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SUPPORTING THE EARLY STAGES OF THE PRODUCT DESIGN PROCESS: USING AN INTEGRATED COLLABORATIVE ENVIRONMENT

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ABSTRACT
Existing technologies designed to support professional product designers focus mainly on the modelling stages of the design process, while the early conceptual stages remain relatively unexplored. There is a need for seamlessly integrating product development tasks into a comprehensive collaborative computer supported design environment that can assist professional product designers. To address this need, a new research and development project funded by the European Commission under the 7th Framework programme has been launched, entitled Collaborative Creative Design Platform (COnCEPT). The research aims to address the technology gap by defining a flexible framework, which can serve as a blueprint for the development of efficient collaborative computer supported environments. The COnCEPT platform will use advanced data-mining algorithms to find appropriate text and visual information to support product designers at the early stages of the design process, making use of past solutions, market data and new emerging technologies. The software will convert the available and contributed information into a form making it accessible to the design team. The project will investigate which interaction techniques are most suited to specific situations and activities, and how they can be combined in one integrated environment. This paper identifies the key design challenges facing the project team, and describes the theoretical basis for the COnCEPT platform's development. The paper also sets out the methodological approach that has been adopted by the researchers, which includes specialists from design, architecture, informatics, and interface design. The research will be evaluated with professional product designers and undergraduate design students. The potential use of a collaborative design platform and its implications for design pedagogy is also explored in the paper.

Keywords: Collaborative Product Design, Computer Semantics & Ontologies, Design Pedagogy

1 INTRODUCTION

There have been many attempts to model the design process and to understand the nature of creativity [1] [2] [3]) within professional design practice. The design process itself is often visualised as a form of flow diagram with iterative loops indicating stages where divergent thinking is followed by convergence on particularly promising ideas. The UK Design Council's well known 'double diamond model' provides an example of a simplified approach to idea generation for product development [4]. Most models don't describe the relationship between client and designer prior to initiation of a brief. The starting point of such design process models is often the identification and understanding of a problem or challenge that requires a design solution. The end point of these models is the implementation of a design solution. The following stages often feature in these design process models:

- Problem identification
- Ideation (divergent generation of ideas)

- Synthesis (convergence on solutions that satisfy the initial brief)
- Iteration (experimenting with multiple solutions)
- Prototyping (both virtual and physical)
- Selection and implementation

This paper describes an EC funded project (COnCEPT) which aims to develop tools specifically designed to support the early stages of this design process model which will include: the analysis of the initial brief; the generation of textual and visual information around the brief; idea generation; and the tracking of contributions made by the design team to projects through to completion.

A wealth of software already exists to support 3D design visualisation and modelling, including applications supporting both virtual and rapid prototyping. Commonly used examples include programs such as RHINO, AutoCAD, Alias, and 3D Studio Max. In addition, software exists to support project management within companies such as Microsoft Project, Basecamp and Merlin. Applications are also available that are designed to support mind mapping, concept mapping, and storyboarding. The COnCEPT project described in this paper aims to develop a holistic environment designed to support collaborating design groups by making use of advanced information retrieval and visual processing algorithms.

The variety of design process models to date is better fitted to design teams working as a collocated team belonging to a single organisation. There is a discernable trend towards open innovation processes that include multiple stakeholders consisting of small design teams collaborating with other stakeholders. In response to this, there is a need for the development of tools that support the work of distributed design teams, collaborating over distance and across organisational boundaries.

The paper considers collaborative design working, and the requirements of professional designers specifically within the product design domain. The authors describe the methodological approach of the project and the proposed solutions for supporting the creative process. The implication of the resulting software for an educational context is also discussed.

2 THE EARLY STAGE OF THE DESIGN PROCESS

Design briefs vary considerably from highly specific sets of specifications to very open non-specific outlines for new products [5]. Typically, the formulation of a brief is an iterative process that is low in structure and requires considerable effort on behalf of the designer and the commissioners of the brief to create a common ground. A design brief that is very open and non-specific puts a greater onus on the designer to add more detail. The degree of dialogue between designers and the commissioners of the design brief will vary considerably from project to project and is dependent on many factors including the degree of trust and experience between the stakeholders [6] [7]. In addition, participants within the design team will often be drawn from a range of professional design backgrounds, this being particularly true within architectural design processes, where the nature of design, even at the conceptual stage, will include the need to consider technical, social, aesthetic and economic drivers and constraints [8]. Since the brief itself must be a key starting point, tools that support a dialogue between client and designer may be a valuable resource.

A lot depends on the experience and skill of the designer at this stage, but given the high stakes of getting the design brief right, it is worth exploring how technology can support this process. For example, Malins and Liapis [9] developed an algorithm that would identify key words automatically and undertake a web search. However it was found that design teams preferred to interpret the document first to identify their own key terms. Starting points for the interpretation of the brief are always highly individualistic. Designers will bring their own experience to bear on the interpretation of the client's requirements.

