Design of a 3D annotation tool for supporting evaluation activities in engineering design

Jean-François BOJUT
Laboratoire GILCO
ENSGI – INPG, 46 ave Félix Viallet, 38031 Grenoble Cedex, France
e-mail: jean-francois.boujut@gilco.inpg.fr

Julie DUGDALE
Laboratoire CLIPS - IMAG
CNRS – UJF – INPG, 385 rue de la Bibliothèque, BP 53, 38041 Grenoble Cedex, France
e-mail: Julie.dugdale@imag.fr

Abstract

In the domain of engineering design a distinction can be made between the design activities related to the production of a CAD representation (embodiment of a design solution) and the activities related to the evaluation of a design solution. Throughout the whole design process annotations play a crucial role by supporting the cognitive synchronization between designers, by acting as intermediary objects in fostering cooperation, and by capturing the design rationale. This paper reports on the design of an annotation tool which supports the evaluation activities in engineering design.

Keywords: design cooperation, shared representation, 3D annotation, engineering design, cognitive synchronisation.

1. Introduction

It is well known that design is a composite and complex activity particularly in an industrial domain such as engineering design. The various activities depend on a large number of factors such as the type of product, the organizational structure, corporate culture, and the current phase of the project, etc. A huge number of scenarios can be developed and it is impossible to encompass all facets of the design activity within a single scenario. In this work we focus on evaluation activities in the context of distributed and collaborative design involving various domains (i.e. the participation of manufacturing experts, after sales services, etc.). In this work we have used the scenario concept in order to frame our target activities. We have adapted the concept of scenario from the scenario based design
approach (Carroll, 1995) in order to fit our problem. We consider that a scenario is set of activities performed in a given context and at a given state of a design project. In the following section we will describe the industrial context and the scenario.

2. Design Scenario

The design activities that are undertaken in an industrial environment are varied and disparate and it is important to make a distinction between the initial and innovative design phases, where the information support is usually poorly structured and the activities are oriented toward creativity, and downstream activities which are concerned with embodiment design and detailed design phases, where the information support is very structured but not suitable for supporting design interactions and constraints elicitation.

2.1. Evaluation activities in design

We make a distinction between the class of design activities related to the production of a CAD representation (embodiment of a design solution) and another class of activities related to the evaluation of a design solution. It is possible to derive a more refined classification regarding these classes of activities, but at a first glance we will consider this level of distinction, i.e. downstream design and evaluation activities. The class of activities related to the evaluation of the design solutions can be compared to conducting a discourse on the solution which may result in redefining the solution itself (but in any case modifications of the CAD models are made at the same time). Evaluation activities mainly involve non geometric information such as pieces of text, schemas, etc. It is clear that there is a major difference between the production of a digital geometric object (a CAD model) which requires some specific modeling skills and the evaluation of a representation that requires expert competencies from various technical domains (manufacturing, mechanical, etc.).

Throughout the design process the modeling activities concerning the production of a CAD representation are undertaken individually and during asynchronous design phases. These activities require concentration and precision and are often carried out by experienced designers. Conversely, evaluation activities are often carried out via group work during design meetings at different stages of the design project and by various stakeholders. During these phases contradictory points of view can be expressed and tough debates may occur. However, evaluation may also be performed asynchronously when the use of complex evaluation tools or procedures are required. For example, when mechanical behavior simulation is required, or when manufacturing scenarios need to be performed, etc. In both cases it is necessary to keep traces of the evaluation results in a very synthetic way, accessible by all stakeholders and shared by everyone.

In those conditions we consider that it is important to differentiate the format of representation used by the designers for annotation from the format used for modeling. Referring to previous work (Zacklad et al., 2003) we propose to use an extraction of a full
CAD model as a main document. This extraction is a view of the object at a given time in the project and carries less semantic than a native format, which is for us an advantage since it allows an easier manipulation. Moreover, we have shown that the evaluation activities, which require annotations, did not require the entire complexity of the geometry.

2.2. Scenario of a 3D annotation activity

Current CAD systems provide functionalities for sharing models. However, most of these representations are digital models, three-dimensional and geometric in nature (i.e. CAD models). In contrast, the design constraints, as they account for requirements and information related to the design problem, are mainly expressed in a non-geometric way (the nature of a material, the manufacturing process, etc.). Annotations are a natural way for expressing these constraints and they provide intermediary representations that may support communication between the designers. This is due to the fact that they do not behave as closed objects (which cannot be acted upon as, for example plans) but rather as open objects that are not fully prescriptive (Vinck & Jeantet, 1995). They play the role of boundary objects (Star, 1988) - or cooperating features (Boujut & Laureillard, 2002). Their function is to represent the various points of view, specific to each profession and each background, and to provide the members with the means to take part in and to support discussions concerning these differences in such a way that a shared understanding may be achieved.

