Supporting The Initial Stages of The Product Design Process: Towards Knowledge Awareness And Inspiration

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Abstract

The creation of new products and services is an everyday activity for many industries, often assisted by professional design studios. It is evident that extensive knowledge is required by designers during the conceptual product design process, matching the complexity of design problems. Techniques based on association, analogy and metaphors are often used to facilitate the process of creative thinking and inspiration leading to new product designs. This paper presents a novel semantic tool, which has been developed to seamlessly assist product designers with knowledge management tasks during information discovery and support the formulation of new product concepts. The technology can be used in combination with a sketching application to support the generation of relevant visual content, helping to stimulate associative thinking, and thus assist creativity at the initial stage of the product design process.

Keywords: Conceptual Product Design, User Experience, Awareness, Semantic Technologies.

1. INTRODUCTION

The exponential increase in the volume of visual material available via the web is now accepted as the norm. Much of this upsurge results from the opening up of visual repositories and the rapid growth of social media. This is potentially an extremely valuable resource for the design profession to draw upon for inspiration and knowledge. However, the sheer quantity presents new difficulties in finding particular images. Designers have gone from *looking for a needle in a packet of needles* to *searching for a needle in a haystack*. The design profession relies on the use of visual resources to communicate, collaborate and inspire new ideas. The research reported in this paper describes the development of tools to help designers make better use of design resources. The initial stage of the product design process typically begins with the initiation of a design brief. A design brief may be a vague statement provided by the client, or it may be a more detailed design specification. It commonly provides basic information about the challenges the new concept should address. The early, conceptual stage of the process is dominated by the generation of ideas, and the term 'ideation phase' is used to denote this process. The ideas are subsequently evaluated against criteria set out in the design brief, and agreed with the client. The design process can proceed in many different ways, as illustrated in Figure 1 [1]. When developing new concepts, existing solutions and ideas that are already in the market are considered. It is therefore critical for any product development team to be aware of past solutions, market data, and emerging technologies, in order to avoid duplication of effort and to stimulate creative thinking.

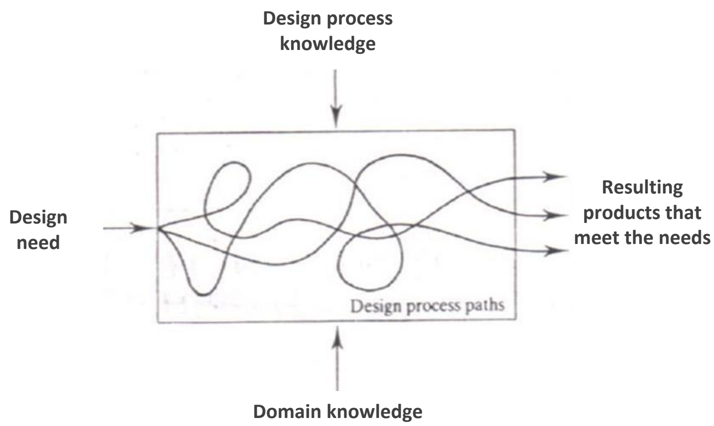


FIGURE 1: Knowledge used in the design process [1].

Creativity is a quality that is highly valued, but not always well understood in the field of design [2]. Bringing together previously existing concepts in new and unexpected ways can be original and considered creative. Thus, creativity is the ability to see connections and relationships where others have not. That creative thinking is based on knowledge of previous work in a given field is the rationale for exploring the aspects and foundations of the area as a resource for future research and creative work [3].

Images are a powerful resource to inspire and convey meanings, in particular emotional values, characteristics and experiences. Selected visuals can serve as an important tool to communicate values not easily expressed in words and can convey ideas in an accessible way. Images offer a vehicle by which designers and clients can shared a language, therefore assisting the development process. Images collated in a 'moodboard' convey specific visual qualities and emotions [4, 5]. The undertaking of such research is an essential yet time consuming component of the design process.

Due to the interdisciplinary nature of the design process, a semantic gap exists in the use of terms and concepts. Designers and clients have to generate and exchange ideas. A variety of tools can be used during this process, which results in the generation of an enormous amount of interrelated heterogeneous data, all of which adds to the challenge of storing and retrieving design content.

During this research phase, it is typical for designers to search for and save a vast quantity of visual data. There are few applications focusing on the conceptual phase [6] catering specifically to the needs of the creative industries, however research suggests that a range of online platforms such as Google Images and Pinterest, are used during this visual research work [7]. Nevertheless, each available system has shortcomings, and no currently available platform answers to the intricacies of this type of work. Images returned by Google is considered predictable and repetitive. Visual repositories like Pinterest return a greater breadth and specialism of visual data, however finding the 'right' content here is problematic since tags are input subjectively by the uploader.

When selected, designers save visual and any other content to their repository of choice, either local or remote. Tagging each image or document individually, then saving it to the repository is the logical approach to an information scientist, however when designers are dealing with tens, hundreds, even thousands of jpegs, and when working to strict client-imposed deadlines, this is unrealistic. The detailed process of tagging individual files is a hindrance to the free-flowing nature of the design process. There are other problems associated with this approach [7]. First, it is often difficult to find and re-find saved particular design content amongst many files. Second, viewing images together is important for the purpose of creating moodboards, yet for most existing applications render the viewing and a selection of images at once problematic. Third, files may be reused and referred to on many occasions subsequent to the completion of the original piece of work for other projects.

