Social tagging as a knowledge collecting strategy in the engineering design change process

Gerardo Alducin-Quintero, Instituto Tecnológico y de Estudios Superiores de Monterrey

Manuel Contero, Instituto de Investigación en Bioingeniería y Tecnología Orientada al Ser Humano (I3BH), Universitat Politècnica de València

Abstract

This article focuses on analysing the feasibility of using social tagging as a tool for knowledge collection and retrieval in the context of the product development process (PDP). This process is a social activity that involves groups of individuals who share a common goal: 'to design a product'. Traditional knowledge-based systems (KBS) are not very well suited to capture the tacit knowledge that is embedded in this process. Social tagging is proposed in this article as the mechanism to externalize the tacit knowledge about the best CAD modelling strategies between the design team members. This knowledge is especially relevant for the management of 'engineering change orders' because this process is closely related to the modelling methodology used to create the three-dimensional (3D) CAD models that have to be adapted to accomplish a specific design modification. In order to analyse the feasibility of this approach, an experimental study was conducted to understand the tagging process in this context and the benefit of using this information in the modification procedure of 3D CAD models. Preliminary experimental results show that tagging represents a feasible approach to support knowledge collection on best CAD modelling practices.

Keywords

social tagging

tacit knowledge

social product development process

folksonomy

This article focuses on analysing the feasibility of using social tagging as a tool for the collection and retrieval of design knowledge in the context of the product development process (PDP). It is based on a social tagging approach where design engineers play a role as taggers. This work is part of more general research, oriented towards creating the infrastructure needed to integrate elements from product life cycle management (PLM) systems, knowledge-based engineering (KBE) systems and social computing applications.

We have specifically analysed the tagging procedures when the 3D CAD model of a product is modified due to an engineering change order. In this context, we formulate three main specific questions: Is it possible to use ‘the social tagging process’ as an engineering knowledge collection tool? How could this kind of technology be used by design engineers in a real PLM environment? Could unstructured metadata (tags) help to find relevant knowledge to support design decision making?

In the remainder of this article, we look for answers to these questions, proposing at the end an outline of the conceptual design of an information model to support product life cycle management and knowledge-based engineering systems and social computing applications. This model extends previous work by Titus et al. (2007) that is based on three elements: the tagged object, the identity (person who tagged the object) and the metadata (tags or comments about the object). We consider it important to add the 'product information' to this model as a complementary component that is relative to the tagged object (CAD model or modelling procedure) to perform the knowledge retrieval process. This means that the implicit knowledge content in the tag/commentary is only understandable in certain product information contexts. Additionally, a new attribute with the explicit time when a tag is created or used provides an operational framework for the integration of the tagging process in a PLM system.

An experimental study was conducted to obtain data on some tagging issues. For example, how often does polysemy or synonymy appear? What different kinds of tag-to-resource association are there (Marchetti et al. 2007)? In this investigation, graduate and postgraduate engineering design students participated through a series of CAD modelling exercises.

The PDP can be considered a social activity because it involves groups of individuals who share a common goal: 'to design a product' (Bucciarelli 1994), and they must be take the main design decisions together involving a complex negotiation process in order to achieve the design objective (Sosa and Gero 2004). Collaborative tagging describes the process by which many users add metadata in the form of keywords to shared content and knowledge. This article argues that it is possible to use such technology as a dynamic knowledge collector, providing an interesting alternative to the conventional knowledge-based systems (KBS). Dijoux notes on his blog that in the social technologies systems:

“There is no intimidating corporate template to follow, no complicated knowledge management system to master or network share drive taxonomy to remember. Folksonomy and social bookmarking have offered a new way to categorize the information. It helped in making the information easy to index and find afterwards” (2010).

In order to make the ‘social tagging process’ interoperable with traditional knowledge-based engineering it is necessary to use some standards based on a resource description framework (RDF) such as that by Annotea (Kahan 2002). With this aim in mind we outline a new information model to use social bookmarking as an engineering knowledge collector in the PDP. This way it is possible to integrate a tagging process in a structured procedure.

In sum, the main goal of the present exploration is to clarify the possibilities for creating a new user-friendly, dynamic and cheap way to capture relevant knowledge in the complex environment of engineering design, based on a social tagging approach.

