A Grand Challenge: Immortal Information and Through-Life Knowledge Management (KIM)

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Abstract

'Immortal information and through-life knowledge management: strategies and tools for the emerging product-service business paradigm', is a Grand Challenge project involving eleven different UK universities and incorporating substantial industry collaboration. It is investigating a range of issues associated with the move towards a product-service paradigm in the engineering sector, in particular the long-term curation of digital data, learning from production and use, and appropriate governance and management techniques.

A Grand Challenge

Within the engineering industry, the business model for companies has traditionally been based on a product delivery paradigm: put simply, making and selling products with little emphasis on after-sales support. This traditional model is now being replaced with one based on a product-service paradigm (Davies et al., 2003; Oliva & Kallenberg, 2003). A product-service is, as its name implies, a product that is sold as a service; in the same way as one might buy electricity rather than a generator, in aerospace some companies are selling thrust ("power by the hour") rather than engines (Deloitte, 2001). This means that ongoing, through-life service support is paramount, and the product itself is less of an issue.

This shift in paradigm has a number of challenges associated with it. The provision of effective through-life support requires that design data has to remain accessible and reusable throughout the decades that a product remains in service, despite it often being embedded in rapidly evolving information technology (Sivaloganathan & Shahin, 1998). There is also an increasing need for products themselves to evolve in response to feedback from both the production stage and the point of usage by the customer. Businesses themselves are having to evolve in order to adapt to the new paradigm. Furthermore, these issues need to be addressed in a dynamic environment of changing and evolving supply chains.

The KIM Project

The KIM Project, or to give it its full title, 'Immortal information and through-life knowledge management: strategies and tools for the emerging product-service business paradigm', is an Engineering and Physical Sciences Research Council (EPSRC) Grand Challenge project with additional funding from the Economic and Social Research Council (ESRC). The project brings together eight Innovative Manufacturing Research Centres (IMRCs) and five other departments from eleven different UK universities. It also incorporates a heavy collaborative element with industry in the form of: the UK Council for Electronic Business (UKCeB), which is concerned with secure, collaborative information sharing in defence procurement; companies in the construction sector; civil aerospace companies; and software suppliers and consultants.

The purpose of the project is to establish good practice with regard to the design and use of information and knowledge-support systems given the demands of the new product-service paradigm. It began in October 2005, and runs for three years.

Project Overview

The KIM Project is divided into three main areas of work, which may be broadly characterised as dealing respectively with product design, production and usage, and business practice. The intention is to integrate these three stands of research through a further activity which will run continuously and in parallel with them. These activities are represented graphically in figure 1.

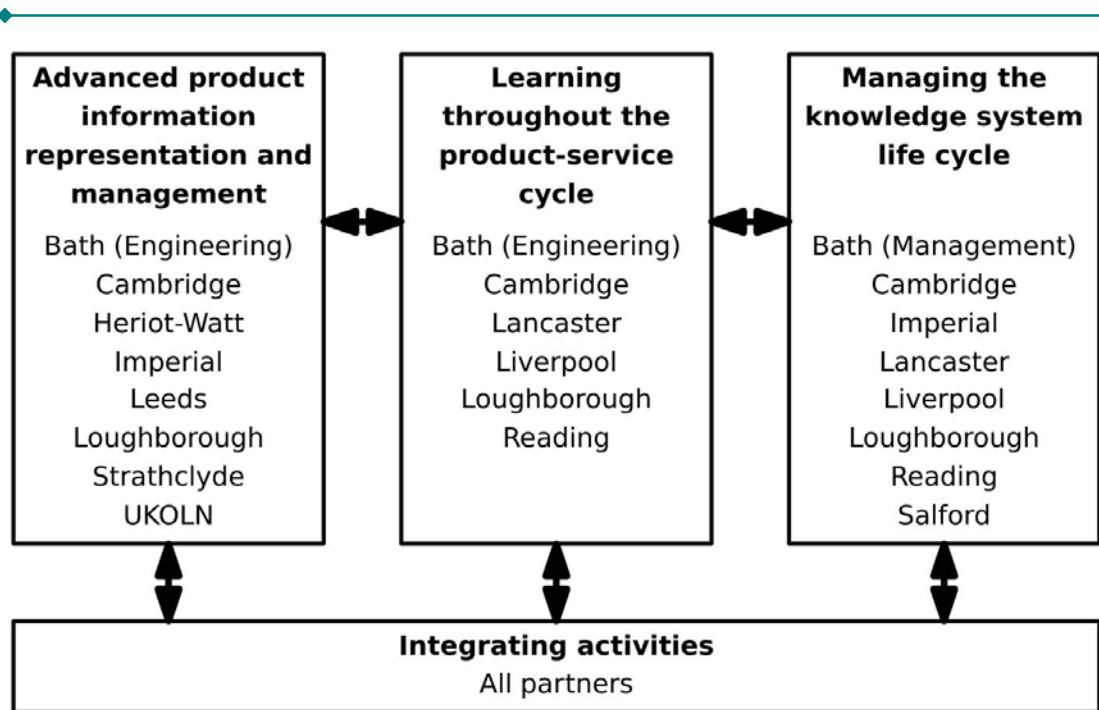| Advanced product information representation and management	Learning throughout the product-service cycle	Managing the knowledge system life cycle
Bath (Engineering) Cambridge Heriot-Watt Imperial Leeds Loughborough Strathclyde UKOLN	Bath (Engineering) Cambridge Lancaster Liverpool Loughborough Reading	Bath (Management) Cambridge Imperial Lancaster Liverpool Loughborough Reading Salford