It is suggested that the initial conceptual stage of the design process is the most knowledge-exploration intensive phase, however current design tools offer limited connection to knowledge management software. Product designers may not necessarily have a ‘technical’ background or in-depth experience of knowledge management systems, and as a result, the usability aspects of knowledge management functions are an important consideration in the design of specialised supporting software tools. The acceptance of a proposed solution is crucial. Ease of use, usefulness and ease of adoption have been found to be important elements of user satisfaction and acceptance [8, 9, 10]. Designers as a group are often early-adopters of new technologies, however usability aspects of software are of utmost importance. This paper presents a new semantic knowledge management toolset that facilitates the early stages of various products design, and which addresses the needs of professional designers. The toolset is web-based and can be easily customised to work with other web-based product design or knowledge management systems.

In section two, the various tools that are required to support designers with knowledge management tasks are discussed. The methods of human computer interaction (HCI) and design thinking were applied to learn how knowledge activities are incorporated into the design process. Section three presents a new conceptual prototype, which was interactively developed with assistance and in collaboration with domain experts. The identified needs and feedback from designers and usability researchers was used as a basis for the development and refinement of the architecture, and the deployment technology, for the proposed solutions. The details of the technical implementation are discussed in section four. The prototype tools were evaluated by professional designers and usability experts. The evaluation results are reported in section five. Conclusions about lessons learned and future research are presented in section six.

2. HUMAN TECHNOLOGY INTERACTION - NEEDS

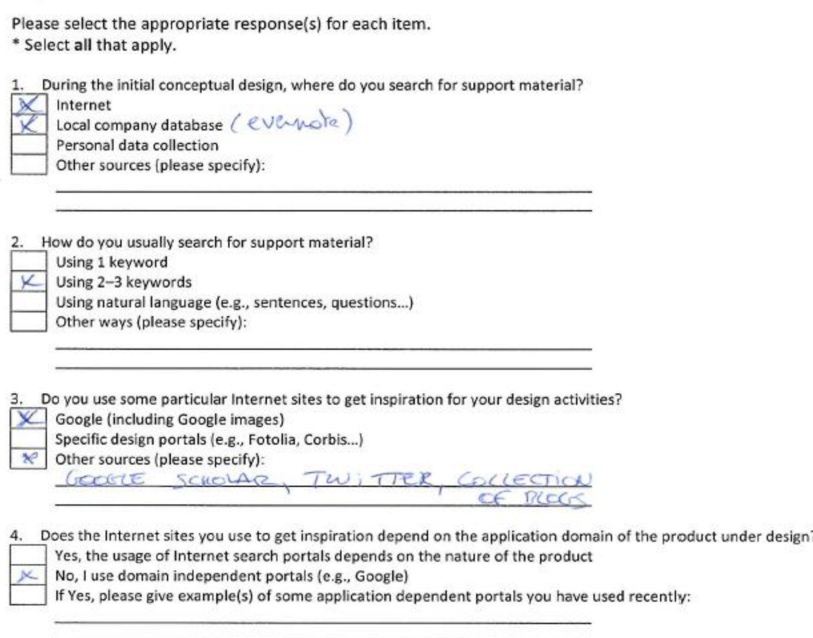
The requirements for the supportive knowledge management technology detailed in this paper have been acquired through a multi-faceted iterative approach, including a literature review focusing on what is needed to support knowledge exploitation processes and creativity across a design team [11, 12], as well as interview based research with professional product designers at internationally recognised consultancies (DesignLab, Athens, and Studio Levien, London).

A crucial element of this process is the analysis of design teams in action. Generally, the initiation of a new project can start in different ways. The design studios may get design briefs from the client, but it is also often the case that they generate their own project. In the former, the brief may detail: a description of the product to be designed; a profile of the target end user; a description of the context of use; the currently available technologies and competitive products already on the market; market positioning for the new product; target cost; functional and aesthetic features; design requirements, etc. The process of conceptual design iterates back and forth before the concept for the new product is crystalized. If, for example, the requirements for a project are not extensively specified, the design team may start their own online research for new concepts, specific information and inspiration. Alternatively, in the case where a brief is specific and detailed, and discussed with the client, designers analyse the information, enriching it by performing additional online searches and making use of any existing company databases and other sources of data. Relevant data, such as images, drawings, notes, specifications, reviews, and websites are collected and saved to a design project space on the studio hard drive. As noted previously, the collected information is usually numerous, heavy in storage, and can be difficult to retrieve from the hard drive.

Designers may also create digital or physical sketches, which can be photographed and uploaded to the project space. In the next step, a moodboard can be created by adding images, videos and other material, to which annotations in the form of notes and keywords are added before storing it to the project space. The moodboard contributes to the creation of a shared vocabulary for the project. In addition, a set of personas for the product can be created. For this task, a short description of the end-user's profile is created and used to search on Google for images to illustrate these personas. Designers also research similar products online. The competitive products are categorized and rated according to their functionality and usability.

