current methodologies but these organisations may benefit from the appropriate management of data and information throughout a product development process. This paper reviews the product development environment in New Zealand, describes PDM system elements and explores reasons why current software PDM systems are unsuitable for Smaller Enterprises. A new methodology for real time rapid product development process data and information management for Smaller Enterprises is introduced and a software platform based on this methodology is presented. The ability of the platform to utilise both descriptive and prescriptive representations of the product development process is then discussed. This methodology and platform is based on research carried out at the University of Canterbury, New Zealand.

Keywords: Product Data Management, Smaller Enterprises, Software Platform, Product Development Process, Real Time.

1 Introduction

New Zealand's largest companies are predominantly involved in the processing of primary resources, e.g. food processing, forest products, petrochemical, dairy produce, mineral extraction and processing. Manufactured products comprise a small but growing sector of the economy as the country attempts to move away from reliance on the production of primary products as the main source of income. These products include; automated production systems, mooring devices, mobility aids, plastic products, power generation equipment, radio-telephones, specialist electronic products, whiteware, healthcare products, marine propulsion systems and many more. A wide range of manufactured products now compete with success in international markets and a 1999 survey [1] found that forty-three percent of companies surveyed exported more than 50% of their output. These products are created by companies that are considered small by world standards (the majority (86%) of the companies surveyed have fewer than 250 employees) and are developed in an environment that has notable characteristics.

With regard to the product development practices of leading New Zealand companies the survey highlighted the diverse range of product development and manufacturing activities and found that these activities are completed in organisational environments that differed widely in such areas as staff numbers, resources, tools used, and management practice. Significantly,

- A majority (82%) of the companies surveyed had 6 or fewer personnel involved in product and/or tooling design activities. In addition, 85% percent of companies subcontracted at least one design related task.
- The organisational structures for product development of the majority of companies most closely matched the Functional or Lightweight Team Leader structures categorised using the definitions adopted by Smith and Reinertsen [2].
- A direct comparison with a list of tools taken from a 1996 survey by Araujo et al [3] indicated that many companies lacked knowledge of the use of formal design tools and that on average there was a 25% higher use of tools by United Kingdom companies.
- Forty five percent of companies indicated they used strategies or frameworks to manage the development of products. Formal (documented) procedures for design activities were mainly used by the larger organisations and 12% of companies stated use of Concurrent Engineering as a strategy to manage the development of products.
- The use of some form of PDM (Product Data Management) software to control and access product data in the product development process was limited to very few (10 %) of the companies. Data and information were stored by application and product attributes but in the absence of any formal systems, control and storage was more likely to be employee specific.

This model of product development practices was developed from the initial stages of a research programme funded by a New Zealand Government Public Good Science Fund grant aimed at developing new tools and methodologies to assist New Zealand industry. The intention of the survey was to reveal the practices of leading companies and to identify any shortcomings that inhibit rapid product development. One conclusion drawn from the survey results was that an increase of computer generated files, replacing paper-based tasks, in the product development process needed to be supported by systems that facilitated the integrity, communication and use of the data and information generated. The almost complete absence of strategies, tools and methodologies used by the surveyed companies with respect to the management of product data and information within the product development process was identified as having the capability of inhibiting rapid product development. The remainder of this paper details research conducted into the development of a proposed methodology for the management of data and information that is suitable for the product development environment that exists in New Zealand.

2 Product Data Management Characteristics

The importance of information as an enterprise resource has been widely documented and, with respect to rapid product development, the timely provision of data and information is known to be essential for commercial success. Furthermore, depending on the purposes for which the data and information are to be used it is clear that different methods of data and information structure may offer both advantages and disadvantages[4]. Documents are one focus of management for

enabling the product development process as product definition information is, for the most case, still stored in documents of some form. Organisations employ many different methods to structure and manage data and information to facilitate effective and efficient management of the product development process. PDM has been defined as “the discipline of making the right product and process related data available and accessible to the right parties at the right time in the product lifecycle in order to support all business processes that create and/or use this data” [5]. PDM systems can be comprised of a number of different technologies and Helms [5] makes the point that it is important to understand that PDM functionality is found not just in PDM systems.