Integrating activities All partners

Figure 1: Relationship between the different strands of the project

Advanced Product Information Representation and Management

Whenever a product is designed, a formalised product model is produced and stored for reference, usually in a Product Lifecycle Management (PLM) system. Currently, product models are made up of computer-aided engineering (CAE) data, bills of materials, and other highly structured and/or numerically based documents, but exclude much of the intermediary and background documentation (Court et al., 1996; Stark, 2004). This is unfortunate as this latter form of documentation may well be essential to any subsequent attempt to audit the engineering reasoning and decision-making underlying the finished design.

Simply including additional supporting documentation in the product model does not solve the problem. This documentation is frequently lacking in formal structure, making it a long and arduous task for anyone unfamiliar with the product design to extract the necessary information. Thus there is a need for greater structure and formalism within the text-based documentation, and a need for explicit cross-referencing between the various elements of the product model.

From a preservation perspective, significant issues arise from the increasing sophistication of CAE data. In the early days of CAE, the computer models were used to produce two-dimensional plans, which could be printed out on paper and preserved in that way. Contemporary CAE models, however, are commonly produced in three dimensions; such data are difficult to preserve in non-digital fashion without losing significant amounts of information and functionality.

Preserving digital CAE data has its own problems. CAE software vendors each use their own file formats, many of which are closed and proprietary. Furthermore, each CAE system can be expected to advance one version every six months, and either become obsolete or advance a generation every decade, thereby breaking backwards compatibility of format. These problems are especially acute since designers often need to revisit old designs to adapt them or re-use portions of them in new designs. Neither emulation nor migration provide satisfactory solutions (Graham,

1993; Rothenberg, 1999; Thibodeau, 2002): it may not be possible to integrate an emulation of an obsolete CAE system into a current workflow, and indeed there may not be anyone left with sufficient expertise to use such an emulation. On the other hand, the act of migrating a design to a new format creates a new file that needs to be re-validated, incurring a significant expense.

These themes are addressed in the first strand of KIM, 'Advanced product information representation and management'. The first task in this area, 'Extended product models', seeks to develop product models that encompass not only the product documentation, but also documentation of process (how the product should be manufactured or constructed) and rationale (the decision-making, negotiation and testing that lead to the finished design). The models should be suited to distributed design teams and be sufficiently open that future computer systems will still be able to interpret them, and the provenance of the data within the model should be verifiable.

The second task within this particular area of work is entitled 'Information Organisation, Retrieval and Visualisation'; it seeks to identify optimal methods of organising the information in the extended product models. These methods will need to decompose engineering information resources at an appropriate level of granularity, and take account of the different information needs and approaches that users of the resources will have at various stages in the product-service life cycle. Complementary retrieval tools will also be developed, using advanced visualisation techniques.

'Automated Information Capture' is the third area of work in the 'Advanced product information representation and management' strand. Extended product models of the quality envisaged by this project could have significant cost implications for those firms implementing them unless some way is found to reduce the amount of human effort involved. This task explores the possibility of logging the activity of designers within their CAE environments and automatically generating structured rationale documentation from these logs.

Learning Throughout the Product-service Cycle

The design of a product makes certain predictions about the finished product, both about its manufacture or construction, such as the duration and cost of production processes, and about its eventual properties, such as its load bearing tolerances, durability, and general fitness for purpose. It is obviously important to ensure that the models that designers use to make these predictions are accurate, and this can only be done by comparing expected outcomes with actual outcomes.

