INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 05 MELBOURNE, AUGUST 15-18, 2005

# "PUSH-BASED" STRATEGIES FOR IMPROVING THE EFFICIENCY OF INFORMATION MANAGEMENT IN DESIGN

D R Campbell, S J Culley, C A McMahon

*Keywords: Information management, information push, traceability in design*

## 1. Introduction

This paper will report on how some of the barriers to effective information management in design may be overcome using a number of novel *information push* strategies. Information push refers to the delivery of information in anticipation of a users needs. This is in contrast to a "pull" approach where a user requests and receives a specific piece of information [1]. The research considers contemporary information management issues faced by designers and a review of the state-of-the-art in areas of information and computing science. It is hoped that the results of the work may provide some direction for the future of information usage scenarios in design.

## 2. Objectives

The main objectives of this research are, in more detail:

- The identification of barriers to effective information management faced by today's engineering design practitioners. More specifically, the current and future technological issues associated with the increasing reliance on the usage of electronic documents will be highlighted.
- The demonstration of how emerging technologies that allow for greater autonomy and artificial intelligence in the flow of information between users and computers may be employed to alleviate present day design information usage problems.
- The presentation of a model that shows the ways in which information can be autonomously delivered to a user by profiling or capturing information needs that relate to current activities or long term requirements.

The principal contributions in this paper are a model for the representation of information push approaches and a number of novel information management strategies in design.

In section 3 we review the characteristics of information use in design and discuss possible criteria for improved information management. In 4, some details on the history and background of information push technologies are given. In 5, a model representing the various dimensions of information push approaches is presented. In 6, a number of push-based information management approaches are discussed. Finally in 7, an overview of the anticipated benefits, but also the weak points of the approaches are discussed.

# 3. Characteristics of Information Use in Design

In this section we start by discussing the importance of information in design. This is followed by a discussion of 2 studies carried out that reveal some of the characteristics of information use in design.

## 3.1 Introduction

Many design researchers note the importance of the role of information in design activities. Wallace and Hales [2] state that the design process is essentially an ***information*** processing activity, usually undertaken by a team of people with its progression depending on the decisions made. Eder [3] defines engineering design as a process performed by humans aided by technical means through which ***information*** in the form of requirements is converted into ***information*** in the form of descriptions of technical systems, such that these technical systems meet the needs of mankind.

It is clear that design is an information intensive activity and it follows that a better understanding of information usage in design may pave the way for more effective information management strategies.

## 3.2 Studies of design information usage

Hales [4] carried out a study in an engineering firm designed to improve understanding of the nature of design in an industrial context. The study included extensive observations of designers' activities over the duration of a large engineering project.

One objective of the research was to determine the focus of effort over the duration of each design phase. In his work he identified and recorded time spent on core design activities and on additional supporting activities. Information retrieval is one of the six identified supporting activities identified by Hales, and makes up a significant proportion of effort towards the end of the design project. This is illustrated in Figure 1 where different aspects of project effort (measured in hours) are shown for each phase of the project. Information retrieval effort has been separated from the other supporting activities so that its impact can be seen. For more information on the core design and other supporting activities see [4].

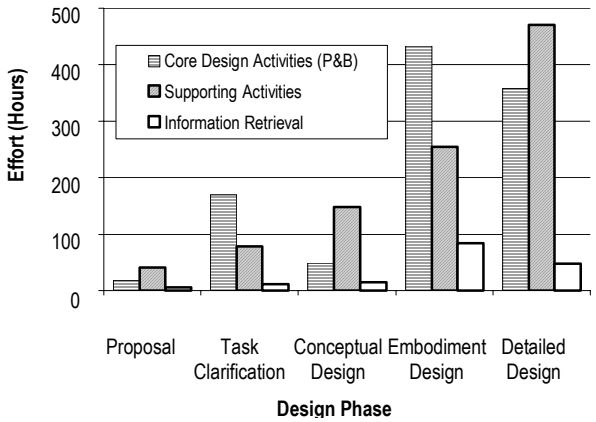


Figure 1. Analysis of the proportion of effort spent on information retrieval in design projects [4].

Although the study is a little dated when changes and advances in the field of engineering design are considered, especially concerning information technology support, it provides clues about the intensity of information usage at each stage. This analysis suggests that information retrieval plays the largest role in the embodiment design phase where it constitutes 11% of project effort.

