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ANNOTATION AND KNOWLEDGE CREATION

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1. Introduction

During collaborative design episodes, product representations are mostly numerical models (especially during embodiment design phases). Today CAD systems provide functionalities for sharing models and sometimes even annotations (attached text, images…). But these functionalities remain poorly employed.

In our study (mainly based on ethnographic fieldwork in various companies and some experimental studies of collaborative design situations such as the one presented in [Jagodzinski & al. 2000] and [Cross & al. 1996]), we observed that the representations created and used in such co-operative situations had two main functions. We categorise them as follows:

- Technical information presentation referring to the product (including manufacturing process)
- Coordination of the collaborative design work.

In fact, we observed that the design participants were coordinating their activity up to a certain extend by means of these representations.

Through our field studies we had the opportunity to experiment how these shared representations could mediate knowledge creation on various aspects (design process, product, problem, …).

We will then present here a knowledge categorisation where we consider three categories:

- Scientific knowledge
- Group specific knowledge, we call contextual knowledge or boundary knowledge,
- Knowledge-in-action (referring to [Schön 1991])

These three categories must be considered as elements of our demonstration as we have no ambition make general developments at this level. But we stress on the intermediate category of knowledge (i.e. contextual knowledge or boundary knowledge) as we think it is of prime importance in the collaborative work and particularly in design cooperation. More precisely, during the fieldwork we will expose here, we proposed to use specific annotations in order to elicit specific rules associated to different design domains. But we observed that some rules were mainly cross domain, and in that sense we called them “interface rules”, allowing to bridge different domains of expertise. Going further on in our investigations led us to hypothesise that these annotations were acting as symbols and elements of a local language, group specific but generic enough to be shared and reused in future designs. Finally, annotations must be addressed at three levels:

- Physical level: representation of specific elements associated to the product (i.e. manufacturing process, …)
- Knowledge level
- Symbolic level: Local language that allows people to communicate that they couldn’t communicate before.

As a conclusion, we argue that providing annotation facilities within CAD systems is not enough. Regarding what we exposed before we think that a work must be done in formalising organisation that

will support the annotation process in all its dimensions. For example functionalities of creating, storing retrieving new symbols should be implemented. Rules elicitations and formalisation should be implemented too, without forgetting the level of organizational learning. Indeed, we consider that the process of creating the rule is as much important as the rule itself [Boujut & Laureillard 2002].

2. Empirical background: design co-operation and intermediary objects

Design co-operation is becoming a big issue in research today. In fact, companies under market pressure tend to reorganise themselves in order to find more efficient organisations. From now on cross functional teams were widely employed for answering this challenge. Companies have developed the concept of business unit independent from each other in terms of results and sometimes driven by the market. But if the independence is apparent, and in fact there is a real need for co-operating in order to reach global goals. This kind of organisation produces wide informal networks, that people has developed in order to achieve their personal and global objectives. Project organisations see the same phenomenon: in the same time as managers develop more tight control procedures, informal communication and "underground co-operation" develops. But today, a new parameter appears that was not so important in the past years. The internationalisation of the companies, and the products. We could call that phenomenon "globalisation", but this is not what it is important to develop here. The simple fact that the participants of a design team can no longer meet physically because of the distance, lead to use new kinds of tools, we call collaborative engineering tools. Among them we find shared spaces, video conferencing, shared databases (PDM), etc.. But then a new difficulty appears, that was not really apparent in the past, though it was already present. The cultural differences, i.e. the design practices, negotiation habits, decision making processes… lead to misunderstandings, quality problems, and finally waste of time and effort.

Our hypothesis here is that people need to develop specific local knowledge that allow them to actually co-operate, that is to say, co-create and collectively produce something (a design, a procedure, requirements…). This knowledge creation or building process involves specific mediating objects that we call "intermediary objects" [Boujut & Blanco 2002] and which are of prime importance in this complex process.

This hypothesis is grounded in more than five years of empirical research within companies and among design offices and various technical departments of big companies in France. Our research methodology is mainly based on empirical studies using ethnographic based observing methods. The researchers, usually PhD students spend long periods of time immersed in design teams as designers. The interest of this methodology relies in the fine descriptions of actual design practices and particularly it gives access to the design process in real world settings. This method allows to access all the informal communication level that remains mostly invisible to the observers and managers. We then access what Moisdon and Weil [Moisdon & Weil 1992] defined as "the technician adhocracy" referring to Mintzberg [Mintzberg 1981].

In the following we will show how the annotation process is at the centre of design co-operation. We observed this process in configurations where participants were in the same location, but we think this process is becoming even more critical in remote configurations. That is why we will analyse some specific functionalities of collaborative design tools with regards to our propositions.