In the following, research relating to this issue is discussed. Then the PDP is analysed from different perspectives. The experimental work for analysing the tagging creation process and its later use is detailed, providing the respective results and debates. Finally, future interrogations and conclusions are presented.

Related work

Knowledge-based organizations such as engineering design firms have to exploit all their resources to maintain a sustainable competitive advantage. One of their assets is the tacit knowledge, always present in any kind of organization. Tacit knowledge in this article refers to the joint reasoning behind trade-off decisions in product design processes, such as in computer-aided design and its implicit design intent. However, managing this kind of knowledge in an efficient and simple way, in the context of the PDP, is a great challenge.

Semantic annotation has emerged in recent years as an important research area. Semantic annotation of textual and multimedia content enables better analysis, retrieval and exchange of digital content globally. Research studies on the application of semantic annotation in design engineering have recently started to capture the attention of researchers.

Some research has been conducted on using annotations in 3D environments. For example, Ding et al. (2009) talk about 3D annotations in lightweight CAD formats to transfer knowledge, but they do not use standard models for data interchange on the Web such as the RDF or the Web Ontology Language (OWL) for authoring ontologies. Hunter and Gerber (2010) use annotations to capture knowledge about 3D representations of museum pieces. Shape Annotator, developed by Attene et al. (2009), use Web Ontology Language to create annotations in surface models and proposed that it is possible to use this technology in product design. Catalano et al. (2008) perform annotations about geometric properties on a 3D car model using a car aesthetics ontology.

There are also some examples in relation to the application of semantic technology in the engineering design process. Szykman et al. (2000) propose the need to use a functional taxonomy to place the management of knowledge into product design repositories. Au and Yuen (2000) propose a linguistic approach to creating sculptured models, and show taxonomic relations between three levels of extractions at object level, feature level and geometry level. Fu (2003) attempted to extract features from a data exchange product model using a taxonomy, which defines relationships between design features and manufacturing features for feature identification in CAD models.

Traditional knowledge capture

Static knowledge capture: KBS

In recent years, KBS, which are based on ontologies, have been used in the PDP to support manufacturing and design decisions. In general the capture of a company's PDP knowledge is based on the collection of design rules and engineering expertise (e.g. best practices), which will serve as the corporate knowledge base or design rules database portion of the KBS. For example, the design rules can be applied in any combination of: if-then-else, For example, design rules can be specified by means of if-then-else clauses where depending of some conditions, design parameters as dimensions and geometric features can be automatically changed or calculated. The end result is a simple-to-use interface that provides endless product combinations that do not have to be designed from scratch. The end user (e.g. CAD engineering designer) has the ability to add or delete rules and component parts from the database in accordance with corporate engineering changes. Once the rules are part of the KBS content, they become static knowledge. In conclusion, the structured approaches of ontologies, taxonomies and databases are rigid and suitable for representing the static objects of a domain in a design scenario.