More recently Lowe [5] carried out a survey of information usage in a large aerospace firm. An interesting result was that on average 20% of designers' time is spent searching for and absorbing information. Lowe concludes that this partly reflects the information intensive nature of design activities and partly reflects the inadequacy of existing information management approaches and support systems. Another observation made by Lowe about modern day design environments is the ubiquity of emails and other electronic documents. This illustrates the need for systems to promote the management and retrieval of text-based information throughout the design process.

## 3.3 Criteria for effective design information management

This section lists a few of the findings made in the design research community that suggest criterion for effective design information management. The list is not intended to be comprehensive but to give a flavour of some of the issues that need to be resolved.

***Effective storage and re-use of information***

A discussion of the most common types of design activity emphasize the importance of information storage and reuse. It is generally agreed that there exists various distinguishable types of design activity. Pahl and Beitz' categories of original design, adaptive design and variant design are widely recognized [6]. There is also agreement amongst researchers that the majority of design is non-original. Pahl and Beitz [6] report that only 25% of products are based on original design. This observation illustrates the importance of effective storage and reuse of information for the purposes of adaptive and variant design.

***Support for the information needs of novice designers***

Ahmed and Wallace [7] are involved in a long-term research project with the aim of understanding how to support the knowledge and information needs of novice designers. Their empirical work has shown that in the aerospace industry, novice designers were aware of their knowledge needs in only 35% of queries. It can be concluded from this finding that conventional information management strategies are not being effective or pro-active in assisting novice designers to help them understand what their knowledge needs should be. The research has resulted in the development of a question-based system (CQuARK) which helps to raise the awareness of what novice designers need to know and not just to provide support for accessing information and knowledge.

***Effective knowledge management in distributed engineering design***

Troxler and Lauche [8], who have carried out studies on engineering service providers to the oil and gas industries, report on some of the difficulties of supporting knowledge management in distributed engineering design. They noted that dispersed design teams often have difficulty transferring work practices, methods and sources of information across locations despite them performing similar functions. It can be concluded that although the trend towards distributed design is continuing the technologies in place to aid cohesion of geographically distributed project teams are failing.

***Management of informal information in design***

It is clear that the increasing complexity of designs will require more all-encompassing information management strategies. Some researchers believe that in order to move forward the management of informal information and general design documentation that often describe the rationales behind designs needs to be more fully supported. Ullman [9] states that PDM systems are beginning to manage some of the needed (non-geometric and informal design) information. However, these systems tend to be oriented toward information that is well-structured and not evolutionary information (information evolving with design(s)). Further, these systems do not have a formal mechanism for managing information about argumentation leading to decisions, an aspect under active research [22].

It is thought that at least some of the issues raised in this section can be addressed using the push-based strategies outlined in this paper. These strategies and how they address the issues are discussed in later sections.

# 4. Background to information push

Information push refers in general to the sending of information to a client without the client requesting it. Broadcasting and the sending of email are examples of push technologies. By contrast, the World Wide Web is characterised by pull – the client requests a web page before it is sent [10]. Push technologies became of interest to WWW technologists in the mid to late 1990's.

## 4.1 Pointcast as an example of push technology

Pointcast, one of several dotcom companies that developed software to exploit the concept of information push in the late 1990's, had some success, but then failed because of flaws in the products developed. The software, which delivered items of news and stock market information customized to the users' interests, was not successful for two reasons. Firstly, corporate networks were unable to cope with large increase in network traffic resulting from the usage of the software. Secondly, users often felt that the delivery of news was a hindrance to their work complaining that the software contributed to problems of information overload [11].

It may be the case that the apparent failure of push technologies in the late 1990's was due to the immaturity of supporting Internet technologies and the lack of control and customization push services provided to computer users.

## 4.2 Evolution of push technologies

Although push technologies fell out of favour because of the reasons stated there are signs that they still hold potential for the future. For example, content syndication specifications such as RSS (Really Simple Syndication) became well-established technologies allowing users to receive personalized news items. A more recent trend has been for a users hosting and reading blog[1] sites to use RSS technology so that new information can be distributed instantly to friends and relatives without the need for visiting each site individually in the search for updates.

[1] Slang term derived from weblog used to describe a personal web page(s) usually incorporating a diary for friends or family to read news.

