DIGITAL REPOSITORY FOR DESIGN KNOWLEDGE REUSE

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Abstract

Many companies in the engineering sector are currently facing the challenge of producing accurate documentation which can be reused during design activities in order to support the life cycle of their products. This is a consequence of the process of transformation in the organisation and the industry, due to the fact that reinvention often occurs because people do not realise that they are trying to do what others have finished doing. To meet the need to records richer and more accurate information in order to synchronise the design activities, this research aims to develop a working prototype of the Digital Knowledge Repository for Engineering Designer system. This knowledge repository not only documents the discussions and decisions related to design, but also the sources of information available on the specific design situation. Through a case study, the system highlights the possibility of a complete picture of a positive direction for the future development of a documentary activity, with a focus on the engineering industry.

Keywords: Knowledge management, Digital Repository, Design Systems

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1 INTRODUCTION

Some studies have shown that during engineering design, less than 50% of the information needed by design engineers to enhance their work is actually available and even then only 20% of the information can be provided by existing applications (Conway & Ion (2013) cites Wood, Yang, and Cutkosky, (1998)). It has also been found that the designers tend to refer back to their own engineering notes, but not those of others. There are two possible reasons for this: first, the search capability for informal engineering records is limited; and second, it is difficult for designers to contextualise the informal work of others (Liang & Leifer (2000) cited by Yang & William (2005)). Loss of information during the design process can have a detrimental impact on the productivity and efficiency of a company in the next stages. For example, in the shipbuilding industry, where many companies based their design activity on the lessons and information generated from previous designs, the recording of information that has been generated through a ship's design, manufacturing and life cycle is crucial. If this information is not documented or recorded properly, companies can find themselves replicating costly mistakes, which in fact they could avoided had the required information been available.
Today, some tools can be found that can help designers to collaborate and share design concepts in real time (Smith, 2013). Knowledge management software that specialises in the way information is collected, stored and/or accessed is also available. Tools such as KBOX Knowledge Networking Platform (KBOS, 2014), Norweco (NOWECO, 2014), PI ETA Knowledge Engine (PI ETA, 2014) or Union Square Software Ltd (Square, 2014) are software programs that can manage intellectual capital by harvesting, adapting and reusing knowledge. However, these tools only store and organise the knowledge that is needed by the company in general - they are not specifically designed for managing product design, particularly related to engineering design.
In their studies, Conway and Ion (2013) have noted that some efforts are focused on developing systems that simply record everything using technologies such as audio and video. Systems such as Memetic (Buckingham Shum, Slack, Daw et al., 2006), Infomedia (Hauptmann & Lin, 2001), and Covera and Ferret browser (Lalanne, et al., 2005) have the ability to capture information using video and audio. However, this approach tends to produce clumps of information rather than specific, detailed items. Based on this, the authors contend that it is more efficient to be selective when capturing information during the design process.
Through a combination of evaluating previous work as stated above and analysing data from technical reports from engineering design projects, the authors have conducted a preliminary study to observe, identify and evaluate examples of information and knowledge generated by the designers during their engineering design process. Then, through the literature review, it was found that the engineering designer finds it difficult to acquire the records of the work that has been undertaken in the past. It has also been found that existing applications do not specifically record the details of an existing design which would make it easier for subsequent engineering designers to re-analyse and reuse. The analysis method presented in this research, makes it clear that over time, knowledge repository systems have been equipped with multi-media such as audio and video recording, which have the potential for improving engineering design in knowledge reuse as an example of further processing.
The main objective of this study is to help designer engineers to record more information than traditional documents contain, thus providing a richer history and enabling the product design process to be referred back to in the future, if required. If the engineering designers need to capture information and knowledge with a view to reusing them at a later stage in the life cycle of a product, there must be a focus on developing a method or system that is fast and effective in capturing formal and informal information that has been generated.

