Issues and challenges for improving email use in engineering design

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Abstract

Good communication within the design process is a key component in an effective design process. As design teams become more distributed, effective communication becomes more difficult. For example, projects may be designed and specified in the UK, developed and produced in India, whilst being managed by a team split between France and the UK. Amongst the many communication mechanisms available to design teams, email has come to predominate, used for both managing the project and assist in developing the design. Despite its importance, little work has been done within engineering to understand email usage or to develop processes/procedures to improve its use.

This paper uses a cross-disciplinary literature review to identify challenges and opportunities present in contemporary email software and usage. The issues identified are separated for analysis into categories based on the time-scale of their effects:

- Collaboration and communication – affecting team working and the discussion and exchange of information and ideas
- User – affecting work by individual users
- Records – concerning the documentary evidence of a project or activity
- Knowledge creation – concerning organisational learning

The paper discusses the general themes which have emerged from an assessment of current research. Those challenges and opportunities which are of particular importance in the engineering domain are then identified and further work to address these issues is proposed.

Keywords: Email, design, engineering, issues, challenges, communication

1 Introduction

The use, reuse and manipulation of information has become a key factor in the success of any organisation in an increasingly competitive and global business environment [1]. Ensuring that employees are able to access (or are provided with) the right information in a timely manner is one of the key challenges facing organisations [2]. Communication is vital to this timely provision of information [3]. With the increasingly global economy engineering

projects are becoming more geographically distributed. As a result of this, effective communication is increasingly difficult due to the distances, multiple locations and numerous companies involved.

Information and knowledge are communicated rapidly and widely during the design process with involvement of a wide variety of parties. Many types of communication are possible [2]:

- Synchronous – a response is expected to follow immediately e.g. telephone.
- Asynchronous – an immediate response is not expected e.g. letter or email
- Face to face – co-located, interpersonal communication e.g. a design meeting
- Distributed – geographically separate e.g. a video conference

The increase in distributed working has seen the rise in importance of those mechanisms which allow for distributed asynchronous communication, foremost amongst these being email.

1.1 Design teams

For distributed design teams email might be their primary communication mechanism, however, co-located teams also make extensive use of email. A recent BAE Systems study has found that 35% of its engineers spend on average over 2 hours a day reading and answering emails [4]. Another, more general study, claimed that knowledge workers spend an average 3 hours a day on emails, and compared this with 2.5 hours a day creating formal documents [5].

1.2 Background

Information is now one of the most important resources to the modern company. In response to this much research is being conducted in the field of "digital curation" and information management [6][7][8]. Communication with the industrial partner for our work, Converteam UK Ltd, identified long-life projects (spanning decades) as being of in particular need of better information management.

In the initial background research for the work reported here it became apparent that the issues associated with email usage within the context of engineering design are not well understood. Furthermore has been little or no work done within the engineering design community to explore the opportunities in using email for information and knowledge management. This paper will draw on the literature from across the computer science, management and engineering communities to identify challenges and opportunities in how email is used in the engineering design process.

A previous review of email literature [9] from within the Computer Science community identified 3 "metaphors reflecting the "collective imagination" of different disciplinary fields regarding e-mail". The three metaphors proposed were:

- Filing cabinet – An individual's use of email and particularly the challenges associated with effective categorisation of email to minimise overload and to aid retrieval.
- Production facility – Relating emails to work flow and aiding collaboration within project groups and organisations.
- Communicative genre - The effect of email on organisational effectiveness.

The review then described the research in each of these fields with reference to these metaphors. However, specific challenges and opportunities were not identified clearly. The purpose of this paper is to more clearly identify what challenges and opportunities are currently recognised in existing research and determine which have most bearing in the engineering domain.

An alternative categorisation is proposed to more clearly identify, and relate to the engineering domain, the challenges and opportunities identified through the literature on the basis of their relationship to the management of knowledge and information. The following four overlapping areas will be used for this categorisation:
- Collaboration and communication – affecting team working and the discussion and exchange of information and ideas
- User – affecting work by individual users
- Records – concerning the documentary evidence of a project or activity
- Knowledge creation – concerning organisational learning

This categorisation is not an attempt to develop a robust distinction between the issues but is intended to guide in the discussion of the issues. It is suggested that more detailed study of the underlying factors which effect email use is required before a more comprehensive conceptual model can be developed.