In early push based technologies the common approach was for a user to specify their preferences for information in a "static" interest profile. In this approach, the interest or user profile, representing a user's mid-to-long term information interests, acts like a filter sifting out information from an oncoming information stream. This process is often referred to as Information Filtering (IF). Examples of early research in this area include: "Using collaborative filtering to weave an information tapestry" [12], and GroupLens, "An open architecture for the collaborative filtering of netnews", [13].

More recently there has been an increasing amount of research looking at ways to profile a computer user's short-term information needs without user pre-specifying them. This type of dynamic profile usually represents information needs related to the current computer activity. This approach often overcomes a problem encountered with the static profile where the information pushed does not match the current computer based activity (only the user's generic interests) and may even be a distraction. Examples of research in this area include: "User centred push for timely information delivery" [14], and the Lumiére Project involving bayesian user modelling for inferring the needs of software users" [15].

# 5. A model for push technologies

This section discusses three features of information push systems and presents a model of how these features can be represented.

It is suggested that there are the following 3 fundamental features common to any information push system.

- Representation of information needs (Profile): This is required in order for an assessment to be made about which information is relevant to a user's information needs. For the purpose of this model this representation is referred to as a profile.
- Information set or stream: An information set (e.g. document repository) or stream (e.g. stream of news bulletins) from which deliver information is the second requirement. Where the Profile represents a user's long-term interests the emphasis is on delivering new or changing information from an information stream. Where short-term interests are represented the emphasis is typically on delivering information from an information set (static).
- Profile-Information association mechanism: The third requirement is a mechanism that associates a Profile with information and decides whether the information should be rejected or selected for delivery to the user. In some information push systems this is referred to as an information filter (e.g. [12]).

Each feature is discussed in more depth in the following sections.

## 5.1 Representation of information needs (Profile)

An information user typically has short-term information requirements relating to his or her current task or activity and long term information requirements usually identified by their interests or specialisms. This section briefly introduces the types of profile which can be used to meet each case.

Long-term information needs are represented by a user profile which is created from a set of statements or rules defining the user's interests. For example, user profiles are often created as part of Internet customer shopping accounts. The Amazon [16] online bookstore builds user

profiles based on the ratings users give to books they have read and a record of their purchases.

In order for an information push system to meet short-term requirements the representation of information needs has to reflect the current activity or task. For this reason the term "activity profile" is used to represent short-term requirements. An activity profile is usually generated from hints gathered from the user interface about the current activity. E.g. the web page opened or a recently typed search term. An example of research in this area is the Letizia project carried out at the MIT [17].

## 5.2 Information stream / set

Depending on the type of profiling being used a dynamic information stream or a static information set is required for an information push system.

A long-term interest or user profile is more suited for use with an information stream as this combination is best able to filter and deliver information that becomes newly available.

A short-term interest or activity profile is more suited to static information sets. This combination is best able to locate information that a user may or may not be aware exists but relates to the task at hand usually through some historical link or association.

## 5.3 Profile-information association mechanism

The mechanisms that are used to associate profiles with information are often those used in the field of information retrieval (IR), the most popular being string matching or an extension of string matching such as Boolean information retrieval or vector-space modelling [18]. Other methods that can be used to match profiles with information include Bayesian inference networks [19] and Latent Semantic Indexing [20]. The basic principle of all approaches is to select or reject information to be delivered based on the closeness of match with the search terms.

## 5.4 Schematic representation of information push model

A schematic representation of the information push model presented here is shown in Figure 2. This illustrates the combinations of profile and information type that can be used in a push based system.