2 LITERATURE REVIEW

Now the world in a 'knowledge age' era whereby land and natural resources have become less important compared to knowledge (Mohd Fadzhil, Jaafar, Abdullah, & Azmi Murad, 2013). The ability of an organisation to leverage its knowledge and identify opportunities to create knowledge faster than its competitors is a key to improving the success of the organisation. Some authors suggest that an organisation can intensify its performance and increase its competitiveness by undertaking careful evaluation of the intellectual bandwidth to create knowledge (Hamel & Prahalad, 1994, Nunamaker et al., 2001 cited by Miller, 2004).

The case of Canadian Tire has shown how business performance can benefit when organisational knowledge is easily accessible. Canadian Tire relocated into the new system more than 30,000 documents which were catalogued from the old system. Employees can explore documents by typing their query into a search field, which promptly provides them with options. The workers and the managers also find it easier to store documents and keep them up to date, even filing up to 50% of the documentation that is inappropriate and obsolete. These documents are even automatically updated according to who has reviewed them, and what the last date of access was (Laudon & Laudon, 2012). Hence, knowledge has been regarded as “an essential asset for the competitive advantage” (Xu, Rémy, Caillaud, & Gardoni, 2011).

2.1 Knowledge Sharing

Unnecessary reinvention is a common problem in organisations and often occurs because people are unaware that the way that they are trying to do something has already been done elsewhere (Scarbrough & Swan, 1999). For this reason, knowledge sharing is not only important for an organisation but it is also important between members within, across and outside the organisation as pointed by researchers such as Chowdhury (2005). Moreover, someone with different knowledge will understand the same data and information in a different way.

Aktharsha et al. (2012) indicated that individuals believe that by participating in contributing their knowledge, they can improve their professional reputation, when they have the necessary expertise to share and be part of a structural network. An interesting finding from their research is that the individual contributions are not related to the expectation of reciprocity, or a high level of commitment to the network. Ardichvili, Page and Wentling (2003) found that the reason withhold information did not have anything to do with selfishness; in many cases, workers worried that what they post may not be important, or may not be completely accurate or may not be relevant to a specific discussion. Moreover, new workers feel intimidated because they do not believe that they have 'earned the right' to post their knowledge. Also, both new workers and experienced workers alike feeling of what might have been their post will likely be criticised or humiliated, or it could be that would be posted related to the problems that they should already know the answer.

Although Gee (2002) cited by Srivasta (2011) suggested that the sharing of knowledge is an individualistic behaviour, Ardichvili et al. (2003) suggested instead that it is natural in the engineering community to share knowledge. Some workers feel the need to make them known as experts by sharing knowledge while experts feel that they have reached a stage in their life when it is time to give back, and share their expertise, and they feel that by participating in the community this provide them with this opportunity.

2.2 Digital Knowledge Repository

The current design of engineering systems has increased to incorporate collaboration between teams that are separated physically, geographically or in time. The complication of modern creations means product development efforts can no longer be managed entirely by a designer or team of designers. A company that tries to develop a product without proper expert in the broad discipline will have a sustained product development cycle, higher development costs and quality issues, but, gaining technical capabilities in the world where the development is regarding multi-discipline could be quiet expensive for the company.

Addressing these issues, the companies increase the number of staff based solely on the core competencies of the company, and depend on other companies that provide complementary knowledge and design effort required to make a complete product. The increasing of complexity of the modern engineered products has also led to a change in the way products are designed and developed. Engineering design has increased to a collaborative work between distributed multi-disciplinary design teams (Szykman, Sriram, Bochenek & Senfaute, 2000, cited by Mocko, Malak, Paredis, & Peak, 2004). As the requirement for knowledge-intensive and cooperative activities in design increases, the need for computational frameworks to endorse the design and usability analysis of knowledge representation for distributed collaborative design becomes more important.