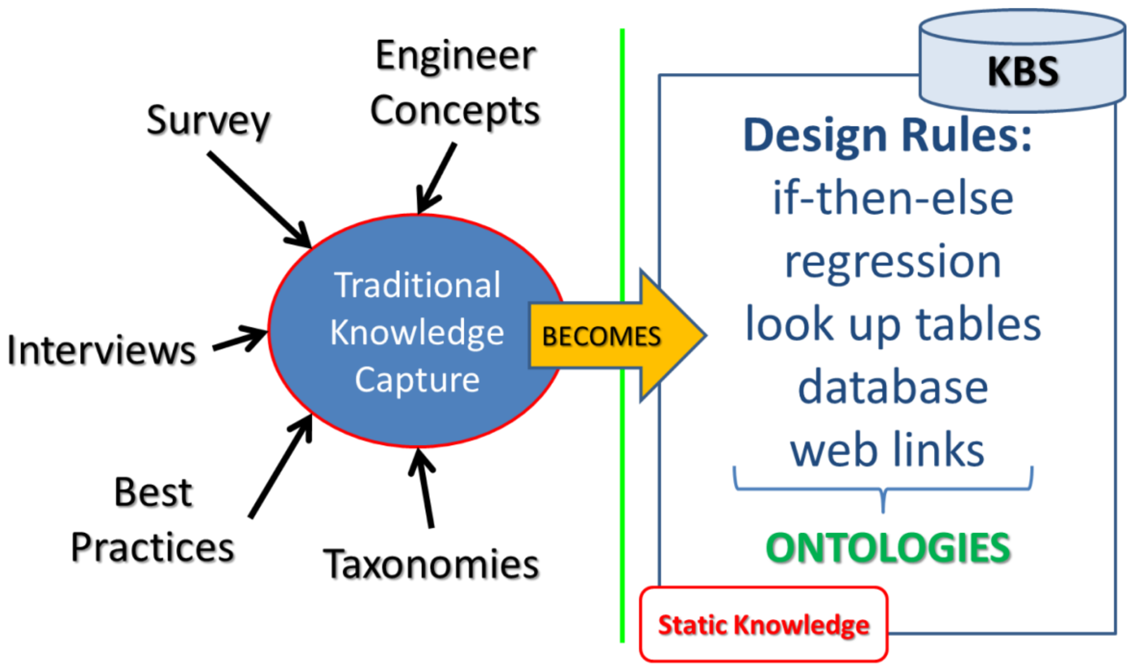

Figure 1: Static knowledge capture.

Dynamic knowledge capture: Practitioners' point of view

However, there are alternatives to conventional KBS. Shilovitsky (2009) supports the idea of incorporating the concept of folksonomy by CAD/PLM vendors. Vander Wal (2004) defined folksonomy as the result of personal free tagging of information and objects (anything with a URL) for one's own retrieval. The tagging is done in a social environment (usually shared and open to others). Folksonomy is created from the act of tagging by the person consuming the information. This approach is potentially very interesting because lost knowledge inside the organization is still an important issue due to the rigidity of conventional KBS. As Dijoux (2010) notes, it is easier and less intimidating for knowledge workers to capture knowledge on collaborative platforms (wikis, blogs, forums, etc.) than to use text documents and knowledge management systems. These simple tools can break one of the biggest barriers to successful knowledge management, that is, staff members' complaints that they do not have enough time to engage in knowledge management (Lugger and Kraus 2001). In addition, these tools are well adapted to the fact that knowledge transfer is in essence a social activity (du Plessis 2008), where one person shares knowledge with one or more individuals through one or more channels. Opening simple and effective new channels of knowledge transfer is one of the goals of this research work.

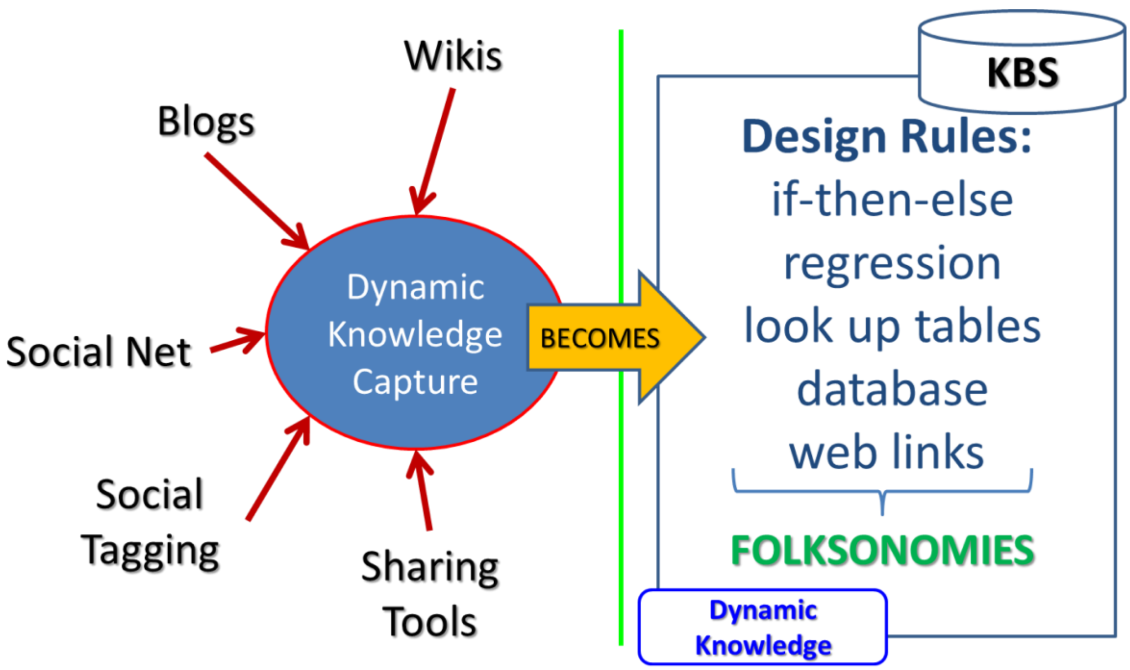

Figure 2: Dynamic knowledge capture.