The challenges and opportunities identified have been separated into three groups to aid in the identification of themes and for clarity:
- General – issues associated with use of email across all domains
- Extended – issues identified which are not directly associated with the use of email but which arise from (or may be mitigated by) the information which it affords
- Engineering – issues which are of particular importance in the engineering domain

1.3 Why is email important?

During the growth in email usage it was often seen as an informal (and perhaps personal) communication tool, perhaps due to the ease with which users were able to exchange messages [8]. The overheads associated with communicating over large distance were reduced almost to nothing, and for co-located workers new affordances were provided. Uptake in email use has been generally driven not by central organisational but by its popularity with users. The result of this is that many companies do not have central policies to guide employees' use of email or to manage the large collections of emails which their employees are producing [4].

Now that email has been established in the workplace for a significant period of time the problems with the current disorganised system are beginning to become apparent to users and managers. The problem which initiated the research reported in this paper relates to the tracking of decision rationale within long life design projects. It is not uncommon for large engineering projects to take decades to transition through the specification, design, implementation and maintenance phases. During these projects the individuals involved will change, they will retire, be promoted, and move on to other projects. Difficulty in tracking design rationale throughout the life of the project is one of the immediate effects of this flux of people. It has been suggested that this problem has been compounded by the use of email. If rationale is stored, communicated or developed using email then when an individual employee leaves an organisation the information present in their email may be lost or become difficult to access.

2 General

2.1 User

Organisation of email archives

The act of categorising email (and other digital documents) is a cognitively difficult task [10][11][12]. This difficulty is increased in a business context by the dual requirements of categorising for the use of the individual and for use by the organisation. Whether or not categorisation is required for an employee to work effectively [13][10], however, it is required for an organisation to make effective use an individual's email archive.

Interruptions to work

Before the ascendancy of emails, employees would have letters and memos delivered once or twice a day. Emails now arrive in a continuous and unpredictable stream throughout the day, which leads to many more interruptions to work. Studies have found that it can take 64 seconds for an employee to resume work having read an email. Work undertaken within the management research community has claimed that significant costs are associated with these interruptions. [13]

Information overload

Studies of users and of the increase in the global exchange of information have reported that individuals are receiving more emails than they can consistently, thoroughly and comfortably deal with [14][4]. As well as the cost associated with the interruptions to work, stress, frustration and reduced effectiveness have also been identified as the effects of this increase in information exchange [8].

Overloading Email

Although email is primarily used as a communication system studies have reported that individuals put their email systems to a number of other uses [15]. Users have been reported using emails for: the arranging to meetings, the maintenance of task lists, the archiving of files, and as a reminder system. Current email systems and standards do not define or restrict the type of usage [16]. This can influence peoples' ability to handle information overload by requiring further work to transfer information from email applications into their preferred applications [14][17].

2.2 Records

No formal structure

Users often see emails as being an informal communication mechanism or only use it for the exchange of short messages and therefore consider templates a hindrance. Few organisations provide employees with guidelines or training on the use of emails [8]. For the sending of standardised messages such as meeting requests or maintenance records these messages would be more effectively included in a record keeping systems if they were sent using prearranged templates [18].

No relation to process

When an email is sent it has no explicit (or machine interpretable) relation to any processes which the sender is currently involved with [19]. A recipient will often be aware of the process, task or activity which has triggered the email, however, if they are not then the recipient may not have sufficient context to understand the message. When considering the long term retrieval of messages the presence of contextual information is essential to successfully understanding the message [15][9].

Requirement for retention

Courts may now request that emails be provided as evidence. However, many companies still allow employees to decide which emails are appropriate to keep, whilst often not providing any guidelines for making those decisions [8].

Identification of value

Many companies have no procedures or guidelines to encourage employees to identify those emails of long term value and present them for archiving as part of a central record keeping system (this is related to issue discussing the organisation of email archives) [8]. This makes having a central record of a project impossible or of little value as a result of there being either too little or too much content.

