Information and Communication Management for Complex Engineered Systems: Back to the Future

(a work in progress)

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Background

Products in are designed, manufactured and sold in globally distributed sites and markets. Product development has moved from the mass production view of the industrial revolution to the mass customization view that is dominant in the wake of the information revolution. Information and communication has made this global distribution possible to the extent unimaginable in the days of industrialization. In effect, globalization has been aided by the change in the bandwidth, reach and interactivity that has been afforded by information technology. The same technologies that have made possible the interconnection between globally distributed sites have also opened up the problem of information management and communication in global enterprises. These problems are not new, but they have gained importance because of globalization of resources and skills in contrast to localized and long -terms relationships that characterized different departments of a product design firm. Information management and communications were local with local and manual practices that were essentially personal and based on the work community.

In our research on information management in industrial enterprise in several countries, we have discovered that, in localized management of information, there often emerges a librarian. This person acts as an historian in the product development group and is a person who has been reflexive enough to create a personal corporate product repository. Often, organizationally these people are not recognized officially. and their importance is realized when they retire. We have also observed that often the members of the product planning group have collective experiences of over 50 to 100 years. They often have created procedures and policies for their work that were formally recorded at one point, but they do not update them as their proximity allows them to correct them as and when needed without any updating of the records. This model is not viable in a globally distributed enterprise as information and knowledge generation takes place in different location and a lack of awareness of the overall picture can lead to extreme difficulties.

In another context, we have also observed that introduction of information technology has created a significant problem in the maintenance and availability of information. In one case, it was observed that the product organization was losing previous manually based procedures for generating triplicate copies, one each for the customer, the designer and the archivist. The new records become the adhoc e-mail and non procedures that computer mailing encourages between the participants. These systems have essentially had no sensitivity to archival needs. This further has led to organizations losing of information and knowledge.

The primary goals of this research thrust will examine the issues raised in this context of information management and communication from a socio-technical perspective. In the next paragraphs we will describe some of these issues.

Communication in distributed organizations

This sub-area deals with the role of communication in distributed product organizations. The primary hypothesis in this area of work is that patterns of communications within groups and organizations are a good indicator of the potential outcome of the work. In other words, measures on communication patterns are significant indicators of project and product performance. Our in initial work in this areas has been in software engineering, and we have developed a quasi experimental approach to the study of communication project groups. The approach uses semi-controlled experiments with case studies to understand the relationships between communication metrics and product outcomes.

The second hypothesis of this area is that managing language in a multi-disciplinary group is critical to the performance of the work and the end-product. Initial work on this hypothesis has provided some insights into the evolution of language, communication between groups and product outcomes. The work at CMU has illustrated that groups that communicate with other groups stabilize their language in the early stages of the project while those who do not communicate are forced to re-examine their terminology towards the later part of the project. This late exchange results in the need for reconciling their language with others, leading to significant delays in the completion of their tasks. The work by (X&Leifer) on the use of language in product design has shown that groups that generate more noun phrases representing concepts of the product being designed performed better than groups that had fewer noun phrases. Clearly, this is vast area of research that can be critical to the understanding of group work. The work here is grounded in empirical studies and in the theory of communities of language by Herbert Clark which argues that people live in multiple communities of language and the often enter other communities of language through redefining and reconciling of the terminology from one community of language to the other.

Information and knowledge management in distributed organizations

Information and knowledge generation and consumption are distributed throughout the organization. Often it is not possible to predict the location of need for a piece of information beyond its immediate vicinity of generation and with the known consumer of that information. We have extensively studied the use and flow of information in a number of product companies that produce capital goods, such as transformers, hydro-power plants and consumer goods. In our studies it is clear that often information and knowledge distribution does not match either with work distribution or information needs requirements. We have also identified a case where the misunderstanding about the management of product variation between marketing and design and manufacturing led a company to near ruin until a concerted effort was made to consolidate the knowledge and rationalize the product variety. Managing products and product information have become synonymous. The failure of sequential engineering for mass customization was the inability to manage the scope and inter-relationships in the product information. The following sub-areas of research address some of the issues in this sub-area.

Living repositories: A topic in this area of Information and knowledge management is the creation of community repositories. Living repositories are an exploration into the creation of repositories of information that are collaboratively developed with both personal and public spaces of information. The goal of this area is to understand the mechanism of knowledge creation and

management by adhoc groups. We have built two significant living repositories: a) for document management and 2) for analytical and simulation tools and their experience history. We are interested in the dynamics of use and creation of repositories in organizational settings. To this end, we have installed and use LIRE, our document based repository, at ICES to support research groups as well as students in the classroom. We use these setting as our experimental testbed for understanding of the usability of such systems and the impact on group work.

Information and knowledge Reuse. Information and knowledge re-use is a very critical aspect of information and knowledge management. To date the estimates of re-use in industry of knowledge is less that 20%. Whether, this is accurate or not is relevant as most agree that, whatever the percentage, it is quite low. Understanding of information and knowledge re-use is critical for achieving scale and speed in the generation of products. Our studies of knowledge re-use seem to depend critically on the attitude and design philosophy of the organization. Further, the issues of what is re-usable becomes a difficult question to answer. This research thrust will examine the extent and scope of re-use in different engineering disciplines and the conditions that encourage re-use through empirical studies of re-use in organizations.