As described, the research undertaken by design companies illustrates that storing and logging vast amounts of creative stimulus material is a demanding task in terms of the resources needed for finding, sharing and accessing the right material. Furthermore, it is paramount to ensure that access to the 'material' is centralised, and remains as simple and clear as possible. The new software is intended as a tool to enhance the creative process and should therefore not distract from the user's flow of creative ideas. After the interview-based research with professional designers, several '*timeline'* mock-ups were developed with the aim of interlocking parts of the support functionality.

As well as analysing use case descriptions and scenarios, designers were asked to complete a questionnaire with the purpose of gaining understanding of how professional designers approach the management of design content. Questions and answers guided the design and prototyping of possible solutions. Designers were asked to provide insights into: how they typically search for the content used as a basis for conceptualizing the new product (e.g. using keywords, natural language, searching for images), what sources of information they use to generate new ideas, and the nature of the content to get the inspiration for their design activities. Figure 2 shows an example of one such completed questionnaire.


Please select the appropriate response(s) for each item.
* Select **all** that apply.

1. During the initial conceptual design, where do you search for support material?
   - [x] Internet
   - [x] Local company database (evernote)
   - [ ] Personal data collection
   - [ ] Other sources (please specify):

2. How do you usually search for support material?
   - [ ] Using 1 keyword
   - [x] Using 2–3 keywords
   - [ ] Using natural language (e.g., sentences, questions...)
   - [ ] Other ways (please specify):

3. Do you use some particular Internet sites to get inspiration for your design activities?
   - [x] Google (including Google images)
   - [ ] Specific design portals (e.g., Fotolia, Corbis...)
   - [x] Other sources (please specify): GOOGLE SCHOLAR, TWITTER, COLLECTION OF BLOGS

4. Does the Internet sites you use to get inspiration depend on the application domain of the product under design?
   - [ ] Yes, the usage of Internet search portals depends on the nature of the product
   - [x] No, I use domain independent portals (e.g., Google)
   - [ ] If Yes, please give example(s) of some application dependent portals you have used recently:

FIGURE 2: A questionnaire completed by a participant.

A detailed analysis of the questionnaire revealed that designers rely on resources available from the consultancy and the client's own database, such as documents or sketches produced in the course of previous projects, as well as a range of external information sources such as electronic books, images, music, online design magazines and image collections (e.g. Getty, Flickr, Co.Design, Yatzer, Designboom, Design Observer and Pinterest). In addition, general purpose search engines such as Google were mentioned as a daily source of information, regardless of the type of project. Ideally the knowledge management tools should be able to cope with various content locations and contexts in a seamless and unobtrusive way. From a content management point of view, the understanding of vocabularies used by team members from other disciplines is the technical limitation which is most experienced by the design team members [13].

The requirements resulting from the analysis of the questionnaire results and interviews are summarised in Table 1.

Category	**Designer needs**	**Derived technical requirements**
Content search	Effective search of company's local databases e.g. documents and sketches produced in the course of previous designs	Availability of semantically rich content metadata Capacity to effortlessly add annotations in various types of content
	Provides convenient ways for content searching simultaneously from multiple data sources. Ability to examine results of different searches in a single view	Capacity to interlink existing and new uploading material
	Provision of the suggestion of relevant material	Identifying relevant contents automatically, establishing connections
Content presentation	Dynamic content organization, filtering	Support for dynamic indexing of content, learning ontologies, crowdsourcing
Common vocabularies	Common content metadata model	Availability of design world vocabularies/knowledge model
Knowledge model management	"No management" i.e. seamless support for managing design taxonomies and vocabularies	Facilitates the understanding of design vocabularies and taxonomies. Enables the creation of new taxonomies and edit existing ones
Creativity support	Knowledge awareness as part of working processes i.e. linking of content recommendation to existing work processes and tools such as e.g. sketching, design briefing	Knowledge Extraction technology
Usability, UX	Simplicity and clarity enabled by UI, as intuitive as possible Support for automatic content metadata provision	Automatic knowledge extraction, seamless semi-automatic content annotation interface, intuitiveness

TABLE 1: Requirements to knowledge management toolset.

The content management toolset was designed to take into account the findings and requirements as described. The next section explains the philosophy and conceptual prototypes of the solution in more detail.

3. KNOWLEDGE AWARENESS – CONCEPT PROTOTYPE

In principal, the designer is always informed about related and relevant material to that may already be stored in the designer's local repository. For example, taking the design brief, uploaded to the system as input, the design-brief analysis application is able to search and suggest content related to previously created content in other design projects, or available on the Internet. To illustrate this, Figure 3 shows the ability of the tool to find, represent and link various contents related to a project for a 'smart running jacket' from local project databases, as well as utilizing Google Search, Flickr and online collections maintained by the Victoria and Albert museum. In the next step, the designer may carefully review the suggested images and store them (along with the generated semantic metadata) in the system for future use.

