A Case Study on Distributed, Collaborative Design: Investigating Communication and Information Flow

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Abstract

A current research project at the University of Strathclyde is introduced which aims to better understand the role of distributed engineering design in industry and address present problems. An element of the first major industrial case study of the project, completed within a multinational in the oil and gas industry, is then described and shown to address the main research questions. This multinational will be described in the text as company A. Sampling and analysis of distributed activity over time is served by the completion of daily diaries and direct observation. This detail design phase of a distributed design project finds that most collaborative work consists of simple information exchange supplementary to the main design activity. Furthermore, concentrated periods of collaborative design are found to follow these information exchange 'cycles'. 62% of distributed activity is found to be with the main design partner and asynchronous communication tools are the most popular. Distributed problems are also listed, including misinterpretation and finding the right person for information.

1. Introduction

The use of globally distributed engineering design teams continues to increase as companies aim to boost profits and decrease lead times by effectively leveraging knowledge and communication from dispersed locations. However, the benefits offered by distributed design are often marginalized by the problems that are inherent in the process [1]. The following problems have been communicated from recent pilot studies [2]:

- Knowledge bases or Domains (KB) are "confused" and "fragmented";
- KB 'islands' exist internally within organizations and externally within projects;
- There is a lack of common understanding between departments and problems with other project partners;
- An additional issue regards awareness. In order to effectively re-use knowledge from past experiences people have to know that it exists.

Currently, for the purposes of this research the manifestation of these problems have been termed *inconsistencies*. This seems to be the most appropriate term for factors that cause disruption to the smooth running and understanding of the design process. They arise, and are most abundant when knowledge and communication are not utilized correctly. These beliefs are re-enforced by the current industrial climate worldwide. Continual technological advancement is set against a backdrop of international mergers, take-overs and partnerships, resulting in a distinct lack of consistency on an organizational and design project level. There is a definite need for measures that will ensure a satisfactory level of continuity across all levels and particularly within distributed working scenarios. These problems have been re-enforced by the findings in the literature. The two main study domains of the project, Computer Supported Co-operative Work (CSCW) and knowledge management, detail the present shortcomings in working at a distance and maximizing the use of knowledge as a company asset.

A set of industrial case studies is required in order to focus the many issues in the field and to give adequate focus to problem areas to be addressed. The overall aim of these case studies is to investigate the distributed design activity within a large multinational that designs complex technical products. Particular attention is to be placed on the role of knowledge in supporting distributed communication and any supporting knowledge or information systems that the companies use. The first case study, discussed here, was carried out within Company A, a company which supplies pressure control and drilling equipment for the oil and gas industry. It is primarily a descriptive case study which aims to provide a snapshot of a part of the distributed design process.

2. Background and motivation - KITE

KITE (Knowledge Integration and Transfer for Engineering design) is a three-year research project based in the fields of Computer Supported Co-operative Work

(CSCW) and knowledge management. The main aim of the project is to safeguard against inconsistencies in the distributed design process by the effective integration and transfer of knowledge. This will be achieved through investigating a number of issues and encapsulating these findings in a Knowledge Integration and Transfer environment for Engineering design (KITE). It is envisaged that continuous consistency will be a key requirement for real progress to be made in future distributed engineering design projects. This will be addressed through investigating the following objectives:

- appropriate knowledge that can be used to enhance the design process;
- the most efficient and useful methods of integrating and transferring knowledge;
- types, levels and location of inconsistencies within the design process;
- the needs of various distributed design teams and required modes of communication.
- define the requirements of KITE and produce a specification and prototype;

These objectives form the core of the research questions. Although these questions were not asked directly during the case they were at the center of all data collection method development as they maintain a strong link between the overall aims of the research and the case study findings.

3. Case study methodology

3.1 Rationale

Company A are worldwide market leaders in the production of pressure control and drilling equipment for the oil and gas industry. The main case study site is in Aberdeen, Scotland. Aberdeen is the head office of the Eastern region of Company A, a region including the UK, Europe, Africa and Russia. The two other main sites are in Houston, USA and Singapore. The company represented an ideal opportunity for the first case of the KITE project for a variety of reasons. Firstly, the company is widely distributed. With regional headquarters in Aberdeen, Houston and Singapore many issues within the CSCW field will be present, including those of distance, time-zones, cultures and the resultant knowledge, information and data which exists within three widely dispersed regional headquarters. In addition to these three regional headquarters Company A has engineering and manufacturing centers, and sales/service offices in 59 locations and 24 countries around the world. Secondly, in designing and engineering pressure control and deep sea drilling equipment for the oil and gas industry, the work that engineers do is necessarily complex. This technical complexity adds another challenging dimension to the company's distribution and necessitates the optimal use of knowledge. Additionally, Company A is a market leader worldwide and already has in place world-class systems and people. This places extra onus on the project and case study in terms of finding problems. It is believed that if a suitable problem domain can be identified in this advanced domain, then it should be applicable on a general scale.