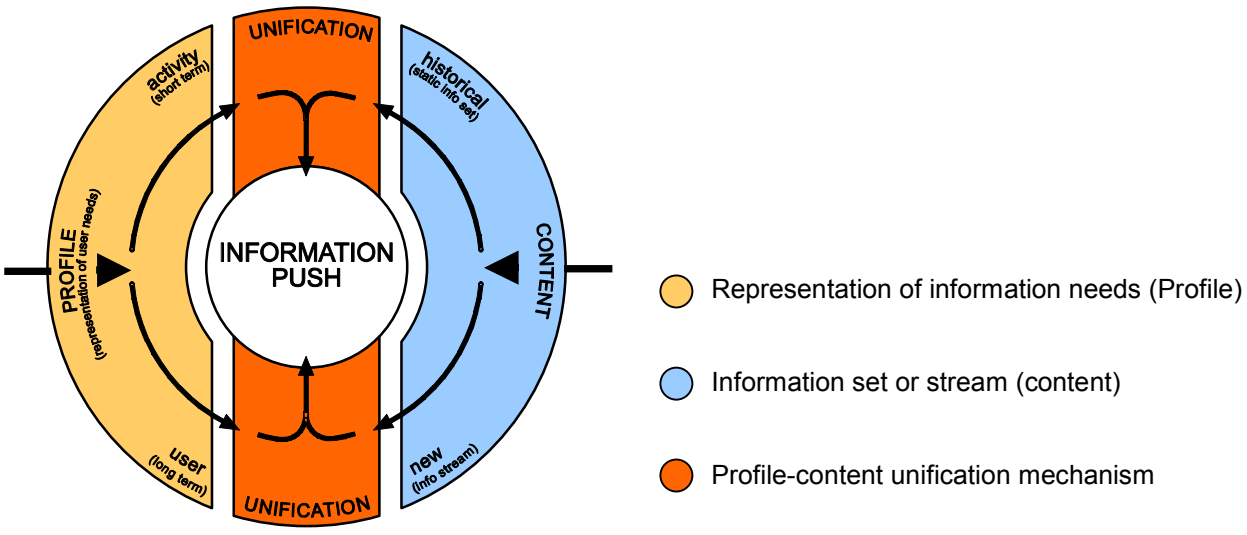


Figure 2. A schematic representation of a model describing information push approaches.

# 6. Push approaches to improve engineering information management

In the remainder of this paper a number of approaches for improving the efficiency or effectiveness of design information management are discussed. Each approach is a member of a generic strategy described by the model discussed in the previous section. The generic strategies are as follows:

1. Pushing historical items of information to a user that become relevant to the user's current activity focus (using an activity profile and a historical information set).
2. Pushing newly created items of information in accordance with the predefined information preferences of a user (using a user profile and an information stream).
3. A combination of (1) and (2).

The approaches are also each discussed in relation to a specific computer based design activity. Table 1 shows which activity and strategy the approaches involve.

Table 1: The strategy and activity for each approach described in this paper. The numbers in the body of the table refer to the sub-section numbers in this section.

| Strategy / Activity | (i) Autonomous Retrieval | (ii) Filtering | (iii) Combination of (i) & (ii) |
|---|---|---|---|
| CAD | **1, 6** | | |
| Technical Writing | **3, 5** | | |
| Browsing Information | **4, 8** | | **7, 9** |
| Communication / Correspondence | | **2** | |

This set of approaches is the result of an exploration of the possibilities presented under the consideration of activities and strategies listed in the table. Where a similarity between an approach discussed in the literature, this is stated.

In the descriptions that follow details of the overall strategy for the approach are combined with details of the possible method for implementation. The approaches are presented in this way to provide the reader with understanding of both aspects.

## 6.1 Context sensitive assistance in CAD

**Summary:** Mechanical design carried out on a CAD workstation using context sensitive assistance in the form of design reference material.

**Method:**

1. An algorithm is used to log the menu selections and commands that are used to add design features to the CAD model or drawing. (Bores, chamfers, draft angles, screw threads, standard components, tolerances, geometrical tolerances, surface finishes, hardness specifications etc…)

2. The log of menu selections and commands is used to form a profile describing current activities.
3. Where there exists reference material in the form of engineering standards or company standards that relate to a design feature added to a CAD model or drawing, this material is shown at the time of feature creation.
4. The facility to add, or remove associations between reference material and the execution of menu selections / commands is possible to maintain and customise the push service to the requirements of the user or company.

**Discussion:** This simple rule based method of linking reference material to the execution of design features in CAD packages can help to raise awareness of information that should be referred to during the design process. It is envisaged that it would be particularly useful for novice designers learning the internal and external sources of reference material.

## 6.2 Cognitive filtering of design information

**Summary:** Newly created information in an engineering firm is pushed to users where there is a correlation between the user's preferences for information and the content of newly created documents.