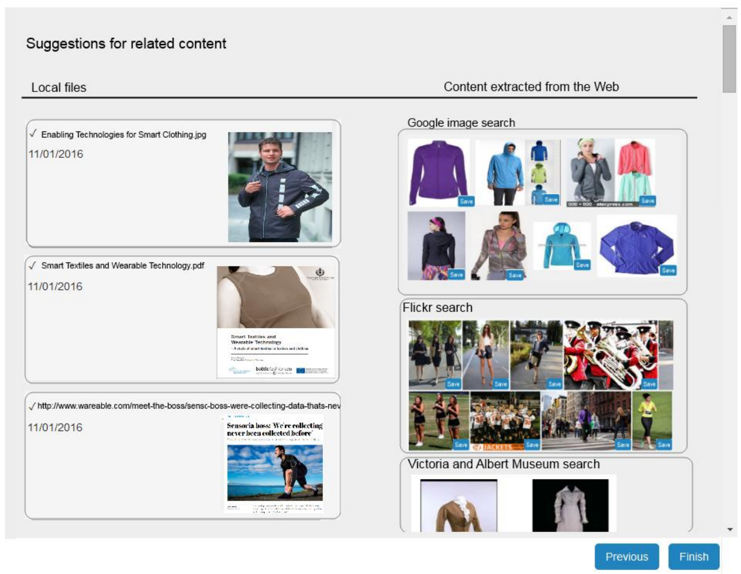


FIGURE 3: Relevant content suggested based on the information extracted from brief.

Sketching is an essential tool for many designers. Sketching is a means by which to explore concepts and to communicate ideas. Sketches can be low fidelity, such as pencil drawings, or more technically advanced, such as isometric computer aided designs. Sketching may overlap with the rapid creation of low fidelity prototyping, such as 3D models. Promising ideas can be scanned or photographed, and uploaded to the project repository.

There is experimental evidence to suggest that the interpretation of previous sketches can be used as a source for modifications in the design space, thus leading the project in new directions [14]. Many studies of creativity in design connect 'unexpected discoveries' with sketching [15]. To support and experiment with this research, interactive sketching application has been developed that supports the generation of new ideas and concepts. Designers may start by sketching concepts using familiar digital sketching tools, or with pencil and paper. As soon as the sketch is uploaded into the active window (see Figure 4 – on the left side), the system starts to work by searching for relevant data in the form of other sketches and images based on the semantic similarity to the original sketch. The search results and associated images update according to the actions taken by the designer. The designer may for example make modifications to the original sketch, edit automatically generated semantic metadata, and upload other sketches from previous projects.

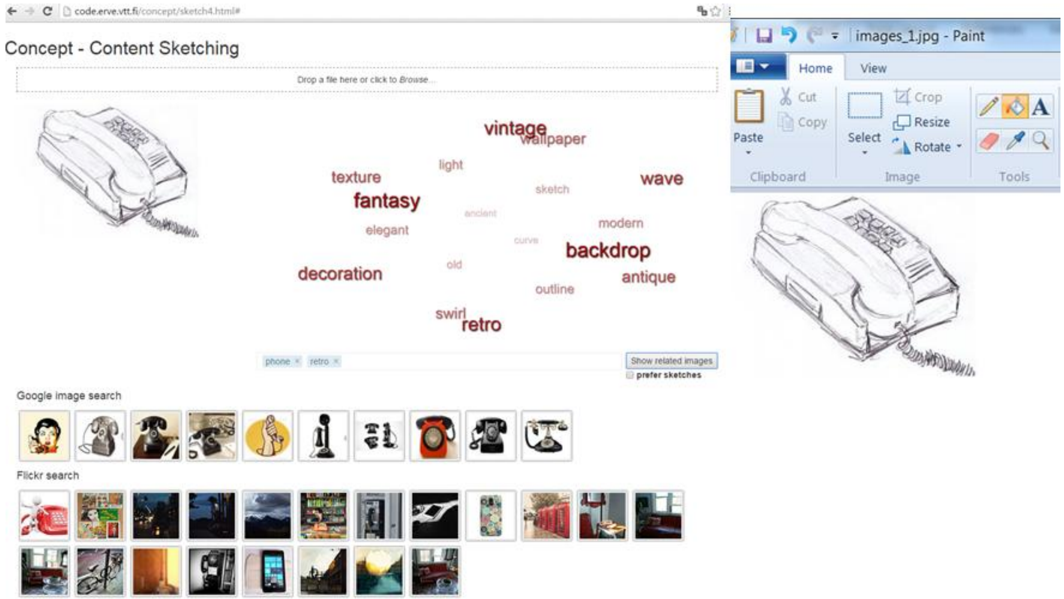


FIGURE 4: Interactive sketching application.

The next section explains the architecture and implementation of the semantic tool in more detail.

4. TECHNICAL IMPLEMENTATION

Semantic annotation, search and recommendation services, as well as the set of knowledge modelling tools and knowledge extraction technology, constitute the intelligence of the proposed knowledge management environment (see Figure 5).