Although internet computing has increased the sense of sharing and exchange of information is facing obstacle. Mocko et al.(2004) cites Mocko & Fenves (2003) stated that a disadvantage of the distributed design also includes difficulties with the sharing and exchange of product information and knowledge between the distributed networks. In addition, Szykman et al. (2000) commented that the

greater barrier to developing an artefact is not delivering distributed access to distributed information but how to find the information needed. The industry requires fast data retrieval and reuse of existing knowledge to decrease product development time, and this has resulted in strong attention being paid to methods for presenting and gathering engineering artefact knowledge.
McDermott and O'Dell (2001), for example, remarked that in Ford 2000 evolved its global product development and design by creating a standard CAD system and open intranet access to other projects. All engineers, both internal and external contractors communicate, share information and use common templates; also, all changes to the specifications for each vehicle are made electronically through the online change control process. They also stated that development teams in Ford 2000 are required to share knowledge and insights at specific development milestones. This translates to reducing the product development cycle time by avoiding "reinvention of the wheel".
Traditional database design, which only provides access to schematic, CAD models and other documentations, is inadequate for presenting and storing engineering artefact for knowledge reuse purpose, because it only presents geometric data types and other information related to geometry, such as constraints, parametric information and features (Szykman et al., 2000). Regli and Cicirello (2000, cites Ulman, 1992) stated that design activity which comprises case-based design in engineering is conservatively estimated more than 75% that to address a new design problem through reuse of previous design knowledge.
The design repository is an intelligent, knowledge-based design artefact modelling system used to facilitate the representation, capture, sharing and reuse of corporate design knowledge (Szykman et al., 2000). Many companies are migrating to design repositories from traditional design databases. The differences between design repositories and traditional design database include the fact that design repositories try to capture a more complete design representation that might involve categorisation of function, behaviour and design rules, although not every aspect of a design can be covered, whereas the traditional design database usually contains only a narrow representation, such as a drawing or a CAD model, a range of information and associated documentation.

3 METHODOLOGY

This paper proposes a prototype of a Digital Knowledge Repository for archiving engineering design. The planned system consists of a user-friendly interface. The images are assumed to be scanned in an appropriate way with desired resolution. This section describes the data analysis, requirement analysis, and design and development of the system.
To make the prototype system reported in this paper useful and practical, the authors used a case study method. Specifically, data were collected from the working files of engineering students who were given an assignment to design a screw jack. This project has been chosen because it can be considered to represent a complete work by engineering designers to design a product by considering a range of issues such as requirements analysis, stress calculation, material selection etc. In addition the waterfall methodology was applied in the implementation of the software system. This methodology consists of four stages: analysis, design implementation, ongoing system monitoring and testing.

3.1 Data analysis

In the project, about 30 working files were created and each working file was used as a unit of analysis for this research as it could allow the researcher to focus as well as showing the personal styles of different engineering designers. Even so, it was realised this would offer less insights into individual styles. Screenshots were collected from different areas of the knowledge management literature, and the researchers undertook a study of different areas of the knowledge management approach. The researchers did a study of engineering designer in normal production circumstances to get a better perception of the work place and work processes. They also made some observations from the records of work done by engineering students with observations from log books and minute meetings that had been taken throughout the design and development process.
Based on the researchers observation of the working files they referred to, the researchers concluded that a number of patterns exist in these reports. These are as follows. In each working paper, there are several sub-discussions including part design, parts to manufacture, safety factor and design review; however, only the part design and parts to manufacture are discussed in this paper as system evaluation would be done before more data were included in the knowledge representation structure.

Each working file actually contains portions of a design of the finished product, in this case the screw jack. Although the students offered a variety of design variations and the parts are different for each of the screw jack, as listed in Table 1, They preferred to choose the most discussed parts: Tube/Barrel, Nut, Legs (and Cross members), Handle (and Grip), Collar, and Cup.

Table 1. Parts analysed in the Screw Jack Design project

Group 1	Group5	Group 7	Group 8
		Screw	Screw
		Main body	Body
Collar cup	Cup	Cup	Cup
Handle grip	Grip	Handle grip	Grip
	Handle	Handle	Handle
	Assembly	Assembly	Assembly
	Exploded assembly		
	Nut	Nut	Nut
	Shaft		
	Stand		
Sub assembly			
Assembly section			
Tube cross bar			
Leg nut			

The patterns in part design as parts of a screw jack which have been discussed by engineering students are requirements, function, material and manufacturing process. In the case of the parts to manufacture, the existing pattern is requirement and reason.