A common starting point for many designers is to search for images that relate to key terms or analogies. From an initial search, visual images may be used to stimulate new ideas based on mood-boards or storyboards. These may serve to form associations and support the ideation process. Algorithms that search for similar, rather than identical, images can be very useful when stimulating associative thinking [10] [11]. This is a process that is not normally formalised as part of the design process. Sometimes it is referred to in terms of serendipity or chance, but in this case it is a way of generating and refining visual imagery based on searching either the designers own image repository, or the wider internet. Before the advent of large visual repositories, designers might have cut images from magazines, made sketches and mind-maps. Idea generation techniques such as mind-mapping [12] and brainstorming [13] are standard practice amongst designers. Stand alone software for mind-

mapping and mind-mapping tools are now much more common, for example, Inspiration, Mindjet, Mind42 and Mind Manager. Early design processes make heavy use of scenarios and sketching. Both are low cost representations of design concepts that leave a lot of room for designers to choose the level of detail they use for different aspects of their design, and are intended primarily as a communication tool and a basis for dialogue, rather than as a design specification.

3 SUPPORTING CREATIVITY

The difficulty with theories surrounding creativity is the lack of a clear definition of the term creativity [14]. What is perhaps easier to model is different forms of thinking, for example intuitive thinking, which can be stimulated by the random generation of images that allows new associations to be made based on existing memories. An alternative model uses more systematic methods to force the generation of ideas, such as the use of a morphological matrix [15] or makes use of case based examples such as TRIZ [16]. Applications exist to support both the use of randomised images and more systematic approaches. In recent years many different organisations have produced sets of cards designed for a similar purpose see for example Innovation Management's card decks[1]. In addition to searching for whole images, designers may have a requirement to search for elements within an image. These might relate to a particular shape, colour, composition or a more abstract characteristic of an image that suggests a particular emotion or quality. The COnCEPT platform will aim to provide sophisticated search tools that allow designers to find imagery based on the properties of the image, allowing them to make more use of abstract concepts for stimulating ideas.

4 COLLABORATIVE INTERDISCIPLINARY WORKING

A major challenge in distributed design teams working together, is the difficulty of exchanging information that is relevant to design, and actionable by a distributed design team [17] [18]. Communication over professional and organizational boundaries can be difficult, precisely because people are distributed over multiple locations, or because they might not be motivated to 'give away' their work [19], or simply because there is no easy way to share their work. Amongst design companies this accumulated design knowledge is a key asset that is not always optimally used. Design knowledge transcends reports or other forms of documentation, that represent formally documented and shared knowledge, onto 'folklore' and 'awareness knowledge' that is shared implicitly within a design team. This knowledge in a technology oriented innovating environment, may refer to specific technologies, their capabilities and performance, experiences from past design projects and local workarounds to problems, or simply awareness of the activities of co-workers. Design knowledge is very difficult to quantify and convey as it pertains to tacit knowledge, which is knowledge that is deeply rooted in action, commitment, and involvement in a specific context. Issues surrounding communication become critical when designers are not collated and the resulting problems may be costly in terms of time and money. For this reason technology is required to support capture, dissemination, and reuse of design knowledge across the design team. Similar issues have arisen with the design of software. For example, Terveen et al. [20] studied software development processes and examined the sharing of folklore knowledge that is usually not written down; rather, it is maintained and disseminated informally by experienced individuals. Nevertheless, their solution to support software developers was based on recording and providing written textual advice. Currently, such practices are easily supported through widely available groupware and collaborative editing tools, such as Wikis or social media.

While the flexibility and fluidity of the capture and display of such information may make it more viable than the formal documentations, text representations are not ideal for supporting the capture and reuse of design knowledge.

Creating and sharing design knowledge across distributed design teams needs to tap into media more appropriate for design knowledge but also to foster and build upon the social interactions between designers and stakeholders. Nonaka's Dynamic Theory of Organization Knowledge Creation [21] identifies two dimensions which characterize this process: one is the distinction between tacit and explicit knowledge and the other concerns the degree to which knowledge is created individually or by

[1] https://innovationmanagement.se/2012/11/12/21-card-decks-for-creative-problem-solving-effective-communication-strategic-foresight/

a community of interaction. He then identifies four modes of knowledge creation that should be supported. (a) Socialisation: tacit knowledge can be shared between individuals without being formally documented. Technology can help by mediating, facilitating and expanding these interactions. (b) Combination: explicit knowledge sources can be aggregated, reorganized, or modified, to create new insights which is something that media can support (c) Externalization: tacit knowledge is made explicit, through attempts to communicate it and codify it (d) Internalization: an explicit form of knowledge is practiced and becomes automated.

An organization can enhance its knowledge by encouraging individuals to experience and practice, to interact, and especially to share knowledge, making what is an individual's own knowledge shared, and allowing it to be enhanced through the four mechanisms identified above. Support for design teams needs to address not only appropriate design representations, but to consider their capture and use in the context of knowledge sharing and the social interaction surrounding distributed design teams, and the complications arising from working across organizational boundaries.