Social PDP

PDP as social activity

The product design process is a creative social process involving teamwork in which individuals with varied and shared expertise contribute to the common goal of designing a product (Bucciarelli 1994). This procedure involves negotiations and interactions between different stakeholders. In addition, language and representations used and generated (e.g. 3D CAD model) during the PDP themselves evolve over time (Subrahmanian et al. 2003). Effective computer-based support of the product design process (e.g. PLM systems) requires a robust product design representation schema, facilitation of collaboration and communication, design retrieval and reuse, and knowledge sharing. Knowledge sharing requires a common design representation schema and a collective design language as enablers.

The design decisions are made as individual or as teamwork tasks, but the ability to change the product becomes increasingly limited. At the beginning the designer has great freedom because few decisions have been made and limited financial resources have been committed. But by the time the product is in production, any change requires great expense, which limits freedom to make changes. Thus, the goal during the design process is to learn as much as possible, as early as possible about the evolving product in such a way that the majority of changes are performed during the early phases of the product design life cycle.

Organizational design knowledge and its sources are spread across the organization. Creating an infrastructure to build and maintain this knowledge should be a process that not only identifies important sources of information, but also collects, indexes, organizes, and makes accessible for mutual participation and understanding this knowledge in organizational memory. It should also store how individuals arrive at a shared understanding of the problem and how they make decisions (Monarch et al. 1997).

Other Web examples

The main CAD and PLM industry software providers are progressively integrating the social Web technologies paradigm in their commercial platforms, in order to capture and transfer data and knowledge during the product development cycle process. Dassault Systems and blueKiwi Software, for example, are collaborating to develop a platform that helps manage secure social networks with partners, customers and colleagues. Their software integrates familiar Web 2.0 services, such as wikis, blogs, forums, RSS and tagging (Dassault Systèmes 2010). Other important CAD providers such as Autodesk have developed a Web portal where they provide access to different Web 2.0 tools such as blogs, forums, wikis, user communities (social networks) and so on. This platform aims to give Autodesk Software users the opportunity to exchange ideas and knowledge in relation to the most common issues in order to improve the CAD learning process (Autodesk-community n.d.). Social product development is a project of PTC (Parametric Technology Corporation n.d.) that includes tools such as content tagging, filtering and activity feeds. These will automatically and instantly disseminate relevant knowledge to product communities and 'communities of practice' (self-forming groups united by shared professional interests).

The tagging process in the context of the PDP

Information model proposal: High-level model

The annotation (folksonomy) representation proposed in this research is a flat namespace consisting of three entities: the identity of the user doing the tagging, the information object being tagged, and the tags or metadata used for labelling the object (i.e. the namespace is (identity, object, metadata)). These three elements of the representation are based on Titus et al (2007). We added a new element in our model entitled 'Product Information', which is associated with the CAD model. A diagrammatic representation of the folksonomy is shown in Figure 3.