3.2 Requirement Analysis

Dieter and Schmidt (2009) suggested that the engineers should build their own technical working files and business information that is relevant to their work. It could be either paper or digital files, or a combination of both. Advances in digital storage make it increasingly easy for any engineer to create and bring together a more expansive technological library, while advances in wireless internet access have opened up greater possibilities for information access. This however has also raised further information challenges, namely how to access information and take appropriate materials as per appropriate demand only.

In a conventional synchronous design activity records, Fruchter (1999) and Fruchter and Demian (2002) as cited in Conway & Ion (2013) observed that background information and calculations are recorded using individual notebooks. However, Fruchter (1999) added that these remain personal documents were not the team documents. Conway and Ion (2013) also referred to Fruchter and Demian observation that, at the point at which knowledge is captured, it is often limited to formal documents. When this happens, a great deal of contextual, informal and inductive reasoning behind the decisions taken is lost.

It becomes clear that the development of a digital knowledge repository for an engineering designer system complimented with multimedia such as video and audio has the potential to improve the recording of informal information for reuse at later instances. If a designer engineer is to capture information and knowledge with a view to reuse these things at a later stage in the product life cycle, the focus is on the development of effective methods of capturing formal and informal information.

3.3 Design Consideration

From the literature analysis and initial studies to observe critical instances of information and knowledge generation among engineering student while performing conceptual design activities, it should be mentioned that capture information that is easy and unobtrusive as it is produced is, according to Conway and Ion (2013), “the key to the construction of a comprehensive project memory” (Conway and Ion, 2013, p. 146). The process of identifying and then capturing both product and process information that is used in an activity is very difficult without causing any additional work for design engineers, and it also has an adverse effect on the design activities.

3.4 Implementation

As stated above, the engineering workspace must have functionality that allows engineering designers or users to access the system through a range of additional devices. For this to be possible, a suitable user interface must be involved. A range of programming languages such as Java, PHP and C++ could be used to develop an adequate interface.

With this repository, regardless of their location, the user is able to store and access information. For users who wish to retrieve objects from a data repository, search and query facilities should also be included, to connect the space between the user interface and the repository. The search facility allows the user to find the data objects that are available in the repository, thereby creating multiple perspective on the data, whether it by date, title or any other relevant metadata.

This system essentially has created two basic workspaces: an engineering design workspace, where designers work and generate design files and paper work and a documentary work space, where the design activity being done is recorded and reused by other engineers. As illustrated in Figure 1, the interaction between different workspaces is facilitated by system graphical user interface, and documented information objects, and is seen through the use of a database repository, the software interface and data convertors.

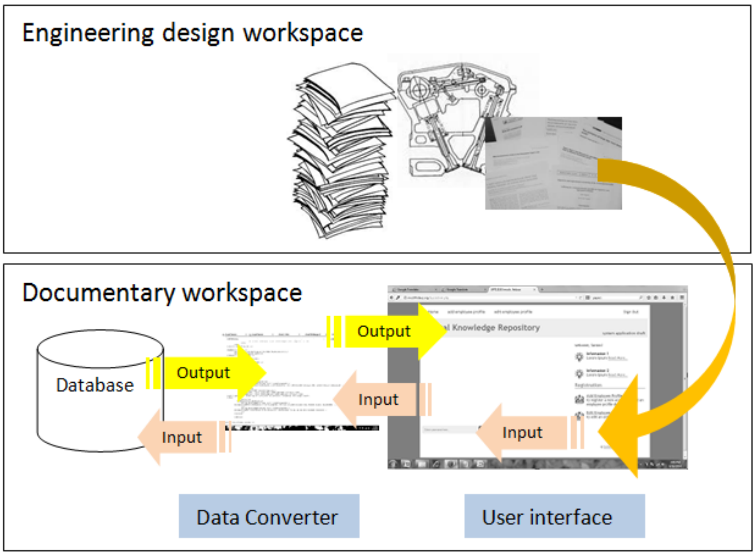

Figure 1. Interaction between engineering and documentary workspace

3.4.1 Admin

The admin dashboard shows articles or dashboard for any common information, sign-out function and registration menu. It includes two main parts: first, the “add employee profile” menu for registering and creating account access to the application; and second, the “edit employee profile” menu for updating or deleting any personal profile data belonging to existing registered design engineers.