Distributed record

Contemporary commercial email systems will often not have (or not be configured to use) a centralised storage facility for emails. This results in emails being deleted or being inaccessible due poor management at an individual level [8]. This relates to the two previous issues: the requirement for retention is made difficult if the emails are not stored in a centrally managed archive, and the identification value is left entirely in the hands on the individual employee.

Integration with other records

Natively emails do not have any mechanism for being related to other (non-email) documents (besides via attachments). Relationships between documents are important for having a consistent and complete project record. Companies have to invest in developing or purchasing document management systems if they want to establish systems which will produce a complete record for a project.

3 Extended

3.1 Collaboration and Communication

Managing organisational communication

Company organisational structures often prevent the free flow of information between employees. Communication between functional groups may have to follow a vertical route up and down the chain of command [2]. This can lead to problems if communication bottlenecks form when individuals with a large number of subordinates are overwhelmed by the number of communications they have to approve [20].

Monitoring the flow of emails can allow for key communication nodes to be identified. This has been identified as providing a number of insights into organisational practice and potentially also allowing for these nodes to be provided with greater support.

Research has also been done to understand the relationship between the formal organisational structure and the informal structure (represented by communication between employees) [20].

Communities of practice

Communities of practice are informal groupings of employees within an organisation. These communities develop naturally within organisations as a result of shared interests and goals [21].

Techniques have been developed to use the email communication records to identify communities of practice [21]. These techniques work by analysing the relationships between employees and identifying subgroups of these employees within a larger network.

3.2 Knowledge Creation

Expertise Mapping

Discovering who knows what within any medium to large organisation is often difficult [22]. In a similar way to identifying knowledge of external organisations (as discussed in Spheres of Influence) it may be possible to identify those employees who hold key expertise. Techniques utilising a combination of social network analysis and content analysis have been developed for expertise identification [22][23]. A study of practice within Rolls-Royce confirms the value of these techniques by reporting that designers sourced 82% of information from people they knew [24]. Expertise Maps by providing an index of expertise associated with each employee would allow users to more quickly identify colleagues capable of providing the information or expertise they seek.

Spheres of Influence

When tendering for a new contract or negotiating with a supplier an organisation can gain an advantage by utilising knowledge from already established relationships. Other than for certain high-profile relationships it might not be clear that an organisation has been dealt with previously.

By employing a similar process as used for Expertise Mapping it would be possible to establish a record of which external organisations an organisation's employees are in communication with. Any communication can be seen as a relationship as a result of which, the sender will have some knowledge of that external organisation. Such a process would also aid the identification of those employees who are key to the maintenance of particular relationships.

4 Engineering

4.1 Collaboration and Communication

Multi-disciplinary teams

Engineering projects often rely on dynamic, mixed discipline teams, with people of different expertise, backgrounds and practices all collaborating on a project [2]

This increases the need for more detailed inclusions of contextual and background information as different participants in the process will "express ideas [differently], and [have] different skills for creating and interpreting diagrams and other visual representations " [2].

An email is a static representation of one person's interpretation of a requirement/state/problem; even considering attachments there is limited scope for the reinterpretation of the information. [3]

Communication in complex projects

Engineering projects often consist of many collaborating companies. Even on simple projects a firm may rely on a number of suppliers or consultants [2]. In such complex projects effective communication of information becomes simultaneously more difficult and more important.

Email is a key mechanism in the communication of information throughout the life of engineering projects, from the initial negotiation of specification through to in-service support, however, records of these communications are often not effectively managed[1].

By effectively managing these communications an organisation could present a more consistent image to an external company and fully utilise existing information about a company to their advantage (as discussed previously under Spheres of Influence).

Intellectual Property (IP) protection

One of the central issues associated with the management of information in complex multi-organisation projects is the maintenance of intellectual property rights (IPR). Participants in a project may in other circumstances be direct competitors. Therefore it is particularly important that through the collaboration no competitive advantage is given away unnecessarily.

Related to the problem of protecting intellectual property (IP) from competitors is that of restrictions on distribution imposed by national regulations. An example of such is the United States's International Traffic in Arms Regulations (ITAR); these regulations restrict the transfer of military technology to any non-US citizen [25]. This causes particular problems for branches of transnational companies operating in the US, who may be prevented from sharing sensitive information with branches in other countries[2].