3.2 Overall methodology

A core team of ten engineers were involved in the case study while informal discussions took place with other employees. The core team was requested to take part in semi-structured interviews, complete questionnaires and a daily diary of five short questions for a period of thirty days. These data collection methods were supplemented by other informal discussions and direct on-site observation. All research subjects were either involved in the design process or some level of distributed engineering work. The case study lasted for a period of ten weeks. Record sheets were completed for significant events, interactions or studies. The types of records and their codes are shown below:

A - Informal staff meetings or interactions (e.g. discussion at lunch, in corridor)
B - Data collection methods
a Interviews, b Questionnaires, c Diaries
C - Documentation analysis notes
D - Significant events (e.g. presentations)
E - Observation notes
F - Impressions and interpretation notes

A significant effort was made to record all relevant data, to create a sizeable and searchable case study database and separate actual events and facts from interpretation and opinion. These initiatives are in line with recommendations from the appropriate literature [3]. In total 21 interviews and 19 incidental interactions took place. This included the core research group of 10 plus other employees at managerial level. This totaled over 130 record sheets and nearly 12 hours of interaction. 24 completed questionnaires and 174 days worth of activity recorded through daily diaries also resulted from the case. This equated to a response rate of 87% for the diaries. Interviews helped with investigation of the main case study issues, while questionnaires profiled current activity and perceptions. Diaries were used to sample distributed projects over time and were preferred to direct observation, although observation augmented the data. Two main iterations were employed during the case. The results of the diaries only, will be discussed in this paper.

3.3 Data collection methodology

The use of daily diaries afforded the opportunity to analyze the engineering design activity over a period of time without having to utilize observation techniques, although observation augmented the findings in the diaries. The diary consisted of five short questions. An e-mail message, comprising the questions, was sent from the research base each evening, allowing the engineers to complete the diary each morning, on opening their mail client (Lotus Notes). This was the best available method, decided in conjunction with the research group. As such the response rate for the diaries (30 days data for ten engineers) was 87%. Each of the engineers completed the diaries with varying levels of detail. The analysis proffered in this paper comes with the aid of one engineer who completed to a relatively high level of detail. The diary questions, together with a typical response are shown below:

1. Did you take part in any distributed activity (yesterday)? If YES, what was it?

Further attempts to gain information about subsea connectors, eventually being passed on to the correct person, still awaiting details. Received Pro/E simplified model of Company B's template, onto which our tree fits. In exchange, sent them drawings of our tree with dimensions in inches and mm.

2. Did you encounter any problems from this distributed activity? If YES, what were they?

Getting hold of the correct person to get the required information. Company B's Pro/E template model was created in mm, which did not convert very well to inches. The geometry converted, but all reference entities stayed at the original size.

3. Did you take part in any activity which involved the use or exchange of data/information/knowledge? If YES, what was it?

Pro/E model and Engineering bid drawings.

4. Did you encounter any problems with this data/information/knowledge activity? If YES, what were they?

As above.

5. Was there any particular piece of knowledge that proved useful yesterday? Details please

The template model was very useful.

The 30 days (6 weeks) of data available for this scenario concerned distributed collaboration between the engineer on site (Aberdeen, Scotland) and a sister company in Norway. The team in Scotland was part of the Subsea production equipment group and the data focused on a graduate engineer with 4 years experience. The teams were working together on a major bid for an upcoming Invitation to Tender for a major oil and gas company based in France. Both teams were working on the design of separate products, which were required to fit together, resulting in an *interface* design project. The work carried out could also be equated to the detail design phase in light of the level of complexity. The data collection period coincided with the start of the project and continued through to an advanced stage. If the contract were to be awarded the design activity preached was to follow specification – concept – embodiment - detail – manufacture. However, investigation showed that engineers just “responded to pressing requirements” working backwards from a contract hand over date. Specifications were rarely tackled thoroughly due to substantial re-use from previous projects. Initial emphasis for the project presented in this paper centered on the interactions which took place over the six weeks. Essentially, this information sharing supported the collaborative design activity between Scotland and Norway. Interactions were identified as being one of five types:

Information Out (IO): Information was sent to the collaborating party in support of ongoing work;

Information In (II): Information was received from the collaborating party;

Request Out (RO): A request for information was sent to a collaborator. In most cases this information was required to progress the design activity;

Request In (RI): A request for information was received, and;

Information Exchange (IE): A congested activity where numerous pieces of information were sent and received over a short period of time.

Each of the above identifiers was specialized by the tool adopted. For example, IOe would signify sending something out by e-mail while IIt would signify receiving some information by telephone. Distributed activity identified in the diaries took the form of either simple information exchange (for example, with a supplier) or collaborative design, as supported by information exchange (for example, a level of discussion and trade-off in agreeing an aspect of a design).

4. Case study findings

As would be expected the highest level of activity took place with the main collaborating partner in Norway (see figure 1). This accounted for 62.5% of all activity. Next highest was collaboration with suppliers at 20%, followed by other parts of the Company A group at 10%. Sub-contractors and customers at 5% and 2.5% make up the rest of the activity. This variety of collaboration calls for measures to be adaptive to certain situations. Furthermore, activity with the Norwegian design team

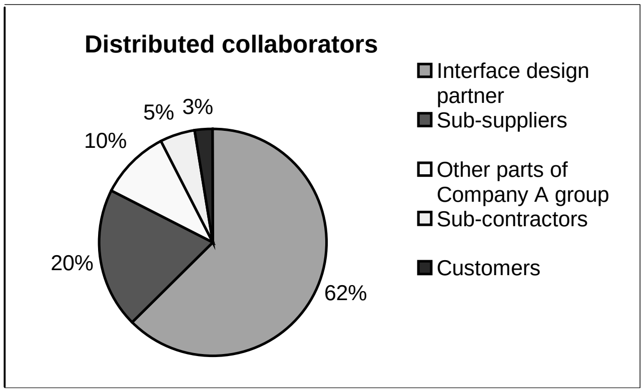

Figure 1. Distributed collaborators

was by far the most prevalent in all groups with the notable exception of *Requests Out (RO)* which consisted of 70% interaction with suppliers. Distributed problems throughout the sample period will be listed below. Examining these types of interactions in more detail (see figure 2), asynchronous communication tools are found to be significantly more prevalent than synchronous tools. This concurs with other research in the field [4]

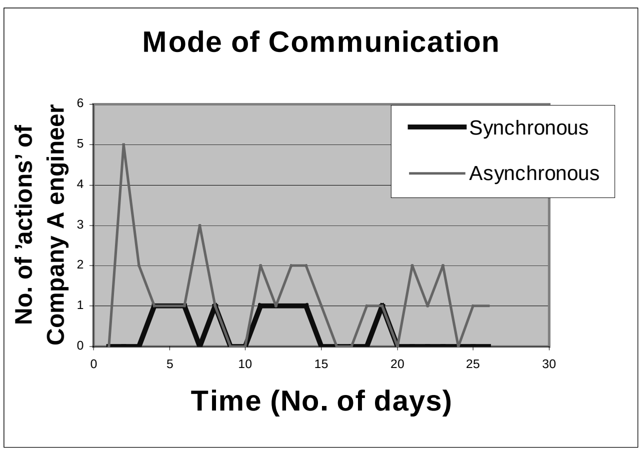

Figure 2. Mode of communication

and could be explained by the slight time difference and the difficulty inherent in the availability of dispersed colleagues. More significantly, it may be that the bulk of the subject of interaction is only *supplementary* to the ongoing design activity with only periods of core designing done distributively, especially in a synchronous mode. These cycles can be examined in more detail by charting the occurrence of each of the types of interactions (see figure 3). A high level of activity in all in all information types is seen at the start of the project. *Requests Out* shows a high level of requests for information being sent out over the first 11 days. *Information Out* shows a consistent occurrence of