**Method:**

1. All users state their preferences for information and these are recorded in "user profiles".
2. The user profile contains the following information in addition to information topic preferences: Profession, current project, position in project team hierarchy, role in engineering product and process.
3. When new information is published to a repository a summary of its content and context, (See Lowe [6]) is used to make a multi-faceted classification. The classifications include the author, type of document, project and the role in product and process. The information could be formal or informal, structured or unstructured. The information could vary in type and be a report, CAD model, specification or form of correspondence.
4. A syndication technology (e.g. RSS ) is used to assess relevance between a user's profile and newly published information. Where there is a high relevance a user is notified of the newly published information via an aggregator.

**Discussion:** The objective in this approach is to improve the communication of work between members of an engineering project team or community. It is suggested that the benefits of this approach are exploited most when cohesion of team or community members is difficult because of geographical spread or cross-functional communities of practice.

## 6.3 Typed text as implicit interest indicator for autonomous retrieval

**Summary**: An editor of a technical report is shown links to information in other documents containing similar textual content to that which has recently been typed.

**Method:**

1. Software is used to capture recently typed text in a word processing application.
2. The recently typed text is evaluated algorithmically to pick out several words that might best describe the meaning of the document being written. (E.g. including words inside a title or abstract of the document or be words that are unusual and more likely to be unique to that document)

3. The words extracted are used to form a keyword query similar in nature to an Internet search engine query.
4. A suitable software technology (possibly multi-agent) is used to carry out simultaneous searches of repositories for documents with a similar content. The searches are carried out on repositories that are local, networked or available on the Internet. (e.g. Local email repository or formal document repository on local network)
5. Information references or links to similar documents are shown to the user on a passive display. The search results are updated to reflect changes to the document as it is being written.

**Discussion:** This form of activity profiling has been covered in the literature quite extensively. The most notable work has been the Remembrance Agent project [23] carried out at the MIT. It is suggested that the approach would be beneficial in design engineering environments where a lot of structured and unstructured text based information is generated.

## 6.4 Web usage as implicit interest indicator for autonomous retrieval

**Summary:** A user browsing web pages is shown links to information in other documents containing similar textual content to text in the current browser window.

**Method:**

1. Software is used to capture keywords on a web page being currently browsed. The keywords are captured automatically by an algorithm which attempts to pick those words which best describe the document.
2. The words used are extracted to form a keyword query that can be used in the same way as an Internet search engine query.
3. A suitable software technology (possibly multi-agent) is used to carry out simultaneous searches of repositories for documents with a similar content. The searches are carried out on repositories that are local, networked or available on the Internet. (e.g. Local email repository or formal document repository on local network)
4. Information references or links to similar documents are shown to the user on a passive display. The search results are updated when a new web page is browsed.

**Discussion:** This approach is the similar in nature to the previous approach. In this case however, the user is provided with suggestions for information whilst browsing instead of report writing.

## 6.5 Semi-automatic referencing whilst report writing

**Summary**: A reader or editor of a technical report is shown links to information referred to during the creation of that document. (Note: the approaches discussed here and in 6.7 are not strictly push-based methods. However, they do provide the foundations for push-based methods discussed in later sections.)

**Method:**

1. During the creation or revision of a technical report, an algorithm is used to log the following data when the author has referred to information contained in local files, intranet or Internet pages. (In parallel with the document editing)
    a. Machine and path name for references to information contained in local files

b. Uniform Resource Locator (URL) for information contained in intranet / Internet pages

c. Time of access to an information reference

d. The current editing position of document being written. (e.g. current document section header)

2. When the technical writing session has finished the log of information references is reviewed by the author and added to the document meta-data in some way.
3. When the document is re-opened for reading or re-editing the information references made in the original preparation of the document are available to the reader or author.
4. The information references are shown alongside the section of the document where the information reference was originally made.

**Discussion:** The emphasis in this approach is to capture designers' rationale in decision making. This is essentially achieved by the designer allowing their references to other information to be captured during the creation of technical reports or specifications. It is envisaged that these sorts of documents would hold more value to colleagues, who may be able to extract a better understanding of rationale from analysis of the information that was referred to. This approach is dependent on authors referring to electronically stored information and not paper-based documents

## 6.6 Semi-automatic referencing in CAD

**Summary:** An engineering designer working on a CAD model is shown links to the history of information referred to during the creation or modification of design features or components that make up the model.