The rapid copying and exchange of digital documents, for example, through emails has increased the risk that information will be inappropriately shared resulting loss of competitive advantage or legal action.

4.2 Records

Rationale capture

There are a number of tools for the capture of decision making processes within engineering (such as Design Rationale editor (DRed) [26]), however, these often focus solely on meetings, as these provide a concentrated source of design decisions. With the move to more distributed working these decisions are increasingly being communicated (recorded) within the email records of a project.

Although a decision may not be explicitly made 'within' an email exchange, emails certainly can provide information to help understand [27] why a particular decision was taken, when it was taken and who was informed.

Relationship to design artefacts

Artefacts are central to the effective communication of design information [28]. Many emails exchanged during the course of an engineering project are sent along with formally produced documents (provided as attachments to the email)[3] but do not make any reference to an underlying centralised artefact. This practice produces multiple, distributed copies of artefacts each expressing a different stage in the design process.

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1   Communication with engineers at Converteam UK Ltd
2   Communication with engineers at Rolls-Royce
3   Observations from reviewing the project email archives of an engineering firm

Figure 1: A set diagram showing relationships between the opportunities and challenges, and the categorisation used.
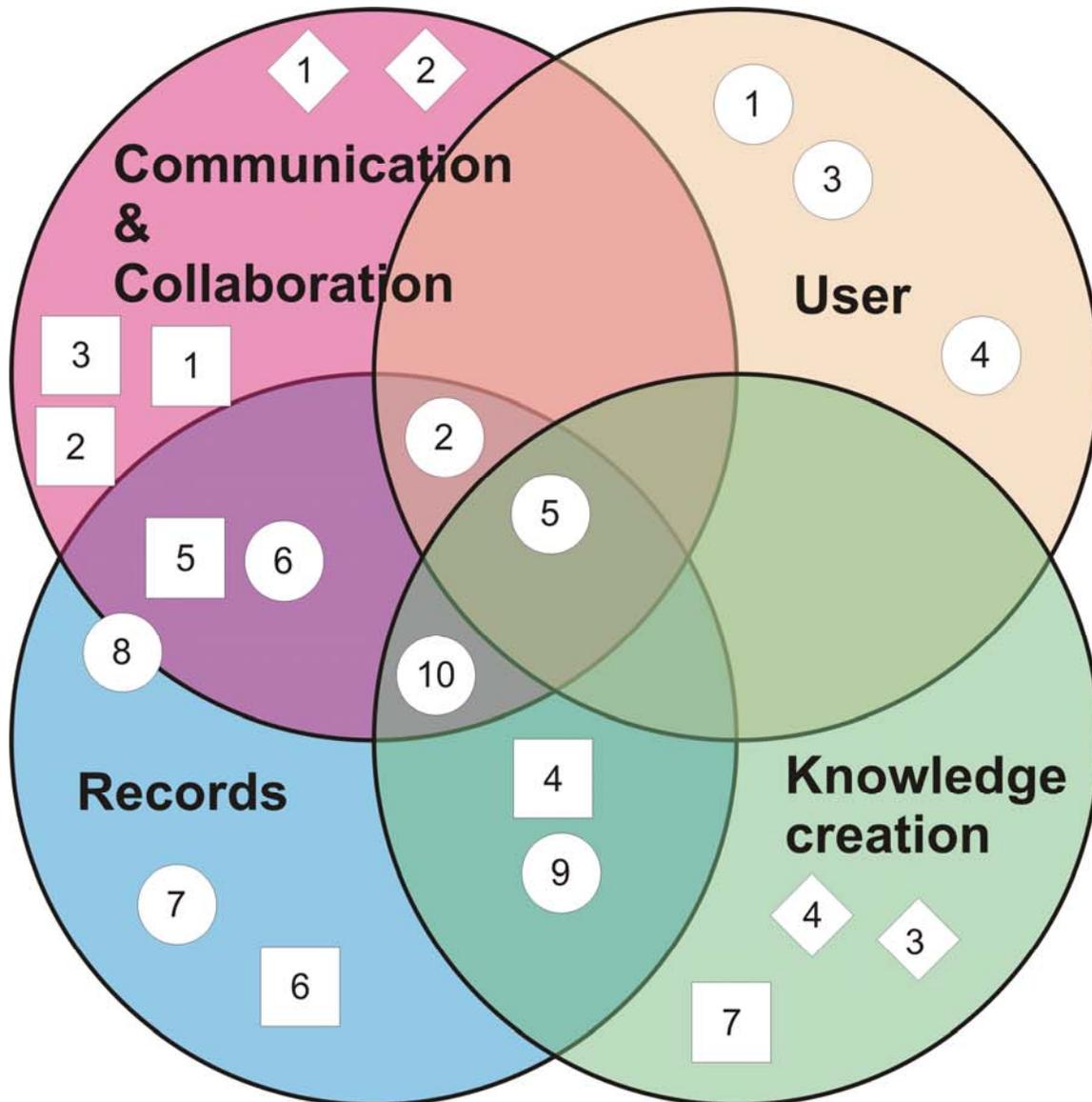
General