3. Annotations as instrument for co-operation: a case study

The case study we will consider here is drawn from a field work we carried out in a great industrial vehicle company. We have had the opportunity to participate to the design of a new front axle and particularly observe the informal exchanges during this process. This case study has been developed more widely in [Boujut & Blanco 2002] and [Boujut & Laureillard 2002], we want to present here the result of a negotiation phase during which the participants had to create specific annotations in order to achieve their design work.

During this work we have been stricken by the distance between the formal organisation, described in the charts and procedures and the actual local organisation developed by the technicians and engineers in order to reach their objectives. Among the numerous informal tools and instruments, they had developed specific symbols, we called "cooperating features" in [Boujut & Laureillard 2002] that were acting as intermediary objects in the co-operative process we were observing.

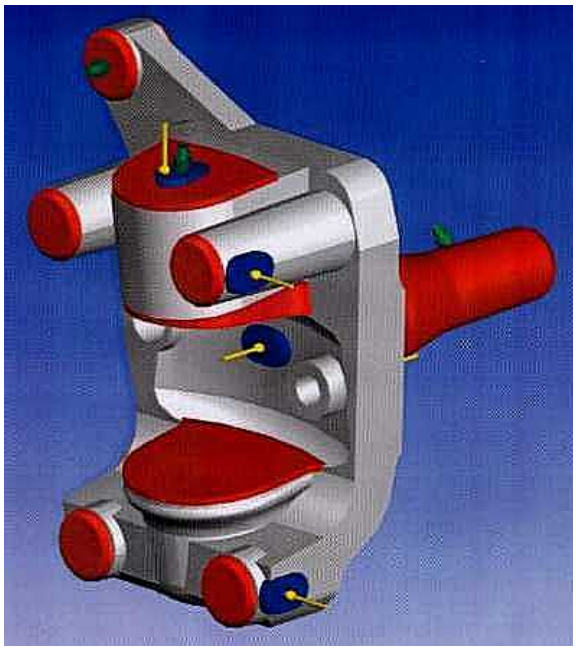

Figure 1. Annotations on a CAD model

Figure 1 shows the result of a negotiation process that involved three participants from three different departments (namely the design office, manufacturing engineering and the forging plant). It is out of the scope of this paper to tell the whole story, and we will only focus on the main features of the case.
At the beginning of the observation, the three participants were already involved in a longstanding collaboration and the project we were observing could have been one among many other similar projects. Although we observed a quite important amount of informal co-operation, we noticed that this co-operation was fairly incomplete and far to be systematic. This led to some crisis during the process and we had the opportunity to witness some tough negotiations between the participants. At this occasion, we noticed that the representations involved were quite poor and not adapted to the context of use. More precisely the information required was not present although it was existing somewhere else. We drew the conclusion that:

- There was a need to provide means for developing a more systematic co-operation
- Their was a need to provide more adapted information to the participants, earlier in process.

We then started a process of elicitation, interviewing the participants and asking them to describe what kind of information they could provide, at the early stage of the process, on the basis of a CAD model such as the one presented in figure 1. This elicitation process was richer than we have imagined and led to the creation of specific symbols representing some process features (for example control points). These symbols placed onto the CAD model, gave specific annotations linked to specific knowledge on the product and on the manufacturing process. But furthermore, the fact of materialising some process features gave the participants some useful information that helped them to propose modifications. In this case the annotation have been used by the participant as instruments for co-operation. These annotations could be compared to Star's boundary objects [Star 1989] in the way that they are the expression of some shared knowledge, and therefore they allow negotiation. But on the other hand the annotations make reference to an objective reality: i.e. some process characteristics. We will see in the next section how the dynamics of the annotation can be at the centre of an argumentative process.

3.1 Annotation functionalities

Many commercial software provide annotation functionalities, but very few allow the creation, storing or sorting of the annotation symbols. Annotations are considered as mere pointers, without other interest than showing, and drawing the attention of the designers. We showed in section 2 that annotations could be farther more.

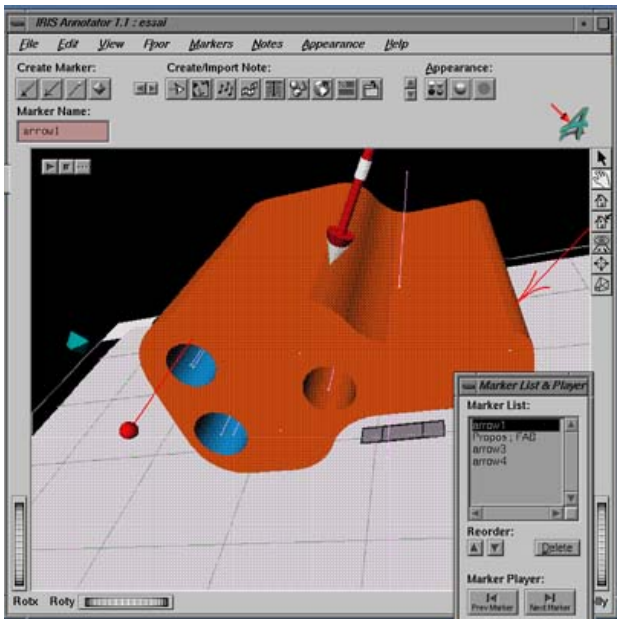

Figure 2. Annotations on a commercial software (Iris Annotator from Silicon Graphics)

Figure 2 Shows an example of a commercial software that provides annotation functionalities. In that software, symbols can be associated with sound, image or linked to a specific application that is launched when the symbol is activated. This kind of software is dedicated to asynchronous communication and therefore cannot be used in synchronous co-operation. However, this is a very interesting basis for initiating communication between different participants.