3.4.2 User Registration

This is a main activity for the administrator that provides form to create a new authorised user. The form allows entry of all user details, including full name, email, photo profile, username that is used as the login name of the user and a password for future visits to the site.

The administrator also could choose status of the user who is registered, whether as an admin or as a normal user. Admin status here means that if the company wants to assign some workers the admin role of registering new users or updating the profile data of registered engineers. Thus in the future, the admin will be able to group users by department, expertise, experience or other grouping in accordance with the division of authority that companies need.

After this information has been registered, the system will redirects the administrator to the next user profile detail that involves skills, experience and position list. Skills, experience and position forms are short online resume of the engineer; they could describe employability skills. Other engineers could look for particularly helpful and relevant work experience and could decide to see whether the engineers in the reviews have referred to the appropriate sector.

3.4.3 Employee profile creating and editing

To remove, change or update the user data that has been registered, the employee is provided with an edit profile menu. This menu will redirects the administrator to a page containing a list of employees who have been registered or may also search for a particular employee based on a username that has been registered.
If the administrator clicks on the details of the user profile, then the personal data, experience, expertise and history of the employee's position in the company can be read and at the same time can also be update or certain data can be deleted.

3.4.4 Employee

The Employee or User dashboard shows articles or dashboard for any common information, sign-out function and two menu options. Specifically, the first is Part Design. In this part the user will get information about the details of the part such as, requirement, function, material and additional information. The second option is Part to Manufacture. Here, the user could get information about how a part will be manufactured. Information such as, requirement, reason and other additional information could be found.

3.4.5 Detail Design Browser Interfaces

In the user dashboard, there are two options although they have similar functions. In both there are lists of designs that have been inputted by design engineers. The user can browse the main part of the design in this section for example nut and handle which, when one of its details is clicked on, this will take the user to a sub section of this part with a list of different designs. When the designs are clicked on, they will split again into specific detail containing information, pictures, document files or audio and video files. The picture of the design allows the users to quickly and easily visualise which objects were presented or used in the design.

3.4.6 Digital Record Searching

In general, the user will use the internal search engine to search for specific data. This is despite the fact that a lot of data or articles that are sought are often listed on the main page, sorted by category in the Index. This case underlines the principle that different people have different methods of locating content on the site.
Search functions provide an easy way for users to find things in the system using terms they know. When it is difficult to find what they want, the user will tend to search under a different name. However, they are likely to give up the search if the word they are using cannot be found, although it could be that what they are looking for is stored under a different name. This is a reason why the search is contained in the system. The draft design of a list of the search result will be a list consisting of the column image, title, additional information and meta-keywords.
On the employee design side, this function allows the user to find the data objects that are available in the repository by any other relevant data that contained in meta-keyword field whereas, the same function in the admin side allow the administrator to search username that have been registered.

3.4.7 Review Creation

To add and edit data into the system design details, a menu is provided to write a review. This menu will redirect the user to a page that contains a form for them to complete. This includes a facility to insert design drawings.
While the addition of video and audio files documents are uploaded to the database on different pages, after the main data have been added to the system. This is to facilitate the grouping of files automatically associated with the data, relative to the specific point in the design at which the upload occurs.

4 SYSTEM PROTOTYPE

The user interface of the system begins by showing the login screen into the system. After logged in, for user admin status, if there is no problem with the login name, it will go into the ‘admin mode’ page where users can add or edit the data profile of the engineer.

The data in this form are temporary, as the requirement is that workers be able to log into the system. Meanwhile, when the administrator goes to edit the employee profile page, it could edit or delete the data profile of the employee.