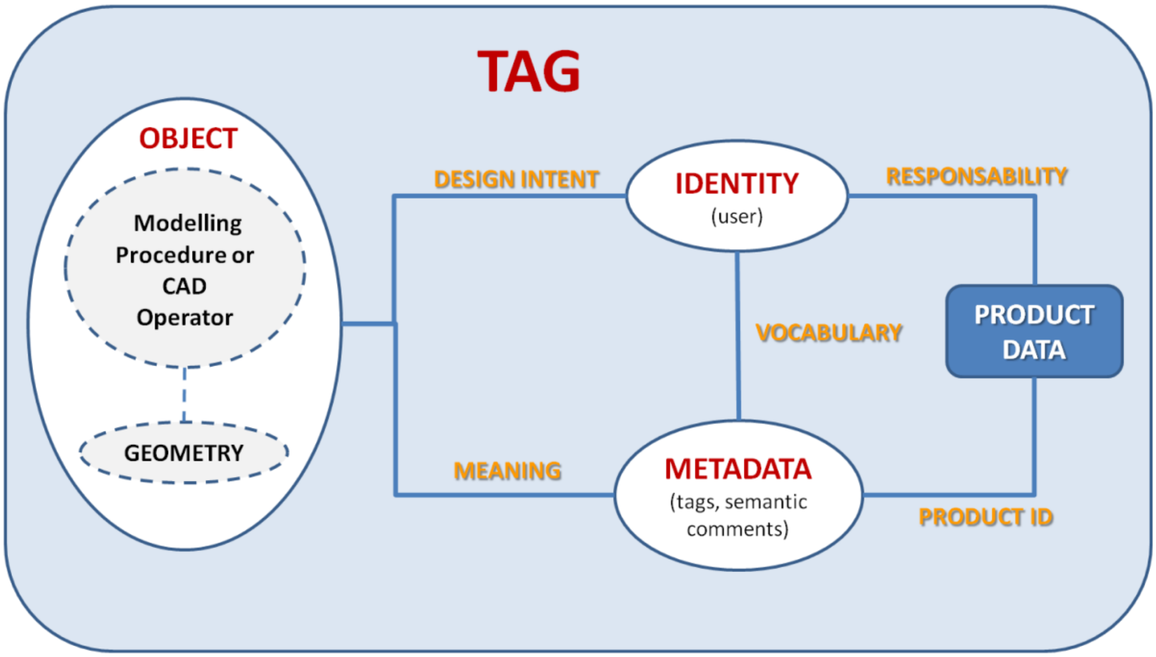

Figure 3: Tag high-level information model.

This tag model is designed to support its integration on a product lifecycle management (PLM) system. Its requirements include a time stamp in order to associate tags with the corresponding developmental stage (Titus et al. 2007). Tags are used to categorize information about the design intent that often is not made explicit. This categorization is specifically related to the context of a product defined by the product information element of the model.

Experimental stage

Social tagging/annotations in 3D CAD models

This experiment was designed to investigate how design annotations are made during the engineering change process by design engineers. Our research focus is expressed through our main hypothesis:

H1: When an information resource is tagged (by engineering designers) during the engineering design change process, it is possible to find the most common tagging patterns (human behaviour) inherent in the social tagging systems.

The features considered in this study are described in Mathes (2004) and Titus et al. (2007). In this experiment, a group of postgraduate students from the Universitat Politècnica de València (Spain) was involved. Most of them had real experience modelling products using CAD software. The students received descriptions of two similar design problems in order to reduce the manufacturing cost of the piece through the modification of the 3D model. After they received this information, they were asked to describe the solution to both problems by using only five keywords.

With this experiment we tried to identify some tagging behaviour from a group of engineers who shared the same idea about a specific design problem. In the same way, we tried to limit the participants' possible vocabulary by using a reduced set of keywords. For this experiment the 'solution process' was the metadata resource that was tagged by the users (students). We then analysed some tagging-process features described in Mathes (2004) and Titus et al. (2007). The summary of the tagging procedure features that were found in the data collected from the experiment is shown in Tables 1–4.