**Method:**

1. During the creation of features or assembly of components in CAD, an algorithm is used to log the following data when the author has referred to information contained in local files, intranet or Internet pages. (In parallel with the CAD session)

    a. Machine and path name for references to information contained in local files

    b. Uniform Resource Locator (URL) for information contained in intranet or Internet pages

    c. Time of access to an information reference

    d. The current features being worked on (in part creation) or the current components being assembled (in assembly creation)

2. When the CAD session has finished the log of information references is reviewed by the designer and stored along side other model data, possibly attached to the PDM record.
3. When the CAD model is reopened for examination or changes the information references made in the original preparation of the model are available to the current user.
4. When a feature or component is selected the history of information references made during the creation or modification of that element are shown.

**Discussion:** Again, the emphasis is on improving the traceability of design rationale. The most notable benefit of this approach is in the associations achieved between the CAD model and the product, supplier, company and standards documentation.

## 6.7 Document references for a user centric collaborative filtering approach

**Summary:** A group of computer users in an engineering project team or company agree to let their document browsing history be used to infer relevance between documents in the firm's document repository. Relevance matches are used as the basis for information push.

**Method:**

1. Time stamped document-browsing histories are logged for computer users in an engineering project team or company.
2. Relevance between documents in a user's browsing history is inferred between any pair of documents that have been accessed in succession or in a close period of time. The relevance is inferred because of the likelihood of the documents both being related to the user's interest at that time.
3. The browsing history of a user is compared with other browsing histories in the group to push information to the user in one of the following ways:
4. In the first case, links to documents deemed to be relevant under step 2 are pushed by searching for the document most recently browsed in other browsing histories. (This is pushing documents in line with the short-term information requirements of the user).
5. In the second case, links to documents deemed to be relevant under step 2 are pushed by searching for documents that are frequently browsed by the user in other browsing histories. (This is pushing documents in line with the long-term information requirements of the user).

**Discussion:** This approach is a form of collaborative filtering which involves assessing relevance between documents based on their historical usage. An assumption is made that different users will agree on the relevance between two documents in this type of approach. However, collaborative filtering has achieved some success in other fields.

## 6.8 Document references for an item centric collaborative filtering approach

**Summary**: Information reference histories contained in the meta-data of documents (See section 6.5) is compared with the information references in other documents and user browsing histories (See section 6.7) to push relevant information to a user working on the document or CAD model.

**Method:**

1. Recent references to electronic items of information are searched for in the information reference histories of other documents and user browser histories.
2. If an information reference is found in the meta-data of another document then a link to this document is shown.
3. If the information reference is found in other browsing histories then hyperlinks to documents deemed to be relevant under approach 6.7, step 2, are pushed to the user.

## 6.9 Combinatory approaches

**Summary**: This section describes how approaches 6.7 and 6.8 can be enhanced by combining the methods described in approaches 6.4 and 6.5.

1. Documents deemed to be relevant using the collaborative filtering approaches described can be compared with a user's preference and interest profile before being suggested as a relevant link. This enables the document relevance specific to the user to be assessed more accurately.
2. Documents deemed to be relevant using the collaborative filtering approaches described can be parsed in the search for keywords found in the current document before being suggested as a relevant link. This enables the content relevance to be assessed more accurately.

# 7. Discussion of anticipated benefits and weak points

As there has been no formal validation of the approaches to date, a general consideration of the anticipated benefits, but also weak points and barriers to implementation, are considered here. There is particular emphasis on the latter approaches discussed in this paper as these are considered to be the ones that will be investigated further in this research

## 7.1 Anticipated benefits of approaches

It is anticipated that the two most significant benefits of employing information push approaches in design are:

- Improved awareness of new events or developments related to an organisations design project.
- Improved awareness of historical information related to aspects of a design

The statements directly relate to the two primary modes of information push discussed in section 5. In regard of the second statement it is anticipated that a further benefit may be the improved efficiency of design tasks resulting from a lower amount of time spent searching for information.