3 Lack of suitability of current software PDM systems for use in SE’s

Methods suitable for larger organisations are not always directly transferable to smaller enterprises for a number of reasons. SE’s in New Zealand use combinations of paper and software documents to support the strategies, communications, tools and methodologies that underpin the product development processes. The adoption of computers by SE’s to support the product development process has become more prevalent and there has been a corresponding increase in the digital data created throughout the process. This digital data and information is created, accessed, modified and shared by participants in the product development process. The survey indicated that the use of some form of PDM software to control and access product data was limited to very few of the companies. Furthermore, unless in transit between collaborators, data and information were stored by software application and/or product attributes (such as a CAD file or project number). In the absence of any formal systems, control and storage of data and information was more likely to be managed in an employee specific manner (that is, the employee would select the method). Most companies recognised this was a problem that would grow as the use of software applications increased but there was a reluctance to accept the structures imposed by current PDM systems. Reasons given were that many tools and methodologies used by larger organisations were not suitable for SE’s due to their restrictive nature and that the underlying concepts, structures and applications that are inherent in the PDM systems created for large organisations often made their use in SE’s untenable. The use of PDM software is also one example where smaller organisations have problems providing adequate resources for successful implementation.

Small Enterprises, by dint of their nature, face hurdles in the implementation of PDM systems that larger organisations can overcome as they have more resources available. Substantial resources are required for the establishment, configuration and use of PDM systems. SE’s rely almost exclusively on Commercial Off The Shelf (COTS) software for their computing systems and are unlikely to have the resources and time to establish an in house computer based PDM system. The main differences between larger organisations and SE’s that can have an effect on the development of PDM systems are summarised below.

3.1 Lack of resources

In addition to resources required for establishing PDM systems, further personnel resources are required to determine, classify record and establish relationships between the product data; functions which are required to be implemented in order to manage and leverage functionality

from the system. This last factor is very important in smaller organisations; we are all familiar with the term “paperwork” which refers to the administration required by an organisation in order to support the development of an activity. The PDM system requires electronic “paperwork” to be completed in the form of the user interfacing with the system. In SE’s (as well as other organisations) it is not uncommon to find these activities take second place to the actual development of the product artefact.

3.2 Management requirements

Current PDM systems are designed for use by larger organisations; their underlying structure is constructed to assist in the management of data and information and address problems inherent in the management of data by large numbers of people cooperating in the development of products. In effect, the structure of a PDM system is used to control users through interaction in a prescriptive manner that is determined by the system management. This type of rigorous approach may not be appropriate for smaller enterprises as their small size and the ability of participants to interact allows a more flexible approach to product development. Many companies in the survey said a major strategy was “*working closely together*” and one inference from this statement is that the strategy allowed participants to exchange data and information more readily and in an unconstrained manner. That is, due to the ability to work closely the companies regarded a lack of prescription as an asset that gave them an advantage in product development.

3.3 Product oriented structure of current systems

Product data managed by the majority of PDM systems is primarily visualised through a product-oriented structure. That is, metadata detailing the attributes, relationships and lifecycles of documents, products, processes and resources used in the development of a product through all phases of its lifecycle are centred on the artefacts produced. The evolution of PDM systems was such that data management functionality preceded the addition of process management in the form of workflow. While both systems are used concurrently, present systems still emphasise product data views while the workflow engine represents the process views.

3.4 Data and information selection

Presently, data managed by companies is product oriented and does not manage all the data generated by a typical product development process. Product data managed by PDM systems is that which has been identified as important enough to be managed with respect to the design and manufacture of the product. That is, someone or some people form a belief that the data warrants management. PDM systems do not presently consider other aspects of the product development process data such as data that is viewed, (e.g. access to information databases, Internet documents), communications and other data that results from the product development process. This is especially true in the earlier stages of the design process where there tends to be a greater percentage of time spent on information gathering and assessment. There is a need to manage and record this information so to more fully represent the product development process. This information would assist in describing both design history and the design rationale behind the product development process and be beneficial for the supporting the creation of future product developments.