Re-use is a difficult area for the use of analytical models. There has been a recent paper in economics to understand re-use from an analytical point of view using the theories of options. We expect to examine these approaches by creating analytical models of re-use to understand the potential effects and the policies that best engender re-use behavior. Our goal here is to combine the analytical empirical models of re-use to create rational structures supporting reuse.

Information archives: Creation and use of archives are critical to the operation of any organization. Archives provide both historical and legal information regarding events and decisions. Archival methods for products have been part of most industries. However, seldom are these archives used, with most people using their personal knowledge of the existence of a pieces of information and their ability access it. Both are difficult when archives span 60 years of company operation. To make things easier, sometimes companies have established formats and types of information that well be stored and made available. The important part of archiving is the need for trade off between access, time, fidelity of information etc.

Information Modeling: Modeling is an critical engineering activity. Models created by engineering activity are generally symbolic models of the artifact used for describing, communicating about and simulating a process or product. While modeling has been pervasive in engineering and other domains, support for modeling has been restricted to specialized domains.

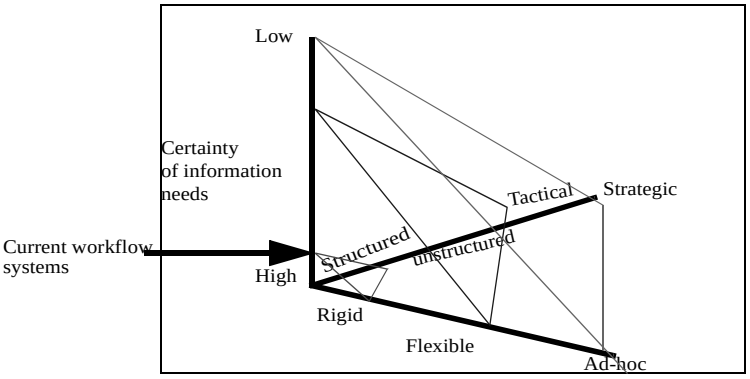
Modeling information to characterize differing granularity, to create procedures that operate on these models and to link models from different perspectives are still in their infancy. Information modeling is critical to the organization and dissemination of information. Information management and knowledge management is critically dependent on the ability to create models of information. Models of information can either be manually created or aided through the use of knowledge extraction, data mining and other techniques. This research are will explore the creation and use of models in different organizational and engineering contexts. In this activity, we

will include standards development as a critical aspect of the information modeling activity. Standards are socially accepted information models.

Workflow modeling and information sharing

Managing work in highly structured situations has produced a class of research and tools in work flow systems. Most of these work flow system are event-based graph structures or petri-nets that allow for serial and parallel sequencing of task. The work on workflow has its cousins in the area of logistics modeling, construction planning for military and large construction projects. Work situations vary depending on the context and nature of work. Studies on workflow modeling have characterized the nature of work flow to be ad-hoc, flexible while the models are rigid. The nature of work is procedural (structured and unstructured), tactical and strategic.

The third dimension is on the certainty of information needs. The nature of work flow has a direct correlation to the level of understanding of the given set of tasks in terms of its structuredness and certainty of availability of information. Figure 1 illustrates the tension between these parameters. Current workflow systems in the market, due to their origins in manufacturing and sales divisions, are concentrated near the origin of this graph. The majority of workflow situations do not fall within this region but in the flexible region of workflow where template workflow structures can be modified on demand due to contingencies that arise in the process of execution. Then there are whole classes of work situations that are in the tactical and strategic areas where uncertainty of information is high and the task cannot be a priori determined and ordered. The research in this area will explore the relationship between different modes of work and the type of workflow systems that best suit the situation. Product development projects of Engineer-21 will provide the testbed to perform these experiments to study the relationship between forms of workflow and information sharing.



Collaborative open design systems: Synthesis and evaluation of systems

Creating and managing collaborative design systems are extremely difficult activities and are often more time consuming than creating the end-product itself. The need for methods for collaborative systems development is critical as the number of new tools for collaborative activity of specialized kinds grows. For example, a number of vendors and university research group address thin slices of the collaboration problem by developing support for synchronous meetings, video/ audio conferencing and document sharing using a variety of process management models. The

time and effort to combine and synthesize these system for collaboration has been very spotty and technology oriented. Often these systems provide different affordances for collaboration but often remain fragmented in their operation. The goal of this thrust is to understand the needs in synthesizing collaborative environments that will combine different affordances for collaboration through different media in the context of specific design disciplines. The areas of design/manufacturing, mechatronics and MEMS provide a rich substrate for which these collaborative systems can be built. These systems can be evaluated for usability, composability and impact on day-to-day work. At ICEs we have embarked on a project to create a prototype collaborative environment for assembly-based design of mechatronic devices. We expect to explore additional issues such as ease of integration and usability and impact on work through the Engineer -21 product development courses. We also anticipate that the research in the three other areas of this research thrust form the components and approaches to creating and evaluating collaborative design systems.

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