Another potentially beneficial aspect of some of the approaches discussed is the linking together of related, but disparate information sources achieved through the monitoring of information use during design sessions. It is hoped that this will enable greater retention of information and knowledge, particularly in regard of the relationships between items of information formed as result of their usage. Further, these approaches promote the retention of information about the evolution of a design and not just information associated with the final design. A counter argument to this strategy is that the capture of possibly "redundant" information in the design process might contribute to issues of "information overload" or becoming "lost in information" [24], [25]. However, it should also be considered that the way in which information is searched for, or disseminated is possibly a significant factor here and that these issues are not just related to the volume of information available.

## 7.2 Anticipated weak points and barriers to implementation

An assumption made in some of the latter approaches, that items of information used during a design session are considered as being related because they have been used to achieve the same underlying goal or output of a computer-based activity.

A possible concern over this assumption is that a user switching focus in computer based activities could possibly make it difficult to distinguish whether an item of information being used is related to a specific task or objective – especially if the process is to be carried out autonomously. A possible approach to alleviating this problem may be to involve the user in

assigning the relationships between information. For example, requiring the user to notify the recording process when the focus of an activity has changed. As a consequence the resulting process is likely to put additional burden on the user, so ultimately there is a trade-off between the accuracy of relationships assigned between items of information and the effort required by the user to help establish them. These ideas are discussed in a related publication [26]

Another concern related to the approaches where design activities are monitored is the possible negative feeling associated with the recording of information usage, specifically to do with invasion of privacy. A number of measures can be employed to alleviate this problem. Most importantly the recording process can be made transparent and controllable by the user so that the information recorded and the periods when the recording process is active is left in the hands of the user. Also, where the relationships between information are used by a group of people, anonymity can be introduced so that there are no traceable links between users and relationships they have created between items of information.

Finally, a possible drawback of retaining extra information about design activities involved in some approaches is the added cost of sustaining larger information archives. Here, the costs involved in allowing for the possible redundancy must be compared with possible added value to a design and its evolution resulting from the adoption of such an approach. Again, these are aspects are discussed further in a related publication [26]

# 8. Summary

It can be seen from more recent studies that time spent managing information appears to be increasing as design activities become more information intensive. A discussion of the changing and unsteady state of information push technologies over the last decade has shown that the benefits of these alternative methods of information management are still unclear and that there are possibilities left to be explored and evaluated.

As a result of the research carried out a model has been created to describe the ways in which information can be pushed. This model has been designed to add clarity to various dimensions of information push approaches. Also, a number of approaches for incorporating push technologies into design activities have been suggested. The benefits to be accrued in design projects have also been discussed although these have not yet been fully evaluated or proved.

# 9. Future work

In this work, theoretical solutions to information management problems have been considered. Work needs to be done to explore the performance and practicability of these systems and the ethical issues associated with the approaches. This is likely to involve observations of computer-based design sessions and the development of prototypical software that can be used for the purposes of testing.

# 10. Conclusions

It is thought that with the increasing complexity of product designs, new methods to manage information will be required in future. The approaches outlined indicate how adopting information push strategies maybe achieved although several practical and ethical questions remain to be answered. A major criticism of push-based systems is the interruption and disruption to computer-based work caused by the unexpected delivery of information. This

has been one reason for the failure of push-based systems in the past. Possible solutions to this issue might be in the use of more passive interfaces for information delivery and the use of relevance thresholds, which determine whether an item of information is to be delivered, based on the likelihood of disruption and the relevance or urgency of information. Another possible issue to be addressed is the invasion of privacy resulting when short-term and long-term interests are deduced by monitoring the user interface actions carried out by computer users.

## 11. Acknowledgements

The research carried out for this paper was funded by the Engineering and Physical Sciences Research Council (EPSRC) and Airbus UK. The authors acknowledge and thank Dr Florence Sellini and Peter Coleman from Airbus UK for their support.

**References**

[1] Cybenko, G. "The Foundations of Information Push and Pull", Proceedings of the Mathematics of Information, Institute for Mathematics and Applications, 1997, Dartmouth College, Hanover NH 03755 USA.

[2] Wallace, K. M. and Hales, C., "Engineering Design Research Areas", Proceedings of the International Conference on Engineering Design, ICED89, 1989, Harrogate, UK,

[3] Eder, W. E., "Information Systems for Designers", Proceedings of the International Conference on Engineering Design ICED89, 1989, Harrogate, UK, p. 1307-1319

[4] Hales, C., "Analysis of Engineering Design Process in an Industrial Context" (Second Edition), 1991, Grant Hills Publications, UK,

[5] Lowe, A., "Studies of Information Use by Engineering Designers and the Development of Strategies to Aid in its Classification and Retrieval", PhD thesis, University of Bristol, UK, Chapter 3.