3.5 Process workflow

Due to the product centric manner in which data is displayed by PDM systems, current methods do not visualise the creation of product data as a process within the PDM structure. The product centric format cannot be used to represent a product development processes. Processes are represented in PDM systems by workflow. The basis of the workflow systems is a *task-oriented* approach; Activities are decomposed into a series of tasks that are then managed – the systems use an "as planned" (i.e. the tasks are pre-determined before the tasks are initiated) approach rather than "as-completed" (where tasks are identified after they have been initiated). There is some evidence [6] that SE's utilise goal oriented product data management in preference to task-based management due to the size of the organisations and the environments in which they are conducted. A completed product development programme is thus represented by an ideal "set" of files or documents (at project completion). At the onset of a programme an "educated guess" of the contents of this set is made. This set may be determined from sources such as:

- Previous product development data sets
- Customer requirements
- Internal administrative requirements
- Quality, Safety and Environmental Management requirements

However, in current PDM systems for larger companies only the simpler processes associated with product development such as engineering change orders are currently modelled. This methodology has shortcomings when used for the representation of product development processes; the main reason for this is the variable nature of product development activities, (i.e. they are not completely known at the outset of the project) as a consequence, only the simpler processes where the workflow is invariable, such as engineering change orders (ECO's), are currently modelled.

Given the characteristics of SE's and the unsuitability of current PDM systems used by larger organisations for transfer to the SE environment which have been detailed above, the goal of this research programme has sought to develop a method by which SE's can achieve PDM functionality without the limitations imposed by adopting PDM systems used by larger organisations. Initial outcomes from this programme are described in the subsequent sections.

4 A Product Data Management architecture for SE's

Assuming an increasing trend towards computer based support of the product development process, our idea is to provide an alternative depiction of the product development process by viewing the documents created with respect to the development process timeline and to do this in real-time. This necessitates changing the primary emphasis of the current PDM systems from a product structure orientation to a temporal structure where the documents are related by virtue of their existence within the projects' timeframe. We are interested in *when* the documents (containing product definition data) were created and *how long* they existed in relation to the overall process timeframe, participants in the process and desired goals. To do this the primary document relationship that is established is one that is relative to the timeframe of the project under consideration. It is hypothesised that by representing the product data information in this

manner and making it available in real time, it will assist SE's in managing product data without the restrictions imposed by PDM systems that have been designed for larger organisations.

We make use of the fact that in a computer based environment the metadata associated with documents' creation and modification, access, printing and communication are readily available. Our model initially considers the activities of a single document and it's use by participants within the process, it then combines data from additional documents in a bottom up approach to construct a full model of the process in terms of the documents created. With respect to the category of data managed, the model extends the type of data that is captured by a PDM system as it is extended to include information, communications and databases that are accessed via computer as part of the product development process. As more and more of these activities are performed within an electronic environment, a more complete descriptive record of the activities associated with the product development process will be able to be determined.

4.1 Establishing a temporal relationship relative to the process timeline.

A graphical representation is used to temporally and spatially represent a documents' existence in a computing environment between single or multiple users with regard to the overall process. Each *single user* creating or manipulating a document in response to activities required by a product development process does so at a particular time relative to the process timeline. A document's active "life" within the project is represented by a length (equivalent to time *t*) and this length is then related to the period that it is used (created, used, accessed etc) within the duration of the project (time T, with start at *T0* and end *Tend*). Graphically, this can be represented as shown in Figure 1.