This annotation scenario is a projection of observed practices into an expected situation (see figure 1). Starting with a given state of the design, evaluations of the various stakeholders are required before the design review. The project leader produces an extraction of the 3D model of the design and publicises it. The design constraints can be expressed by displaying various predefined symbols and enriched by text comments (see section 4.4).

In order to prepare the design review the project leader may summarise the various annotations and build the agenda of the meeting so that all the points can be properly
addressed. The annotations can then be commented and discussed during the meeting and a decision can therefore be reached after the discussions. The next version of the design can be developed by the designers taking the annotations as a basis for their work.

The annotated extraction therefore carries a trace of the various expressions of the design constraints. These constraints, being produced by the various stakeholders, embed the expression of the rational of the various points of view regarding a specific problem. By indexing these annotations it is be easy to rebuild the various arguments involved for the given problem.

3. Background

Annotations play a crucial part in the design process for three reasons. Firstly, previous work (Guibert et al., 2005) has shown that annotations play an important role in the cognitive synchronization between designers. Furthermore, it was important to consider annotations not only as deictics (e.g. underlining, pointing, etc.) but also as containers for meaning in a figurative form such as arrows, pieces of mechanical parts, etc.

Secondly, we want to stress the important interface role played by the annotations. In fact, annotations are intermediary objects in the sense of Jeantet (Jeantet, 1998). They carry a certain meaning that in some cases may be clearly expressed, and they mediate the interactions of the designers.

Finally, another important dimension of annotations, which is of prime importance in design research today, concerns their ability to capture the rationale behind the design decision. In fact this aspect is very poorly addressed by current industrial tools and there is a clear need to develop specific tools which will help the designers to capture the rationale of the decisions in order to reuse or learn from their past experiences (Bracewell et al., 2003) and in line with previous work on design rational.

4. Application design and implementation

4.1. Aims of the design

The aim of the tool is two-fold: firstly it is intended to support a heterogeneous team of workers in the asynchronous design of an engineering artefact. In this case each member of the team works independently on the design, making modifications and adding annotations where necessary; secondly, the tool is intended to be used in the project review phase (typically at a milestone) when members of the team work synchronously in order to agree upon a design.
4.2. Description of the design

To help us devise the required functionality for the tool we adopted a scenario based approach. Using data obtained from previous studies, we constructed a plausible and typical design scenario involving six team members who work together in order to develop a bicycle trailer. The roles of each of the actors in the team are as follows:

- Designer 1. Using a CAD tool this actor is concerned with modelling parts of the artefact specified by the architect.
- Designer 2. This actor performs the same task as Designer 1, but works on different aspects of the artefact.
- Assembly. The main concern of this actor is the practicality of assembling parts of the artefact to form the final item.
- Marketing. In collaboration with the client, this actor defines the functional requirements of the product. The main focus is therefore the functionality and the ease of use of the final item.
- After Sales Service. This actor is concerned with the replaceable parts of the product; in particular, their accessibility in order to facilitate easy replacement.
- Leader. The head of the project whose overall role is to ensure the coherence of the design. Specifically, the leader is responsible for ensuring that the product adheres to the functional specification and that the design does not breach any technical constraints.

By analysing the video data obtained from previous studies and in line with other works in cognitive ergonomics (Darses et al., 2001) we were able to identify five broad types of annotations used in collaborative design (Table 1).

<table>
<thead>
<tr>
<th>Type of annotation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarification</td>
<td>highlights a particular problem for attention</td>
</tr>
<tr>
<td>Solution Proposition</td>
<td>a tentative solution</td>
</tr>
<tr>
<td>Solution Evaluation</td>
<td>a positive or negative evaluation</td>
</tr>
<tr>
<td>Solution Validation</td>
<td>the final validation or rejection of a solution</td>
</tr>
<tr>
<td>Technical constraints</td>
<td>related to a technical specialty</td>
</tr>
</tbody>
</table>

Table 1. Types of annotation identified from video data

Obviously, it is not always possible to classify definitively each single annotation as some annotations may fall into more than one category. Given that there may be some overlaps the classification of some annotations is quite subjective.

Symbols were defined to represent each type of annotation. The idea was for the user (being one of the design team) to attach the symbol to a part of the design and then to describe in text format the annotation in further detail. There is no restriction on who may perform an annotation and so each category of annotation may be used by any of the actors. However, annotations concerning technical constraints are defined according to the speciality of the user (for example, if a user is defined as being concerned with ‘Assembly’
then all the technical constraints that he or she defines will refer to that domain. Since any user can comment on the annotations of another user it is possible to develop a thread of annotations; in essence, this could document the justifications and underlying rationale towards a certain design choice.