The availability of rich content metadata is necessary to achieve effective personalised and dynamic content management. Semantic technologies and tools have undergone significant development in recent years. Methods for knowledge exploration based on semantic annotation using ontologies are recognised as a powerful approach, which can make the processing of information resources more 'intelligent' – i.e. machine interoperable, effective and meaningful [16, 17, 18]. Ontologies can provide elegant mechanisms to organise content in logically contained groups while linking them with other related concepts. The recently introduced Open Linked Data technology [19, 20, 21] has the potential to facilitate the interlinking of unconnected documents images from various data sources to generate large interlinked data ecosystems. The main components of the proposed support environment are explained in more detail in the following sections.

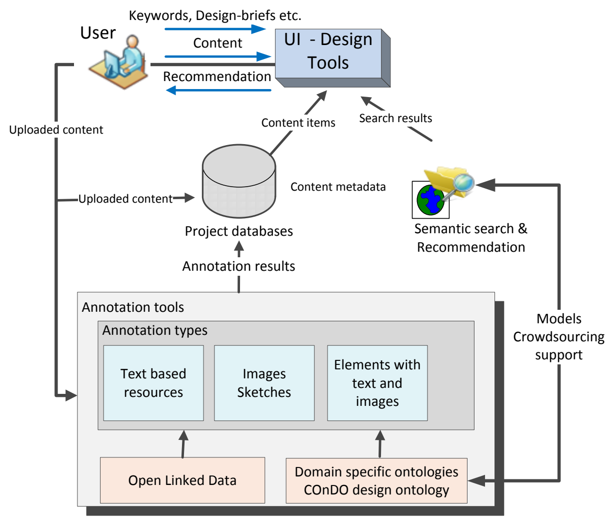


FIGURE 5: Content management architecture.

4.1 Content Annotation

The annotation of text and visual resources is performed semi-automatically. This means that the system automatically generates suggested metadata, but the user has the ability to edit it (i.e. to control the technology). The process flow of content annotation in the example of provision metadata for the textual resources is illustrated in the sequence diagram presented in Figure 6.

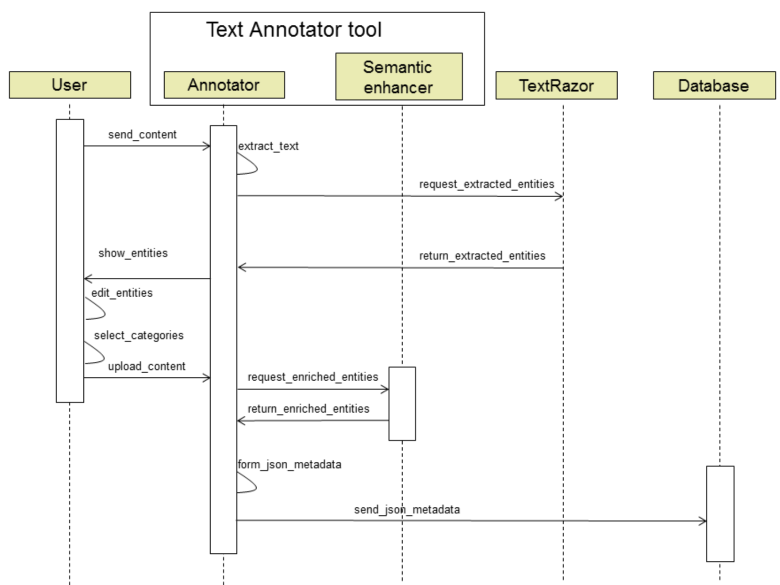


FIGURE 6: Sequence diagram of text annotation process.

The annotation process begins by indicating the content to be annotated. The content is sent to a Text Annotator sub-component that utilizes Boilerpipe [22] API for extracting textual content from web pages, Apache PDFBox [23] for parsing text contents from PDF documents, and Apache POI [24] for parsing text contents from Microsoft Office documents.

In the subsequent phase, the Text Annotator component sends the extracted text to the TextRazor tool [25], which supports identifying named entities from texts. After analysing the text, TextRazor returns the extracted entities (i.e. keywords or tags) to the Text Annotator component, which is shown to the designer using the system. The designer is able to edit the list. In addition, the domain-specific concepts are presented and can be selected by the user (the domain specific design ontology is discussed in section 4.2). The annotation of visual material is, in many ways, similar to the annotation of text-based resources. The image recognition and tagging open software [26] is leveraged to facilitate the extraction of high-level semantic features from images and sketches.

Once the designer has approved the content annotation data, the content can be uploaded to the system. Subsequently, the Text Annotator component sends the tags to the Semantic Enhancer sub-component that enriches the extracted entities by utilizing Open Linked Data knowledge bases. The enrichment process aims to facilitate machine-readable comprehension, and to improve the findability of the content items. The Semantic enhancer component uses the APIs provided by DBpedia [27] and ONKI [28] services. DBpedia extracts structured information from Wikipedia and makes this information available on the Web. Furthermore, the ONKI service contains Finnish and international ontologies, vocabularies and thesauri.