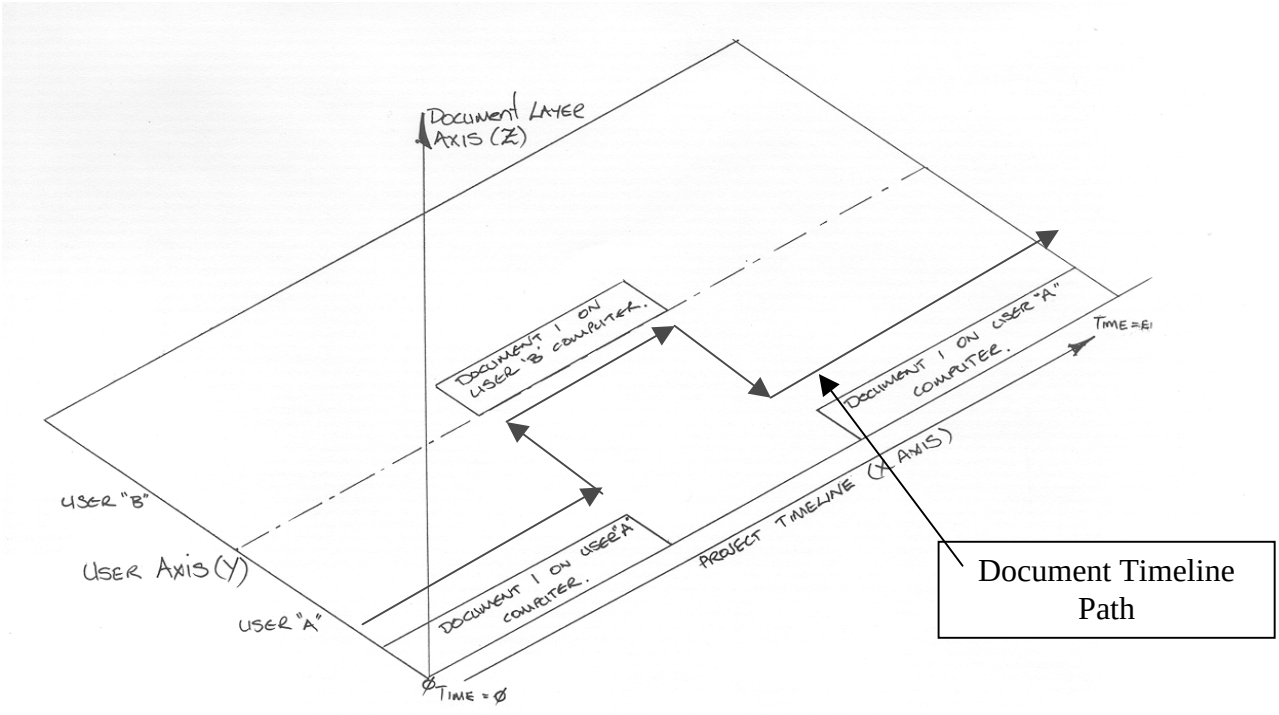

Figure 1. Representation of a single document along a process timeline between two users.

As more documents are created in the process they are viewed relative to the original timeframe and existing documents. In the graphical representation further layers, representing additional documents, are added along the Z axis. The documents are not represented when they are stored, only when they are being "used" by participants. In effect, a "map" of the activities (creating and modifying data, accessing information, communication), denoted by the use of documents which are associated with the development process, is created in relation to the timeframe of the process. For more than one user the "Y" axis is extended to record additional personnel involved in the process. Furthermore, as each additional document is added in the process they are represented on additional layers in the Z axis. Documents that are transferred between participants of the process are registered on the new users "map" and a serial trail between different users can be established. This trail assumes that no concurrent manipulation of documents by users occurs, however, it is considered that multiple concurrent use of a single document could be represented by this schema. Once an initial relationship has been established in this manner the metadata associated with these relationships can be used for further PDM purposes. That is, for author X at time *t*x working on a particular document we can assess metadata such as document location, current revision status, etc through the relational database.