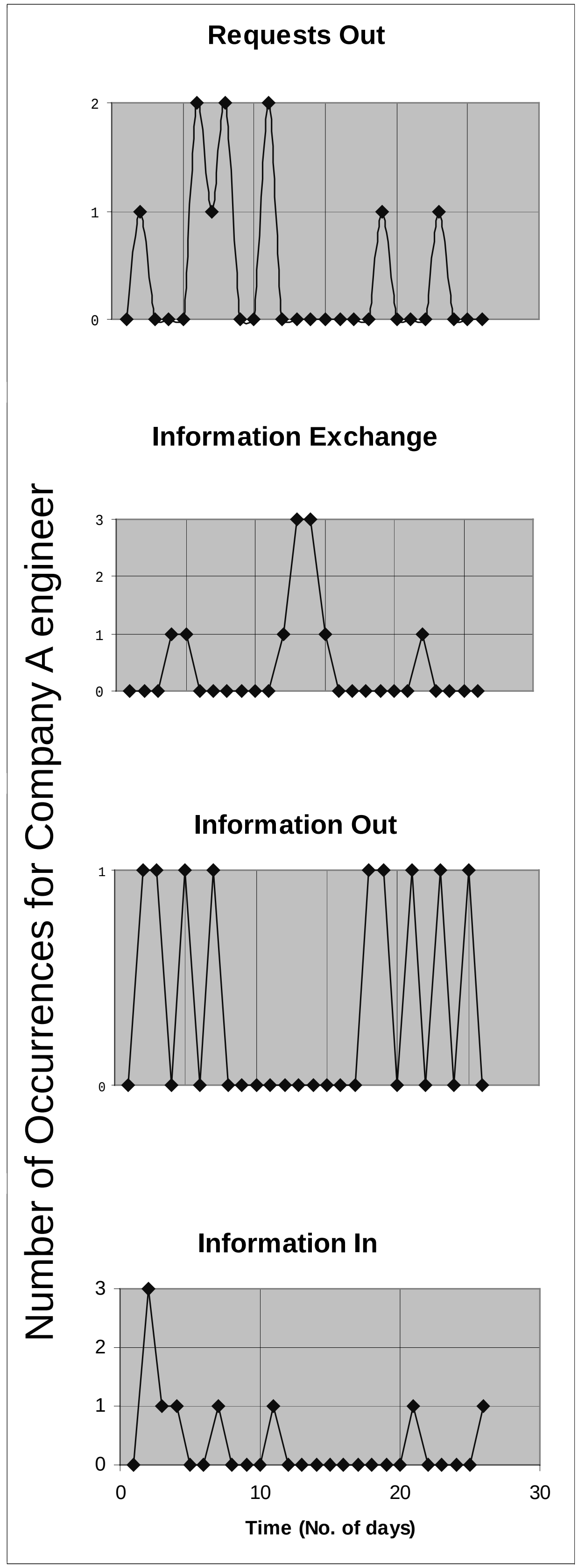

Figure 3. Information cycles

information being sent out over the first 7 days while the amount of information being received is consistently high over the first 11 days and especially on day 2, as shown by *Information In*. This activity followed on from a meeting which called for a series of actions. Most of *Requests Out* occurred during the first two weeks and were sent to sub-suppliers. The rest of the information categories involved, on the most part, collaboration with the main design partner in Norway. *Requests Out*, *Information Out* and *Information In* all have their highest level of activity at the beginning and the end of the sample period. The middle phase is taken up by a focused period of *Information Exchange (IE*). This indicates periods of simple information exchange followed by collaborative design with respect to the information shared, and then on to the next cycle. We propose that the results for the time period after 40 days would include another period of concentrated IE. Distributed activity is also *continual*. On very few days was there no distributed activity at all. It is important to note that the data collection period coincided with the beginning of the project and ended at about 65% completion. The most popular type of interactions week by week were:

- Week 1 – Information In;
- Week 2 – Requests Out;
- Week 3 – Information Exchange;
- Week 4 – Information Exchange;
- Week 5 – Information Out;
- Week 6 – Information Out.

Requests In (RI) only occurred once throughout the thirty day period on day 12. Further studies are required to detect how each of these activities *combined* to make up the distributed design activity. Further investigation would also estimate the type of information interaction in the rest of the project, from week 7 onwards. A series of problems were also communicated during this sample activity.

Week 1 - Design indecision, use of unfamiliar abbreviations and acronyms, not knowing whom to contact for information, unachievable design detail.

Week 2 - Misunderstanding during call, no reply/response (2 instances), getting hold of correct person for information, geometry conversions from metric to imperial.