1) Interruption to work
2) Organising email archives
3) Information overload
4) Overload email
5) No formal structure
6) No relation to process
7) Requirement for retention
8) Distributed records
9) Identification of value
10) Integration with other records

Extended

1) Managing organisational communication
2) Communities of practice
3) Spheres of influence
4) Expertise Mapping

Engineering

1) Multi-disciplinary teams
2) Communication in complex projects
3) IP protection
4) Rationale capture
5) Relationship to design artefacts
6) Communication record
7) View of the design process

Communication record

Long-life projects can last for, in the order of, 50 years. The barriers that act to prevent the effective recording of information in long life projects are primarily associated with change which will occur with the passage of time: the engineers involved with the project, tools and methodologies, the stakeholder organisations, and terminology [29]. The effects of these barriers have already been highlighted by industry as of major influence in the effective management of their information[4].

4.3 Knowledge Creation

View of the design process

Much research has been conducted within engineering to try to better understand the design process (with a view to improving its management). Ethnographic studies have shown that engineers rarely follow the prescriptive models of the process, which often fail to include the elements of informal interaction which take place in parallel with more formal work [28].

As a mechanism of informal communication, email may provide an important source of information for analysing the design process (and other engineering processes).

5 Discussion

Figure 1 is a set diagram showing a more complex picture of the relationships between the opportunities and challenges identified and the categorisation used. It also intended to give a more visual representation of distribution of opportunities and challenges from the three domains across the categories.

The General issues (§2) identified can be seen (from Figure 1) to be concentrated in the User and Records categories. Many of the Records issues have considerable overlap with the Collaboration and Communication category. The Extended issues (§3) are split evenly between the Knowledge Creation and Collaboration and Communication categories. The Engineering issues (§4) are mainly concentrated in the categories of Records and, Collaboration and Communication.

The daily activities of a design engineer are essentially the same as any other knowledge worker. In the context of a tool for communication, email works as well for engineers as it does within wider industrial and commercial spheres, therefore it is perhaps not surprising that engineering specific user issues have not been identified from the literature.

The Extended section (§3) focuses on opportunities for the use of email in improving organisational practice and understanding. Email has been identified as providing access to otherwise "hidden patterns of collaboration and leadership" [21].

Our work has identified the unexploited opportunities for the use of email in the creation and management of records of the design process and also the further work needed to explore the role email plays in communication and collaboration of design teams and their interactions with external organisations.

6 Conclusion

This paper has outlined the key opportunities and challenges associated with email use within the context of engineering design. Many of the issues identified are generally applicable to all email users or business users and their employers and are the focus of ongoing research.

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4 Communications with Converteam UK Ltd

However, unexploited opportunities for the use of email in the creation and management of records of the design process as well as to aid in communication and collaboration of design teams have also been highlighted.

A more detailed study of the place of email within the engineering design process is needed to improve the understanding of the effect and role of email. Why it has risen to such prevalence over other communication mechanisms? What affordances does it offer the engineering design team and how effectively are those affordances are being utilised? Work is also needed to shed light on the role of emails in the exchange of information during the design process and their place in the creation of records of the design process.

7 Acknowledgements

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