4.2 Metadata extraction

The metadata associated with the process timeline includes data which can be extracted from within document files as well as the operating system itself. This extraction process operates in real time as the software metadata extractors monitor the users computing environment. The information is collected at start and end points while the file is open in the computing environment to determine the length of the documents life. Further metadata is captured to provide data for PDM purposes. This information includes:

- File Creation Date/Time,
- File Open Date/Time,
- File Close Date/Time,
- File Modified Date/Time,
- File Printed Date/Time,
- Current Author,
- Document Location.

Additional metadata is also frequently available in document files from specific software packages which may be used. E.g. the CAD program Solid Edge provides the ability to record revision lifecycle data.

4.3 A platform for real time rapid product development process data and information management

A platform for real time rapid product development process data and information management is presented in Figure 2. This platform is designed so that it is extendable to operate with different operating systems and document file formats through accessing standard formats and protocols used in these functions by the computing software industry. The platform is a stand alone unit which is associated with an individual computer and, by aggregating metadata, can be extended for use over a network.

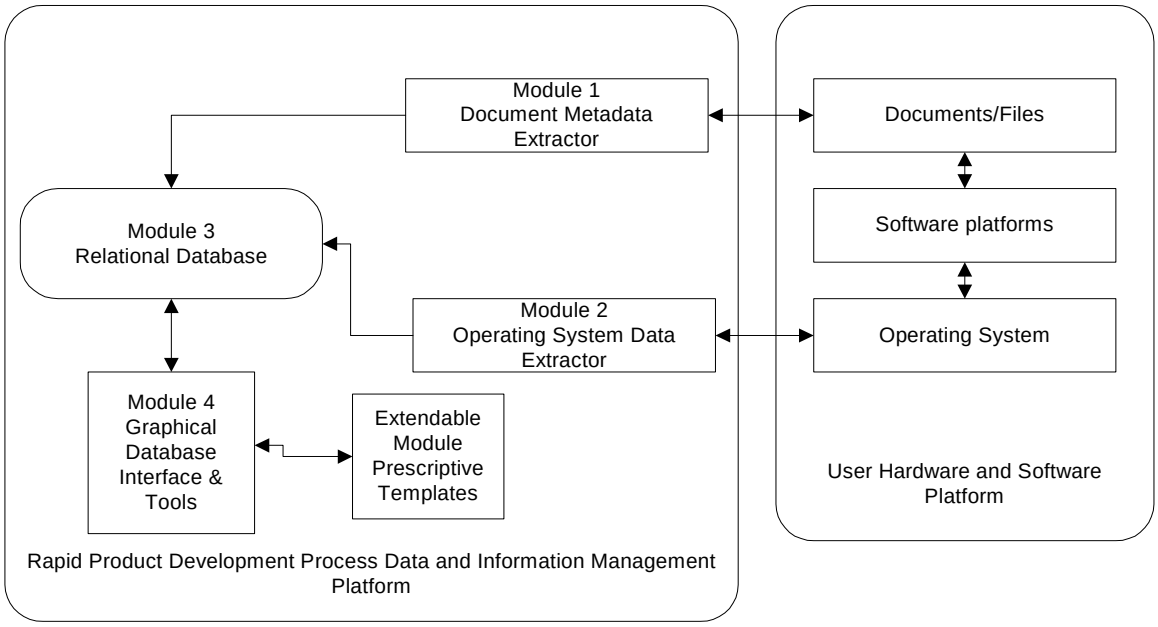

Figure 2. Software platform for real time rapid product development process data and information management

The document metadata is gathered by using two separate software modules. Module 1 works on the document layer and parses the metadata. Module 2 data mines the operating system information for the required metadata. These two modules operate in real-time to continuously poll the computing environment.

Module 1 is a parser that reads the metadata relating to the creation, access and modification of document files which is contained within a document file. This is performed in real time and passes this information for storage in Module 3 where it is related to the project timeline. The parser utilises the fact that files contain industry standard common information such as “author”, “date created” etc. COTS software known as “Spyware” is utilised for this purpose.