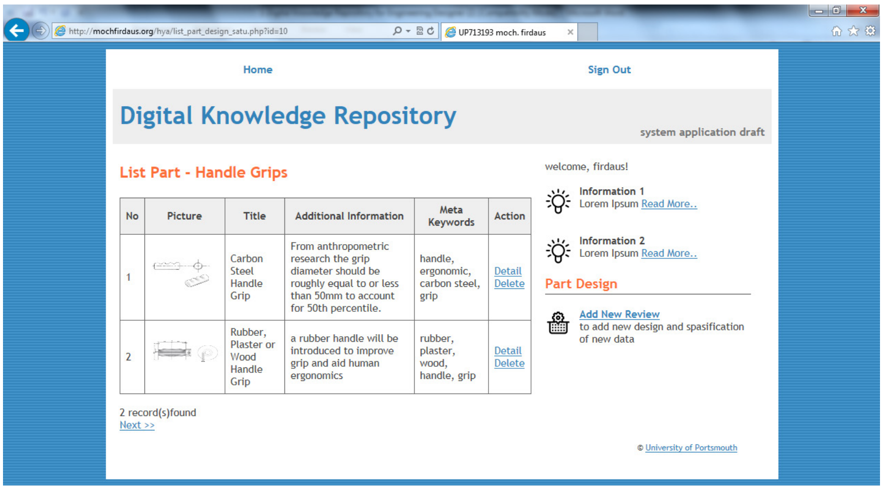

Figure 2. Screenshot of the list of search results

In other part, the engineer who accesses the system as the user will view the first entry that has two options, namely part design and parts to manufacture. On both pages, engineers can choose to view the data that are available through the search box or directly view a list that is already available. Figure 2 shows a screenshot of the Digital Knowledge Repository interface when a user was looking at one or more part designs. The details allow for the user to expand and see the details of the part design, while the rest of the other details that are not of interest to the user will be hidden. When a detailed design is being displayed, all information associated to a specific object is retrieved from the database and delivered to the client side Web browser. To prevent a user from getting additional details, the system presents only a subset of the information associated with the object design. A screenshot of the interface is shown in Figure 3. The user also could download audio videos or document files related to the design.

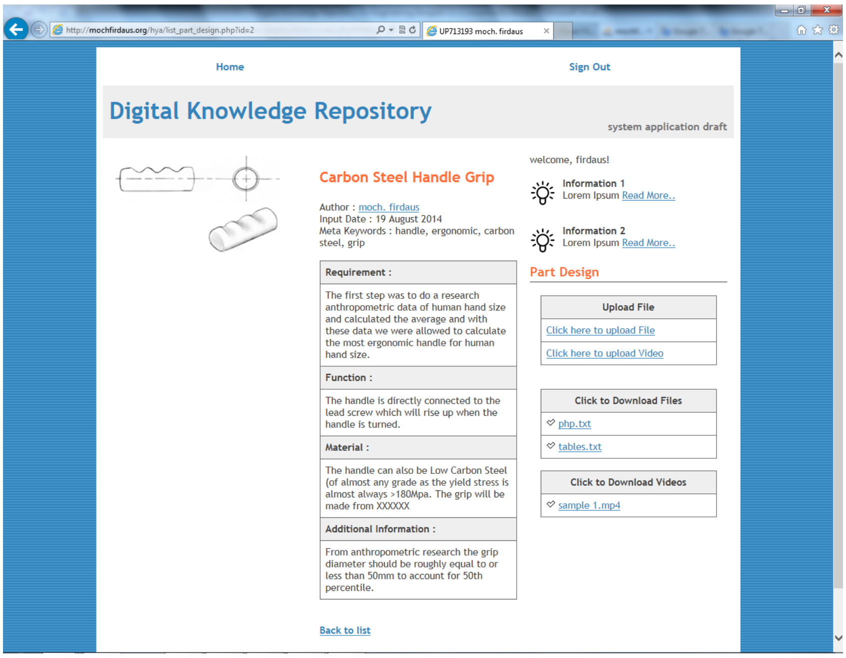

Figure 3. Screenshot of the detail design interface

The user can also see the author of the design by clicking the author name. The page provides a summary of the author's profile and displays their skills, experiences and positions history. If the author name is the same as that of the current user who has logged in, then the user can edit his or her information profile. In addition, the user can also insert information on new skills, summarise their experience, modify their passwords and change their profile pictures. The details of the author are shown in Figure 4.