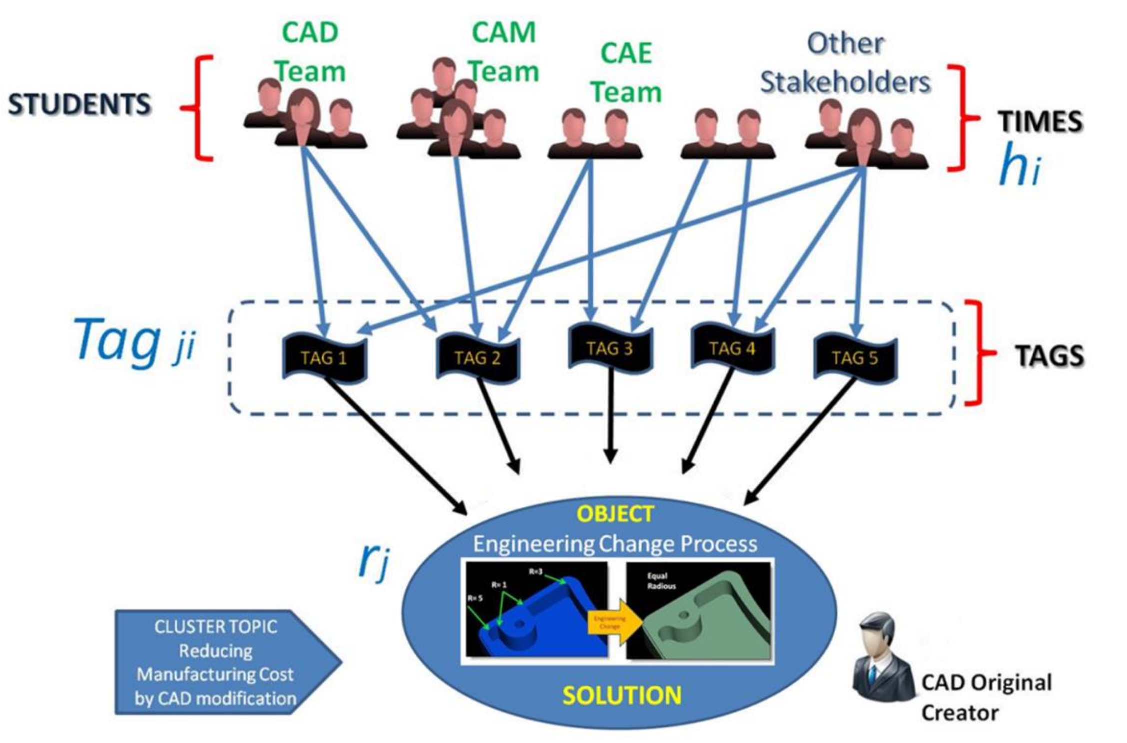

Figure 4: Experimental tagging process.

Experiment: Productivity improvement by using social annotations experience

The objective of this second experiment was to investigate how design annotations influence the user performance during the engineering change process. This was performed before analysing the dynamics of the social annotation process, because we had to ensure that the availability of these annotations provides an added value to the CAD models.

Our research focus is expressed through the following hypothesis:

H2: CAD operators, using annotated models where original design intent is made explicit, are more efficient in dealing with CAD model modifications.

In this context, efficiency is related to the time used by CAD users, when they have to perform a change in the 3D geometric model to accomplish an engineering change order.

From our perspective – and following the product data quality model by Contero et al. (2002) – if the design intent information is made explicit by means of these annotations, the corresponding CAD models will be created with better semantic quality. We envisage that this annotation process can be performed following the behaviour of social networks, where knowledge associated with the CAD modelling process is made explicit through the collaborative annotations performed by design engineers.

For the experiment, an undergraduate-level class from a CAD course of La Laguna University (Spain) was split into two groups, one experimental and one control. The experimental group received a CAD file with additional comments (equivalent to tags). These comments were implemented using the engineering notes functionality of Autodesk Inventor, which was the CAD system used in the CAD course. The control group received the same CAD without any comments. Students were given a maximum of 50 minutes to complete the required modifications. They had to write down the initial time and the final time for each model modification. In this experiment, the time was considered as the dependent variable.

The sample size used in this experimental study follows the recommendation by Polkinghorne (1989) and Meyer and Booker (1991) to include between five and twenty designers for an exploratory phenomenological study. It is important to note that participants showed a similar level of knowledge of the CAD system (basic training) and that they followed the instructions correctly. Therefore, this group could be considered a homogeneous sample within the application of statistical analysis.

Figure 5: Autodesk inventor annotation example.

Experimental results

Tagging process analysis

In the experimental data collection, we recorded the most common features that were present during the tagging/annotation process. An attribute set is composed of the most frequent combination of tags related to the same concept. The summary of the findings is shown in the following tables.

Analysing the results summarized in the following tables, it can be seen that in an engineering change problem context, the users (designers) tagged the information resources in the same way, for example metadata tagged on the Web. For instance, from our experiment we can say that a ‘manufacturing cost reduction by CAD modification’ issue (cluster topic) could be identified (knowledge retrieval) by using five attributes defined by only fourteen words in the design-problem context (Tables 1 and 2). In addition, we observed that patterns such as polysemy and synonymy (definitions and examples in Table 3) are present. Thus, for potential developments of social tagging systems in a CAD environment, it is necessary to consider including (as part of the system) elements that check these two patterns and others shown in the tables, in order to avoid inconsistencies during knowledge capture and retrieval.