The Text Annotator tool utilizes the APIs of the above-mentioned services in order to search terms that are somehow associated to the entities extracted by TextRazor and Imagga. A weighting (number from 0 to 1) is assigned to the enriched metadata concept based on the semantic relationship (i.e. measured semantic similarity [29]) between the original extracted entity and the concepts in DBpedia and ONKI ontologies. Besides the highest weighting (number 1) is assigned to keywords provide by user, if available. In the final phase of the annotation process the Text Annotator component forms a JavaScript Object Notation (JSON) description that defines the created metadata, which is used for the content search and recommendation.

4.2 Domain Specific Concepts

The domain-specific product ontology - Concept Design Ontology (COnDO) has been developed to facilitate the designer's creative abilities whilst managing content metadata and supporting the dynamic personalised indexing and search of design content looking for associations and analogies. It is a mean of compensating for the quality and general nature of DBpedia datasets, which are used by the semantic annotation tool previously discussed.

The design ontology is represented as an extendable set of core classes: at the centre of the top level nodes of the ontology are *Product*, *Person*, and *Content,* as well as *DesignProject* and *DesignTeam* classes (see Figure 7). The semantic network of five classes interconnected with a set of object properties is defined to represent both personal and collaborative aspects of the designers' work, connecting the user as both designer and end user, product under design, and the related design content associated with the product. The class content represents the associated resources (documents, sketches, images, videos, etc.) used or created to facilitate the conceptualization of the product.

The model of product class in the COnDO ontology is based on the Offenbach theory of product language [30] and is defined to attain a common vision through the set of ontological concepts, allowing the product to be described from different points of view, such as the domain of the product being designed (e.g. web, fashion, kitchen-ware or consumer electronics), deployment technology, ergonomic, economic, and ecological properties, and emotional response and associations created while interacting with product (e.g. historical aspects, style, cold, warm, aggressive). The design ontology is released as open source software and can be downloaded from the GitHub repository[1] for further investigation and reuse.

[1] https://github.com/OntoRep/COnCEPT

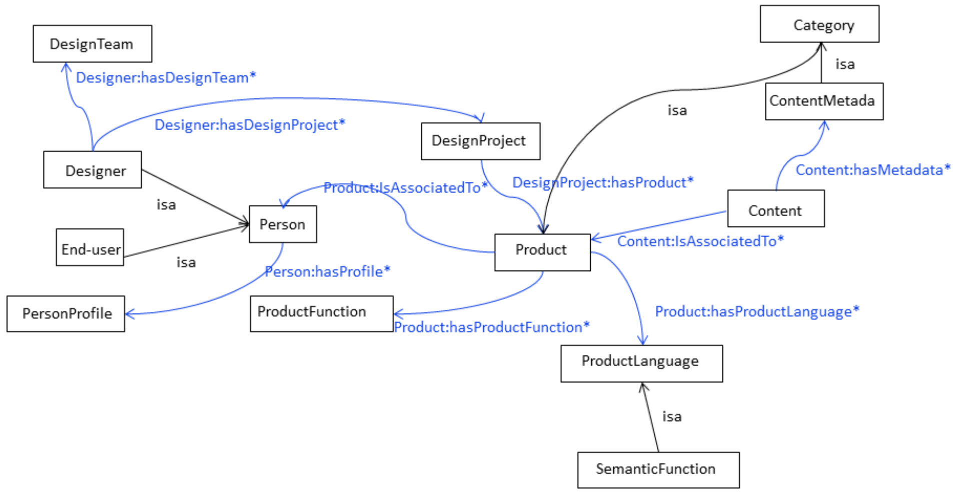


FIGURE 7: The top-level classes of design ontology.

The reuse of the pre-defined domain specific ontology is often restricted by its static nature. Thus, functions are provided to enable the designer to customise i.e. add, rename or remove ontological concepts as a part of the annotation process.

In addition, several mechanisms have been developed to ensure the customisability and usability of the proposed COnDO design ontology to better serve the needs of different designers, such as relevant ontological concepts being suggested (highlighted) to designer when the content is uploaded (as visualised in Figure 8).