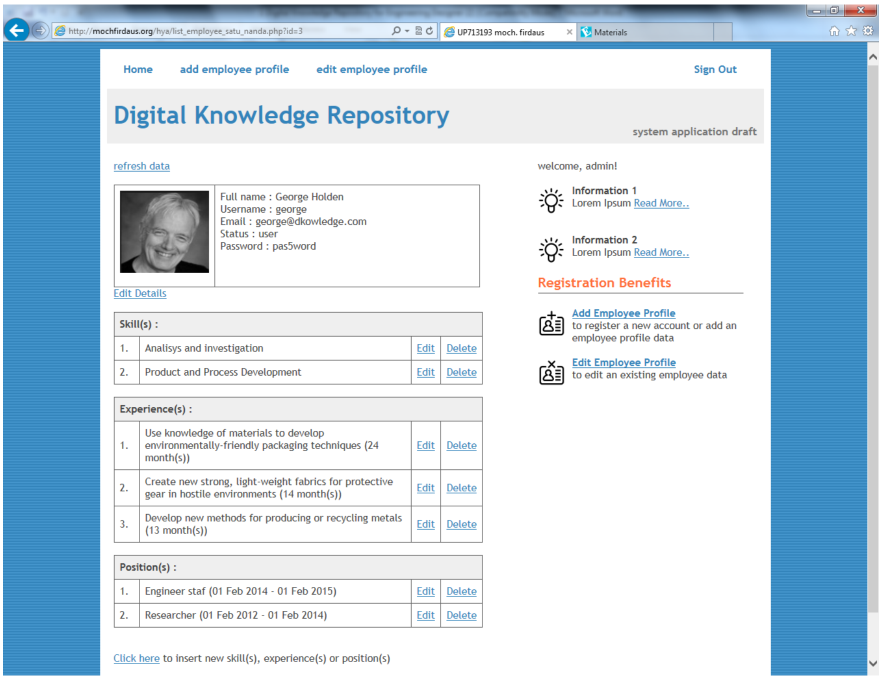

Figure 5. Screenshot of the employee profile interface

5 CONCLUSION AND DISCUSSION

A small and stable organisation with employees who can be reached by hand may be able to survive without management knowledge. However, for large, distributed organisations whose environment is constantly changing, or which have high turnover, managing their knowledge assets is critical to their survival.

Engineers working in different geographical locations will need to collaborate, communicate and coordinate, and engineers who are working in different times, will need to reinvent, reuse, and re-develop the work already done by another engineer. However, care should be taken not to replicate work that has already been done by others. The Digital Knowledge Repository for Engineering Designers system presented in this paper is designed to support the creation of the repository as a design project proceeds.

Different from existing work on design knowledge management and design repository, the proposed digital knowledge repository emphasises a user-centred approach to knowledge management. The skills, expertise and experiences of designers are linked to data records in the repository, which will also be used in further retrieval and reuse. The repository is based on a knowledge representation with fine-granularity of information that facilitates the integration of informal knowledge to formal digital objects. Moreover, the procedure of design knowledge capture is based on the undertaking of design tasks, which means knowledge is captured as design activities are completed. Last but not least, the proposed prototype system emphasises multimedia information so that information can be better presented using graphical representation, 3D interactive models, video-format details and audio-format reviews and comments.

The prototype proposed and developed in this paper has adopted the online collaboration capabilities and has the capacity of be accessible on any Web-enabled hardware. In addition, by conducting a series of functional testing, it is proven that the system allows for collaborative work between design engineers and achieves improved information recording and knowledge capture for engineering design activities. Through understanding the existing concepts of recording design activities through conducting experiments on a case study, it is also shown that software-based implementations can have a positive impact on the creation of more accurate data recording as well as on the supply of design knowledge to support engineering design activities.

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