In a product design review meeting, one of the most critical aspects is being able to see all of the comments on the design that have been previously made by members of the design team in order to identify problem areas. The 3D tool was designed so that it is possible to view all of the annotations together at one time. Whilst this can mean that the screen may become cluttered with annotations, the advantage is that it is immediately obvious from a simple glance where the potential problems lie in the design. Rather than simply viewing all of the annotations, it can be useful to order the annotations according to their type (e.g. clarification, solution proposition, breach of technical constraint, etc.) or according to the originator of the annotation (e.g. designer1, marketing, etc.). This would allow the project leader to see, not only the localised areas, but to see, for example, all of the annotations concerned with a particular technical constraint.

![Figure 2: Relationship in the 3D tool between a project, milestones, views, and annotations](image)

### 4.3. Normal use of the 3D tool in the collaborative design process

The process of designing a product occurs in several stages during which the product is continually modified and reviewed. The review meetings, which involve all of the design team, typically occur at various critical milestones throughout the design period.

The developed software is intended to be used asynchronously by members of the design team to help with the goal of supporting the synchronous review of the project at the milestone periods. To manage this process with the 3D tool, the architect (or project leader) first creates a ‘project’, typically there is only one project for each product (figure 2). The architect then creates the first of several ‘milestones’. In this milestone, each team member has their own ‘view’ (3D geometry) of the product for annotation. In this way, several
annotated views of the product exist for one milestone, and each view may contain several annotations. The aim of the review meeting is for the members of the design team to agree upon the required design for that milestone. This process involves resolving any problems with the current design by resolving the various annotations made by each of the team members. When the review meeting is finished, the team members will modify the product design according to the suggestions and begin the next phase. For the second milestone, the architect will create a new "milestone" so that members can begin the process again. The product design is finalized with the last milestone. In this way, there is a tractable record of the annotations which resulted in design modifications throughout the project period.

Conceptually, projects, milestones and annotations, etc., are linked according to figure 3 which may be read as follows: a project, which is identified by its project ID and name, contains one or more milestones. To identify the various milestones associated with a project, there is a project milestone ID, associated name, and date. The milestones are composed of a number of views (again identifiable by their ID). Annotations belong to a particular view (that is, one view can contain many different annotations). The annotations (which in the tool are text descriptions) are identifiable by their ID, date of creation, and...
description. The annotation is composed of one or more symbols which are linked to one of the five types of annotation via stating the ‘symbol type’. An actor, (i.e. a member of the design team) is identifiable by an ID, surname and first name, email address and password. This actor possesses a certain speciality (e.g. designer, marketer, architect, etc) and works on a particular project.

In order to manage the various views, annotations, and milestones, etc. a relational database was defined consisting of eight tables. This provided the framework for supporting annotation related queries (such as “what are all the annotations concerning marketing?” or “what were the annotations made in the previous milestone”, etc.) and gives us a valuable permanent tractable record of the entire design process.

4.4. Implementation

The database was implemented using MySQL and the 3D annotation tool was implemented in Java3D (Java 3D). The symbols, which were intended to be attached to the designed product and which represented one of the different types of annotations, were created using SolidWorks (Solidworks). SolidWorks is a CAD tool used for 3D modeling which can produce three dimensional forms translated in VRML format. The decision to work in VRML format at the symbol level was motivated by the fact that many CAD packages, which are used by designers, generate this format. It was envisaged that having the same format for the symbols and for the basic product design would help to reduce implementation problems. Both the 3D image of the product and the symbols in VRML format were imported into the 3D annotation tool. It was at this point that a major problem was encountered; whilst both of these images could be easily manipulated in the 3D tool, it proved hard to specify geometrically (using the mouse) exactly where on the 3D design the symbol should be attached. The crux of the problem was using 3DJava methods to interact with a VRML image. Currently, we have solved the problem albeit not in a very satisfactory way; the user can attach a symbol to a design and provide a suitable annotation, however, the process for doing this is not intuitively easy to use. Figure 4 shows a screenshot of the tool in use.

5. Discussion and future work

In this paper we have described the design of a 3D annotation tool for supporting collaborative design work. At present, we do have any results of the tool in real-life usage,
but we believe that by exposing the design, the rationale behind the design, and some preliminary thoughts on how the work should progress, it is a useful contribution in working towards a tool which supports annotation as being an important element of collaborative design. Currently, the implementation of the tool requires further work to make it more usable and after this work has been completed we aim to conduct a series of experiments using the tool in a real-life design situation. The results of this phase should provide feedback for us to redesign and improve the tool. At this stage we are interested in assessing the ability of the tool to support various points of view, and also how it may be used to provide support for arguments of different design choices. However, our ultimate goal is more general in that we would like to use this tool as a means to assess the role that annotation plays in providing cognitive support for collaborative design.

6. References