Collaborative working may refer to an individual developing a design that is then presented to colleagues who may be asked to contribute in some way, for example, to provide feedback. An alternative form of collaborative working involves the development of a single design by a number of individuals working synchronously or asynchronously or sometimes referred to as distributed collaborative working. The COnCEPT project is aimed at supporting either of these scenarios. Providing support to a group of individuals working on a single design from different locations presents considerable challenges. An environment that can keep track of multiple contributions, whilst providing related information, is seen as a valuable addition to the designer's toolkit. The research that is being undertaken by the COnCEPT project is looking closely at the nature and types of collaboration, which are commonly seen within design consultancies, to ensure that the tools that are developed, are appropriate for the product design domain.

The COnCEPT platform has been conceived as a set of tools aimed at supporting product designers, however that also implies a considerable amount of interdisciplinary working. The COnCEPT project itself provides an example of interdisciplinary development. It involves the close collaboration of expertise drawn from Design, Architecture and Informatics. The designers on the COnCEPT project are concerned with gaining an understanding of the end-users' requirements and translating these into a set of specifications which can be developed into software solutions with intuitive interfaces. This requires bridging barriers caused by contrasting research paradigms.

5 SEMANTICALLY DRIVEN SYSTEMS

The initial stage of the design process relies extensively on knowledge-exploration. Many studies have demonstrated that designers make intensive use of analogies, adapting design solutions from other fields to find new design solutions [22]. Moreover, it was shown that often the most creative analogies are those that are made between unrelated knowledge domains [23] [24]. Often the problem or desired product is not presented to designers with a detailed specification, rather, it results from uncertain real-world situations that are ill-defined. The formalization of problems requires that alternative viewpoints of context be taken into account. To achieve appropriate solutions, good communication mechanisms between designer and client are critical, making use of the client's knowledge and experience. As the designer proceeds from the problem analysis stage to the development of concepts, the knowledge search-space becomes narrower, more structured and domain specific.

The critical information being sought by the designer may be embedded in part of a document, image, sketch or even a piece of music. One way of searching for this critical data is by making use of the meta-data attached to these resources. Meta-data can be in the form of key words or tags. In addition the visual properties of an image can also be used to specify search criteria. Availability of access to large repositories of information is an essential resource for a design team. The type of information that designers may draw on to support their creative process might potentially include visual resources, including stylistic information, using for example, colour, shape, behaviours and other properties discussed previously. The quality of the meta-data attached to information, directly affects the relevance of any particular search that is undertaken.

Existing web search engines and databases are very effective at providing simple ranked lists of results. In the context of a creative task however, the information needed may be only partially specified, which creates an additional challenge for the design of search patterns. As the creative search is a very subjective and personal process, tools that allow customisable searching are required.

The COnCEPT project will employ semantic technology to describe resources that will allow the user to align their search requirements corresponding to formal conceptual models or ontologies. The methods are based on semantic annotation using ontologies that are recognised as powerful tools that can assist with the processing of information resources. The system will allow for the development of a more "intelligent" or more machine interoperable, effective and meaningful way of searching for information [25]. Annotations with well-defined semantics are a requirement to ensure the interoperability of information that is consumed, and for sharing meanings in the collaboration design community. Describing explicitly the relationship amongst multimedia resources, visual content and other support material is supported by recent advances in Open Linked Data technology [26]. The digital content from companies' internal repositories can be linked to each other and to other useful knowledge databases and cross-application domains. However semantic annotation presents several challenges that will be tackled by the research undertaken for the COnCEPT project, such as usability and the maintenance of conceptual models.

The usability aspect is related to human involvement in the generation of semantic meta-data. It is unrealistic to expect designers to spend a lot of their time annotating resources, however this could be made easier if they could make use of a natural intuitive interface. If the Concept platform is to be useful, it should provide where possible a degree of automation in the process of knowledge, whilst reducing the need to annotate material in use.

The knowledge management framework envisaged for the Concept platform will not be able to address all the designer's needs across all application domains. The knowledge management framework will remain domain specific. However, it will be possible to extend the COnCEPT platform to other knowledge domains over time.

6 IMPLICATIONS FOR DESIGN PEDAGOGY

Professional product design is increasingly a collaborative interdisciplinary activity. Providing a learning environment that accurately simulates the professional context whilst allowing for individual development and assessment of progress, can lead to disconnect between the needs of the academic environment and that of professional practice. The COnCEPT platform may be used to provide an environment to support collaborative learning that can be used to overcome some of these tensions by making it possible to track individual contributions to student projects. A common problem for students working within a computer environment is the tendency to overwrite designs thus making it difficult to track the student's development and to provide appropriate feedback. The system simulates a professional product design context and makes it easier to re-use solutions from other domains.

7 CONCLUSION

The COnCEPT project will provide a powerful set of tools to support the early stages of the product design process. The project's emphasis on user-centred design means that the resulting interfaces will be intuitive and take into account working practices within the professional product design domain. Unlike conventional search engines or project management software, the COnCEPT platform aims to support the creative process by generating relevant information either in the form of text based documents or visual resources. In addition the platform is being designed to support collaborative distributed working across interdisciplinary teams. By designing tools for a specific design domain it is anticipated that targeted solutions may be developed where these will have wider implications for professional design practice, teaching and learning.

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