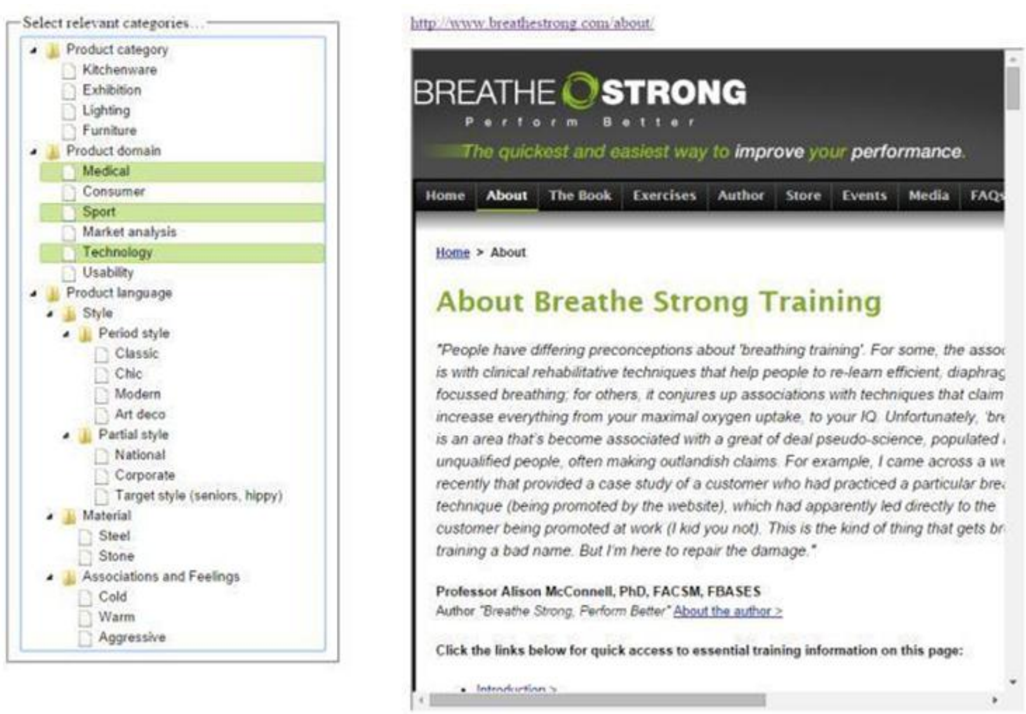


FIGURE 8: Working with content and design ontology: three concepts are suggested to include into the metadata as most relevant to the content of web page.

The ontology management component analyses received content and attempts to deduce whether it fits certain categories defined by the COnDO ontology. If matching categories are discovered, a list of relevant categories is returned to the Annotator component. This process is facilitated by DBpedia Lookup service. The method is based on the calculation of the semantic similarity of the semantically enriched concept in the ontology, with keywords being extracted from the design content during the content upload process

4.3 Search and Recommendation

The objective of the search functionality is to provide more relevant results to the designer based on the current project. The semantic search service utilizes the Apache ElasticSearch [31, 32] component to manage content metadata and to implement search functions. Semantically enriched metadata, as well as content items, are stored to MongoDB that is part of the ElasticSearch toolkit. The Apache Lucine engine is used to accomplish the search functions over JSON metadata in local database. In the indexing process, every field of JSON metadata is indexed and semantic weightings of metadata are also taken into account.

The recommendations of relevant content is performed by comparing enriched keywords provided the by designers, or derived from the analysis of documents and images with semantic metadata describing the uploaded content. The utilized matching method also considers the weighted values that indicate the relevancy of the metadata. Relevant content is recommended for the user based on the comparison analysis between enriched entities data and uploaded content metadata using classical Information Retrieval vector-space model [33].

In the case of searching web-based resources, the semantically enriched keywords provided by the designer or extracted from material used in the design (e.g. the brief or sketch) are passed to the search engines leveraging various open APIs (e.g. Google, Flickr, V&A museum, etc.). The results from both searches (local- and web-based repositories) are presented to the designer. The presented content can be further filtered and organised by the designer according to the concepts of the design ontology.

5. EVALUATION RESULTS

The semantic tool aims at supporting product designers in managing vast repositories of content in the course of design conceptualization work. Considering the demanding nature of the user group, we believe that usability and the perceived usefulness are the most important characteristics to be assessed in the early prototype version. These criteria can be further interpreted in more practical, measurable attributes, such as efficiency; how effectively the user can complete the tasks; emotional response; system feedback or how well the user is informed about what is going on; and consistency across the entire application including dialog logic and other similar applications existing in this domain.

Several methods have been established to evaluate software system usability. They can be classified into empirical methods, including collecting user data, and analytical methods, which use other means to collect usability related measurements. Empirical methods always involve end user representatives working on typical tasks using the system or prototype being tested [8]. Analytical methods are usually validated by empirical methods. The ‘perceived usefulness’ and ‘perceived ease of use’ metrics are related to usability, and are the one of the main drivers for acceptance of technology by the user [9]. Perceived usefulness as a scale is measured using the following criteria: working more quickly, job performance, increased productivity, effectiveness, and making the task easier.

The testing group containing 12[2] participants was constructed as a mix of end-users with diverse expertise in the areas of product design, UI/UX experts and business.

[2] https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

The evaluation was supported by constructing an evaluation scenario related to the conceptualization of a new 'smart sport jacket'. Each participant was asked to perform various tasks, such as working with the design brief and other material, sketching and testing the design ontology, while inspecting the suggested content metadata. Moreover, test-users were encouraged to experiment with the tool using their own material (documents, images, web-pages, etc.). Furthermore, qualitative feedback related to performance issues experienced, desired functionalities and preferences regarding the maintenance of knowledge models (crowdsourcing vs. original ontologies) was queried and recorded. The assessment questions were built around three fundamental issues contributing to the usability and user experience: fluency and ease of use, experience and 'liking', and the position of technology in human action. The quantitative assessment questions and the obtained results are presented in Table 2 and Figure 9 respectively.

Q.	Feedback (5 rating levels, from excellent to poor, 5-1)
1	How easy it was to learn how to use the toolset?
2	Did you find the automatically suggested (metadata) keywords appropriate?
3	The "select category" functionality provides the ability to supply own content metadata. Did you find this functionality useful?
4	Did you find the structure of category tree logical. What would you change?
5	How useful did you find the content recommendation? Did you find design-brief and sketching apps functionality interesting, inspiring?
6	Do you think that such toolset would improve the management of your content? If, so, how much?
7	Would you like to have such toolset as part of your design environment suite?
8	How would you rate your overall experience with the toolset?