[6] Pahl G and Beitz, W, "Engineering Design", The Design Council London, 1984

[7] Ahmed, S and Wallace, K. M., "Identifying and Supporting the Knowledge Needs of Novice Designers within the Aerospace Industry", 2004, Journal of Engineering Design, 15 (3).

[8] Troxler, P. and Louche K., "Knowledge Management and Learning Culture in Distributed Engineering", 2003, International conference on Engineering Design ICED03, Stockholm, August 19-21, 2003

[9] Ullman, D, "Toward the Ideal Mechanical Engineering Design Support System", 2002, Research in Engineering Design, 13

[10] Webopedia online dictionary, Definition of Push, [WWW], http://www.webopedia.com/TERM/p/push.html, cited on 14/3/2005

[11] Wolf, G., "The Return of Push!" 2004, [WWW], ww.wired.com/wired/archive/12.05/start.html?pg=2, Wired Internet Magazine, Issue 12.05

[12] Goldberg, D. et al, "Using Collaborative Filtering to Weave an Information Tapestry", 1992, Communications of the ACM Vol. 35 No 12

[13] Resnick, P. et al, “GroupLens: An Open Architecture for Collaborative Filtering of NetNews”, 1994, ACM 0-89791-689-1/94/0010

[14] Underwood, G. M. et al, “User Centered Push for Timely Information Delivery”, 1998, Proceedings of the Seventh International World Wide Web Conference, Brisbane, Australia

[15] Horvitz, E., “The Lumiére Project: Bayesian User Modelling for Inferring the Needs of Software Users”, Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence, Madison, WI, July 1998, Morgan Kaufmann: San Francisco, pp. 256-265.

[16] Amazon Bookstore, 2004, [WWW] www.amazon.com

[17] Lieberman, H., “Letizia: An Agent That Assists Web Browsing”, 1995, International Joint Conference on Artificial Intelligence, Montreal

[18] Salton, G. & Lesk, M. E., “Computer Evaluation of Indexing and Text Processing”, Journal of the ACM, 15(1):8-36, January 1968

[19] Broglio, J., Callan, J. P., Croft, W. B., Nachbar, D. W., “Document Retrieval and Routing Using the INQUERY System”. In D. K. Harman, editor, Overview of the Third Retrieval Conference (TREC-3), pages 29-38. NIST Special Publication 500-225, 1995

[20] Furnas, G. W., Deerwester, S., Dumais, S. T., Landauer, T. K., Harshman, L. A. Streeter, L. A., Lochbaum, K. E., “Information Retrieval Using a Singular Value Decomposition Model of Latent Semantic Structure”. In Proc. of the 11th Annual International ACM SIGIR Conference on Research and Development in Information retrieval, 1988, pages 465-480

[21] Rhodes. B., “Remembrance Agent: A Continuously Running Information Retrieval System”, in PAAM’96, 1996, pp. 486-495

[22] Bracewell, R.H., Ahmed, S. and Walace, (2004) “DReD and Design Folders: A Way of Capturing, Storing and Passing on Knowledge Generated During Design Projects”, Design Automation Conference, ASME, Salt Lake City, Utah, USA,

[23] Rhodes, B., “Just in Time Information Retrieval”, PhD Thesis, S.M. Media Arts and Sciences, Massachusetts Institute of Technology, Cambridge, MA,

[24] Edmunds, A. and Morris, A. (2000), “The problem of information overload in business organisations: a review of the literature”, International Journal of Information Management, 20, p.17-28.

[25] Waddington, P., “Dying for information? A report on the effects of information overload in the UK and worldwide” NSF Workshop on Research Directions for Digital Libraries June 15-17, 2003 Chatham, MA. Pittsburgh University

[26] Campbell, D., McMahon, C., Culley, S., “A Methodology for profiling computer based design activities”, 2005, International conference on Engineering Design ICED05, Melbourne.

Mr Duncan R. Campbell
Mechanical Engineering Dept., University of Bath, Bath, BA2 7AY
England
Phone: +44 (0)1225 386131
Email: D.R.Campbell@bath.ac.uk