Attribute, frequency (%)			**Attribute description**
ATT1	Same, equal	12, 90	The problem/solution is a process that is relative to geometric unification/standardization/homogenization.
	Standard, standardize	4, 70	
	Standardized measures	1, 20	
	Homogenize	3, 50	
	Unify	8, 20	
ATT2	Radius	10, 60	The problem/solution is relative to the part's rounds
	Rounds	3, 50	
ATT3	Tools, tooling	9, 40	The problem/solution is relative to something about the tools used in the manufacturing process
ATT4	Machining	3, 50	
	Manufacturing	1, 20	
ATT5	Reduce	1, 20	The problem/solution is relative to reduce something in the process
	Decrease	3, 50	
	minimize	1, 20	
	Number of words: 14	64, 60	Fourteen words represent 64.6 per cent of total words (34) used by the participants

Table 1: Topic clustering and attributes first experiment – Exercise 1.

Attribute, frequency (%)			Attribute description
ATT1	Reduce, reduction	12	The problem/solution is relative to reduce parameter's value of the geometry
	Decrease	3	
ATT2	Radius, radii	9	The problem/solution depends on the rounds of the geometry
	Rounds	7, 50	
ATT3	Overlap, overlaps	7, 50	The problem/solution is relative to geometry/tooling interferences
ATT4	Standardize	6	The problem/solution is relative to the tool dimensions must use a standard diameter value
	Standard	1, 50	
ATT5	Tool, tools	9	The problem/solution is relative to the manufacturing process
	Number of words: twelve	56	Fourteen words represent 56% of total words (34) used by the participants.

Table 2: Topic clustering and attributes first experiment – Exercise 2.

General features of collaborative tagging system		
Feature description	**Present in the experiment?**	**Examples**
Polysemy: the same word can refer to different concepts	Exercise 1=Yes Exercise 2=Yes	Exercise 1=unify Exercise 2=standardize
Synonymy: different words that refer to the same concept	Exercise 1=Yes Exercise 2=Yes	Exercise 1=radii=rounds Exercise 2=reduce = decrease
Different kinds of tag-to-resource association: implicit kinds of relations that link a tag to a specific resource ('interesting' expresses an opinion on the resource, 'car' expresses the topic of the resource and so on)	Exercise 1=No Exercise 2=No	Exercise 1=n/a Exercise 2=n/a
Different levels of precision: the specificity of the word chosen to tag a resource ('jazz' is more specific than 'music')	Exercise 1=Yes Exercise 2=Yes	Exercise 1='minimize' is more specific than 'reduce' Exercise 2='diameter' is more specific than 'rounds'
Different lexical forms : the same concept can be referred to by different noun forms, for instance plural nouns ('car'/'cars')	Exercise 1=Yes Exercise 2=Yes	Exercise 1=tool, tools Exercise 2=standard, standardize
Tag convergence: after a certain amount of time the number of tags given to a resource	Exercise 1=Yes Exercise 2=Yes	Exercise 1=same, equal, radii, tools and tooling, are

stabilizes as the relevant categorizations are made and the most common words for those categorizations become the majority.		keywords that represents the tag converge of 33% of the keywords used. Exercise 2=reduce, reduction, radii, rounds, overlap, overlaps, standardize, tools, are the keywords that represent the tag converge of 51% of the keywords used.

Table 3: Tagging process analysis results (general features).

Keywords	Times	Keywords	Times	Keywords	Times
Geometry	1	Modification	2	Part	1
Radii	9	No changes	1	Minimize	1
Single-tool	1	Reduce	1	One	1
Equal	11	Tools	7	Commercial	1
Standard	4	Interior	1	Facilitate	1
Standardized-measures	1	Manufacturing	1	Economy	1
Unify	7	Decrease	3	Time	2
Optimization	3	Selection	1	Unique	1
Simplification	5	Operations	1	Symmetry	1
Homogenize	3	Normalize	1	Machining	2
Saving	2	Diameter	1	Participants	21
Rounds	3	Use-same-tool	1	Total Keywords	34

Table 4: Resource representation Exercise 1.

Productivity improvement

The results of the second experiment showed that there is a significant difference between control and experimental groups. The results of those statistical tests are shown in Table 5. While the control group completion time was greater than that of the experimental group, in this case the results were statistically significantly different. Results support that the use of annotations can help to improve the CAD designer's performance during the engineering change process.