TABLE 2: Assessment questions.

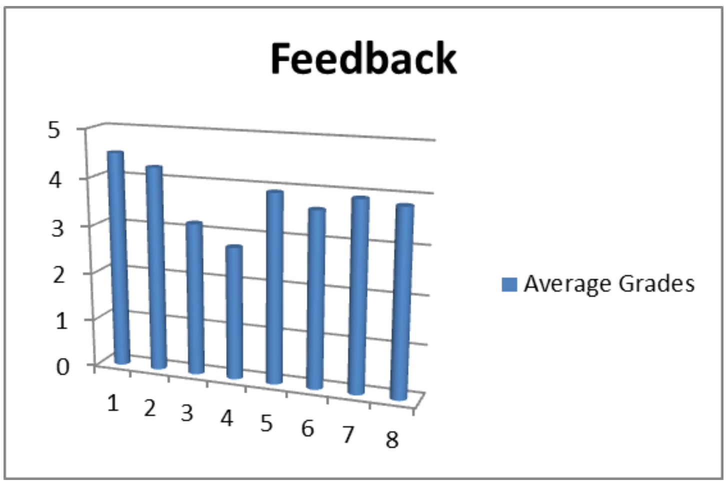


FIGURE 9: Evaluation results.

The quantitative evaluation results were positive. In particular, questions 1 and 2 scored an average grade of 4 or higher. Questions 5, 7 and 8 also received high average grades. This indicates that the respondents perceived the functionality of the tool as easy to learn, useful and inspiring. Moreover, most of the respondents indicated that they would like to have tools as part of their design environment suite.

Further analysis of the answers reveals that questions 3 and 4 received an average grade below than 3.5. This indicates that while the ontological design concepts were found to be useful, the provided category view was not seen as entirely logical for everyone. Some participants suggested simplifying the initial version of the design ontology to a basic structure as a start point.

This didn't surprise us. In fact, the analysis of the answers provided for the qualitative questions indicates that, in general, respondents prefer crowdsourcing and adding their own categories rather than using a default set of ontological categories.

The respondents also proposed some additional features that could improve the usefulness of the toolset. For example, the approach should better indicate how documents are related to each other and enable adding free-text comments and notes to content items. In addition, graphical views that summarize the available information contained by the content repository would enhance the user experience. Finally, more explicit links to information resources such as university libraries and e-book or article/magazine databases were requested, especially by respondents' professional designers.

6. CONCLUSION

This paper has provided a detailed technical description of a new semantic toolset which aims to support designers with the management of various heterogeneous content created while working on the conceptualization of new products. The software uses an advanced semantic and visual search engine to create a unique, intuitive software application which automatically generates content based on text or visual imagery.

It was demonstrated that knowledge extraction tools have the potential to support designers in knowledge exploration tasks. The advances of web based multimedia repositories and access tools, combined with recent developments in information extraction technology used to, for example, analyse design briefs or the result of brainstorming sessions, can bring real benefit to product designers by providing the means to bring associations stimulating creativity, or to facilitate the development of various mood boards, as well as to ease the access, filtering, selection, interconnection and presentation of project related information.

Considering that the target user group requires a seamless, intuitive and easy to use technology, the challenge for the developers is to create a "knowledge management interface" that can be integrated into a set of design tools, and which is automated as much as possible while keeping the technology "in control". The user may add or delete metadata or select one image over another, and the software is able to use this information to prioritise searches and present new information to the user as efficiently as possible. The focus is on the content generated rather than the 'interface' in its traditional meaning. As far as the end user is concerned, the system is performing magic by presenting new content based on the initial design brief or sketches. As the designer interacts with the software, it should become 'smarter', returning more relevant content as it learns the user's preferences.

The system must also allow for a different way to manage search results. Search algorithms are conventionally judged on how accurately they return information. However, accuracy is not necessarily the right criteria to apply. In this case, the software may be looking for associations and analogies. To some extent, the user may only know what they are looking for when they have found it. The user is relying on making connections to trigger ideas. This might be seen as a different type of uncertainty principle, in which the more certain a result is, the less lightly it is to stimulate new ideas. In contrast, the more uncertain the result the more possibilities there may be to make new connections.

Based on the evaluation results, it can be concluded that the toolset was positively perceived by the assessment participants taking part in the evaluation of the software. The evaluation provided a good opportunity for designers to participate and contribute to the development process. Further research work will concentrate on considering some of the deficiencies highlighted during the assessment. Future studies will carefully consider how to best exploit the full potential of the COnDO design ontology, including leveraging it for more efficient content grouping and presentation. A crowdsourcing approach was perceived positively by designers. This supports a starting point for further study of the importance of semi-automatic approaches to be supported by technology. Conceptual design of the product and the methods of organizing knowledge are extremely personal since the creation of products is strongly dependent on the creators and their criteria in decision-making.

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