Module 2 accesses the operating system of the user in real time to provide further information relating to activities associated with documents that are performed on the system which are not contained within the documents themselves. This is performed in real time and the module passes this information for storage in Module 3. This extractor utilises security functions contained within all operating systems that are a standard within the industry. Standard operating system software is used for this purpose.

A further two software modules collate, store and present the metadata for PDM activities. Module 3 is a relational database used to collate the metadata, establish a relationship between the metadata and the process timeline and store the real time data. Module 4 uses the data contained in the relational database to construct a graphical interface to present the data in a temporal and spatial configuration. A VRML 3D world is proposed as a method for visualising the data. The world will represent the “product development process space” and the objects within the world the data created. As the model is in 3D, CAD analysis and verification

techniques like a “walk through” can be achieved; adding to the utility of the model. Similarly, maintained hyperlinks can be invoked to enable the examination of individual metadata.
This platform is extendable to make further PDM and other management functions possible. An additional module is detailed in Figure 2 and called “Prescriptive Templates”. The use of this module is detailed in section 4.4 below. The platform is extendable through the addition of further modules with functions such as optimisation, costing etc.

4.4 A module for descriptive and prescriptive maps of product development.

Our method creates a *descriptive* model of the product development process in terms of the documents created and accessed as part of that process. Section 3 of this paper suggested that SE’s utilise a “goal oriented” approach to the creation of documents for product development processes. That is, companies have a *prescriptive* list of documents that must be completed to indicate that a particular process is complete. The companies have a template of what they consider is a “document set” at the completion of a process. They may not know *what* the documents contain, nor *who* will create them but they have established that they *will exist* at points throughout the process and at the completion of the project. This fact is used to create a template that can determine what documents can be required and are associated with particular temporal points in the product development processes. That is: a prescriptive model. This template can then be compared with the descriptive model that is built up in real time to provide real time information for management purposes.
As the product development proceeds, the “as created” set of documents is continually compared to the “as required” document map template. It is believed that this structure will more fully describe the product development process than at present and in a manner more suitable to SE’s and will provide some of the functionality of the existing PDM systems available to large and medium sized organisations. Furthermore, as the model is generated in real time from available metadata without user involvement, it is considered that this will not tax the resources of SE’s. Thus the advantages realised by larger organisations in reducing the product development cycle through the implementation of PDM systems will be available to smaller organisations. Finally, it should not be overlooked that this representation and the manner in which the model is created can provide another tool for design and manufacturing process researchers to investigate the methodologies behind the processes involved.

5 Further work

The software platform Modules 1 & 2 described above have been proofed using COTS software; software suitable for modules 3 & 4 and a prescriptive template are currently under consideration/construction. The complete platform is scheduled to be tested in a small enterprise specialising in electronic and mechanical product and automation machinery design during 2003-2004 to test our hypothesis that representing product data information in this manner with an ability to present it in real time will assist SE’s in managing data.

6 Conclusion

Based on the initial survey of SE's in New Zealand we concluded that in order to support Rapid Product Development to reduce time to market, SE's in New Zealand required tools and methodologies to manage product data within the environments they work. Such a rapid product development process system must operate in *real time* and not burden product developers with unnecessary "paperwork". The ability to visualise the product development process as it unfolds and to utilise a combination of descriptive and prescriptive methodologies to manage the process is seen as important in supporting the management of such processes in SE's.

This paper has presented a review of the characteristics of SE's in New Zealand, and argues that current software PDM systems used by large organisations are unsuitable for use in this type of environment. An alternative method for representing a product development process through monitoring the real time status of product development documents was described and a software platform to implement this methodology presented. A methodology that compares a real time *descriptive* representation of the product development process with a *prescriptive* representation in terms of document use was then introduced as an example of the platforms' use in visualisation and management of a product development process. Successful trials of modules one and two for extraction of metadata have been completed to date.

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