The second strand of KIM, 'Learning throughout the product-service cycle', deals with the processes needed to ensure that experiences from the production and usage of a product are fed back into the design. There are clear issues that need to be addressed, such as the use of codification systems for the experiences to enable efficient feedback, and ways for the feedback to be incorporated into the design process. One obvious route by which feedback can be added into a design is by annotating elements of the original design with the lessons learned from production and usage. The particular concern with such annotation is that it must be accomplished without altering the authorised documents in any way, so that the official record of the original design is preserved.

The first task in this area, 'Information capture and feedback', seeks to identify theoretically sound methods of capturing and representing experiences of working with a design/product, so that they can be used to refine error models, use case models, etc. This task also explores the possibility of tracking how information elements have been derived from earlier information elements, and documenting these 'information trails'. The insights gained from this will be used to derive methods to prevent excessive growth in documentation.

The second task, 'Learning from Use', examines various facets of organisational learning, both endogenous and exogenous. By conducting and analysing a number of contrasting case studies, the task will produce a package of policies and practices that enhance learning within a project (e.g. manufacture feeding back into the design), between projects and sites, between the organisation's strategic and operational levels, and between organisations and their customers.

Another concern that underlies both of the first two strands is document growth. Myriad information elements, recorded in vast quantities of documents and data sets, are generated and used during the design phase of a project, and adding feedback documentation into the equation only worsens the resulting problems with storage. Current practice is to store any and all documentation, and clearly this is not a scalable or long-term solution.

The third task in the 'Learning throughout the product-service cycle' strand, 'Value of Information', addresses the problem of document growth from the perspective of efficient document management. It seeks to identify classes of information critical to through-life system support, categories of stakeholders and contexts with regard to which information needs to be valued, and finally develop a practical system of metrics to determine what information needs to be archived.

Managing the Knowledge System Life Cycle

The third major area, 'Managing the knowledge system life cycle', is less concerned with the technicalities of curating documentation, and more with the flow of knowledge between people and organisations. Its scope is the cultural and procedural changes that organisations need to go through in order to adapt fully to the product-service paradigm.

'Commercial incentivisation: espoused intentions and experienced realities' seeks to uncover the best ways for clients to procure product-services from contractors, with regard to integrating inter-organisational processes, managing value across supply chains, and the strategic management of multiple supply chains across projects. Of particular concern are the roles of small and medium-sized enterprises (SMEs) in supply chains, and the incentives required to encourage innovation.

Secondly, 'Human resource management' examines the human resource management issues associated with moving from the product-delivery paradigm to the product-service paradigm. Of particular interest are the varying extents to which different engineering sectors have implemented 'high commitment' or 'high performance' management and the reasons for this, and mechanisms for supporting learning throughout the life cycle of a product service.

The third task in this area of work, 'Life cycle decision support models', investigates how decision support models at key points during the product-service life cycle can be better integrated to improve continuity and knowledge flow, and how decision modelling ought to be influenced by its relationship to dynamic communities of practice.

Integrating Activities

The final area of work, 'Integrating activities', is concerned with bringing all the different strands of the project together. The first task in this area, 'Intellectual Framework', steers and integrates the research effort, while the second task, 'Emerging Outcomes', ties together the deliverables and outcomes from all the tasks.

UKOLN's Role in the Project

UKOLN (n.d.) is a centre of expertise in digital information management, located within the University of Bath. It is involved in KIM to provide expertise on digital curation and other information management issues, and to facilitate knowledge flow between KIM and related activities in the spheres of digital libraries, digital repositories and e-Science, in particular the Digital Curation Centre (DCC, n.d.).

UKOLN is primarily involved in the work related to 'Advanced product information representation and management' (see *Advanced Product Information Representation and Management* above), with a secondary involvement in the tasks associated with 'Learning throughout the product-service cycle' (see *Learning Throughout the Product-service Cycle* above). The main focus of UKOLN's research will be to examine the extent to which lightweight representations of product models and registries of file format and software information can be used to offset the problems surrounding the long-term re-use of product model data. In addition, we are currently helping to set standards for document control and metadata within the project.

Next Steps

Having established a theoretical foundation for the project and resolved the majority of the terminological differences between research teams — no small feat in an interdisciplinary project of this size — research activity is beginning in earnest. Much of the initial activity will be fieldwork to identify and evaluate the current state of practice; various tasks will also be developing the preliminary models that will form the basis of later research. Within UKOLN's own research, the next steps will include surveying the KIM Project's industrial collaborators to determine the most commonly used product model file formats, the most significant properties to be targeted for preservation, and the most commonly encountered problems with migrating between formats.

Acknowledgements

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