Second experiment	**Time (minutes)**					***t***	**Significance**
	Control group	**SD**	**Experimental group**	**SD**	**Time difference (minutes) (%)**		
Exercise A	37	8.2	28	7.3	9 (37)	-2.243	0.045
Exercise B	8	3.5	5	2.8	3 (24)	-2.165	0.046

Table 5: Statistical *t* analysis for second experiment.

Knowledge mapping tasks

In both groups, participants displayed a similar amount of declarative knowledge (knowledge about CAD commands), but they had a lack of procedural knowledge (knowledge of how to apply the commands to achieve a goal) due to their short experience. The high number of create–erase contiguous events was an interesting behaviour pattern exhibited by the undergraduate group. This is related to the fact that they only knew the most basic commands of the CAD system, so they did not waste time trying to use complex commands or trying to find them in the CAD user interface. The majority of the participants who completed the exercises used the most simple and direct solution.

Future work

One of the most important limitations of this research work relates to the sample size of the CAD users who participated in the experiments. The sample size was small as this pilot study, being exploratory in nature, it was intended to give us suggestions for more extensive studies in the future. More investigations are to be conducted with larger groups of participants (Experiment 2) and with multicultural groups of designers that are spread over different countries (Experiment 1). Another factor that could be a limitation is the users' expertise. The undergraduate group cannot be considered to be composed of expert CAD engineers, but it offers a homogenous composition. In the future, it is expected that participants in the experiments will be postgraduate students or CAD instructors. We feel that working with more advanced CAD users will allow us to propose more complex modifications in the 3D CAD models that will make more evident a different behaviour with respect to modifications completion time, when users work with tagged or annotated CAD models.

Future work will be focused on mitigating some of the limitations mentioned above. The first stage was carried out during the first semester of 2011, in collaboration with Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico). The second stage will consist of redesigning the experiments applying all the expertise obtained during the previous work. The goal of these actions is to obtain more conclusive results during the next experimental round.

Another future project will be to design an experimental stage in order to test the tags-based information retrieval process.

Conclusions

In this article we have explained the main findings when social annotations/tagging are used to collect the design intent during an engineering change process (Experiment 1). The results show that this tagging process behaves in a similar way to other tagging processes performed by Internet users. This means that it is necessary to include filtering units to eliminate issues such as synonymy and polisemy when a CAD model is tagged. The results of Experiment 2 show that annotations have a positive impact on the required time to complete an engineering change order (ECO) procedure. This equates to increased productivity. The observed time reductions are about 10–20 per cent. These preliminary results support the idea that social tagging/annotations could be used as a knowledge collection tool, well adapted to the dynamic environment of the PDP.

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Contributor details

Gerardo Alducin is a Ph.D. graduated (2011) in the Engineering Design School at the Universitat Politècnica de València (UPV), Spain, with a Masters in CAD/CAM/CIM from UPV (2008). His research interests focus on engineering knowledge management, with particular emphasis on issues concerning product design and manufacturing. He is a

full time professor in the Industrial Design Department atInstituto Tecnológico y de Estudios Superiores de Monterrey at Puebla, Mexico.

Manuel Contero is a full professor of Engineering Graphics and CAD in the Graphic Engineering Department at the Universidad Politécnica de Valencia, Spain. His research interests concentrate on sketch-based modelling, collaborative engineering, human–computer interaction, development of spatial abilities, and technology-enhanced learning.

Contact:

Dr. Gerardo Alducin-Quintero

Industrial Design Department

Instituto Tecnológico y de Estudios Superiores de Monterrey

Vía Atlixcáyotl 2301

Reserva Territorial Atlixcáyotl

Puebla, Puebla.

Mexico

Zip: 72453

E-mail: gerardo.alducin@itesm.mx

Dr. Manuel Contero

Instituto de Investigación en Bioingeniería y Tecnología Orientada al Ser Humano (I3BH), Universitat Politècnica de Valencia.

Escuela Técnica Superior de Ingenieros Industriales

Departamento de Ingeniería Gráfica

Universidad Politécnica de Valencia. Edificio 5L

Camino de Vera, s/n.

Valencia, Spain

Zip: 46022

E-mail: mcontero@upv.es