Week 3 - Ill informed design changes, poor distribution of information, misinterpretation of e-mails.

Week 5 - Describing and interpreting, poor distribution of information, ambiguities.

Week 6 - Disagreement, no reply/response, colleague with important information absent.

Obviously, some problems are human based and will occur during any collaborative or work activity, regardless of distribution. However others such as the problems with abbreviations and ambiguities may be solved through the aims of the KITE project, by making best use of the design knowledge abundant in the work activity. Others such as disagreement with the design are compounded with distribution, making it harder to come to an agreement. Taking the framework proposed by Gutwin and Greenberg [5] some of these problems may be associated with the *taskwork* and others, the *teamwork* or the work of working together.

5. Summary

5.1 The findings

The findings so far from the case study increase the understanding of distributed engineering design within the modern day workplace, giving an overall perspective of the role of collaborative design and distribution. Time series analysis is an important facet of any case study investigation. Daily diaries were the main method in this case as opposed to direct observation. Valuable results for level of work with different partners came from analyzing the diaries:

- 62.5% of distributed activity with main design partner;
- 20% with sub-suppliers
- 10% with other parts of the ABB group;
- 5% with sub-contractors, and;
- 2.5% with customers.

Adaptability of any implemented systems seems to be a must. Cycles of information exchange and collaborative design are also apparent from figure 3. Significantly at this stage, for this type of *interface* design the bulk of distributed activity is supplementary or in support of the design, rather than collaborative design itself, which only occurs in concentrated periods. Furthermore, the identification and analysis of this type of activity may be reflective of much collaboration in the modern marketplace where companies concentrate on their own specialisation which is interdependent on other companies and functions. Problems in the sample project are also interesting. Some are solely attributable to conflicts inevitable in teamwork. Others may also be attributable to a poor use of design knowledge while most, although in some cases not caused by distribution, are certainly made worse by distance and are harder to solve. The design studio concept as practiced by Maher et al. [6] is one possibility of addressing some of these problems, primarily within education, while Regli et al. have attempted to leverage specialized design knowledge for distributed work [7]. Other papers *compare* the educational and industrial arena [8].

5.2 Project progression

It is important to view the case study in the correct contextual light and relate the findings to the overall aims of the research project. It is crucial to address any perceived level of tenuousness between the case study findings and the project. Firstly, the findings, in general, have confirmed the results of the pilot studies undertaken during the initial stages of the research project, while obviously adding significantly to the problem domain. The following points have been confirmed:

- KB 'islands' exist internally within organisations and externally within projects – *issues of this nature were apparent* in *the diaries where particular problems occurred when trying to source information from outwith the company. Internal problems were not as frequent*;
- There is a lack of common understanding between departments and problems with other project partners – *misunderstandings, ambiguities and misinterpretation occurred from time to time in the diaries. This happened on a distributed level only. Collocated problems were rare*;

Secondly, the case study findings have begun to address the overall aims of the project. The research questions (reflective of the aims and objectives of the project) have been addressed in the following areas:

- What are the needs of various distributed design teams and their required modes of communication? – *the diaries have shown a live project showing that asynchronous communication is more prevalent and the information profile charts have addressed the needs of engineers at different stages of collaboration;*
- What are types, levels and location of inconsistencies within the design process? – *a series of problems relating to distribution and knowledge were communicated. Problems of ambiguity and misinterpretation communicated through the diaries may, in turn lead to inconsistencies if they are not continually checked and confirmed;*
- What is appropriate knowledge that can be used to enhance the design process? – *an understanding has been advanced through the diary questions and times of greatest progress during distributed activity;*
- What are the most efficient and useful methods of integrating and transferring knowledge? – *understanding afforded through the case will indicate various options suitability or otherwise in the future.*

6. Further Work

The findings to date address the overall aims and objectives of the project. However, further material from the case will augment the present results. This will come specifically from interviews, questionnaires and an additional in-depth scenario from the daily diaries completed from a different perspective. Furthermore, the medium term will witness the completion of a further case that will enable a different perspective on industry and enable the required cross case analysis. One element of focus will include the identification of types of inconsistencies within the distributed design process. Generally, the case studies will help to produce a *description* of distributed design activity within industry today. Finally, the medium to long term will include some form of prescriptive solution (KITE) in response to this descriptive phase.

7. Acknowledgements

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