4. Argumentation and knowledge building

4.1 From information sharing …

The observations described above showed a situation where the participants of the design process were sharing information on the process by the means of annotation on the CAD model. They used these annotations in a process of argumentation in order to express a view point. This process has been well described by Martin and al. in [Martin & al. 2001] in the case of project reviews in the aerospace industry. But at this level a clarification is necessary for understanding the different levels at which the annotation work, and the dynamics of interactions during argumentative processes. We will take a quite classical typology composed of four entities.

At the first level we have *data* which are composed of simple facts. For example in our case, the weight of the part is a data, but the symbol, as an object, is also considered as a data. A data can easily be stored in a data base or in any other computerised structure. The same for the *information*, which is however more complex. An information is a data or a set of data in a specific context. For example, the positioning symbols of the figure 1, represent a data if they are considered alone, but they become an information if they are considered as three symbols representing the positioning scenario of the part *a*, of the project *P*, and have been placed there by M. *y*. These elements of context are of course of prime importance for the designers in order to understand why theses symbols have been placed there. This level is also easily stored in computer systems. Information systems, knowledge managements systems (although we think the term *knowledge* is not appropriate here) provide very good tools for storing data and information.

But we noticed during our fieldwork that there was obviously fare more than data and information involved in a co-operative process. The arguments used by the participants, the rules they were using was more complex than the participants were even able to express. But on the other hand the fact that they expressed the rules and formalised the symbols produced a learning process. We conclude that the participants were building something we called *knowledge* and that Schön described as “personal repository of knowledge” which allows the participants to actually perform their action.

4.2 … To knowledge building

On the top of this classification, we find what people usually call "knowledge" which are in fact *theories.* Our purpose here is not to come into epistemology or have a general discourse on Knowledge, rather we want to clarify our pragmatic point of view that will help us to show the complexity of annotation processes and its deep interrelation with knowledge. For us a theory is the externalisation or formalisation of scientific knowledge and it is usually considered as the ultimate form of generalisation. It can be presented in books or scientific reviews. This form is totally independent of the context and is supposed to be applied by the engineers in order to predict some physical phenomenon or more generally to predict the state of the world. A typical theory is the theory of solid mechanics that is used by many engineers in order to predict the failure of mechanical parts.

But theories are insufficient, and Schön [Schön 1991] showed that their was another source of knowledge for practitioners (including engineer). This kind of knowledge is rooted in the action itself and called "knowledge-in-action". For Schön knowledge-in-action is mainly composed of a "personal repository" that everyone creates and enriches by its daily practice. For use *knowledge* is fundamentally personal and cannot be externalised as is.

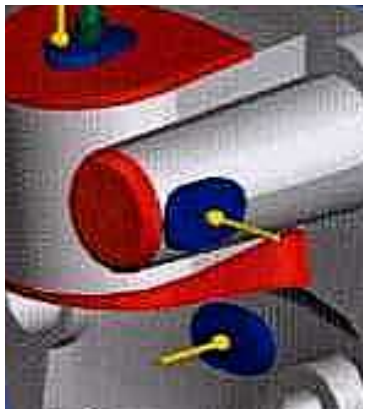

Figure 3. Materialisation of a new "boundary knowledge"

Both scientific knowledge and knowledge-in-action are necessary for performing a technical work. But if scientific knowledge can be built from theories, knowledge-in-action is drawn from the action itself. The first being a reference and the source of education, when the second is a transformation and a mix of different experiences together with a translation of the theories guiding the professional action.

But during our fieldworks on co-operative processes, we have been faced to another level of knowledge. When observing the dynamics of co-operation and particularly through annotation processes, we noticed that the involved participants were sharing a level of knowledge that allowed them to communicate. In a first time the process of eliciting the rules associated with the symbols have created a learning process and the participants have learnt some new characteristics especially concerning the domain of their colleagues. This cross-learning process initiated at this time developed even more when the participants had to discuss their respective propositions. When the participants had to argument on their own propositions, they were forced to elicit their rational and formulate some rules that were transformed or incorporated by the others, creating new knowledge. We propose to call this knowledge "*contextual knowledge"* because of its local and contextual character. But the context here refers to a group and the key point is that this knowledge is shared among a small group.

To go further on we can add that the knowledge involved during the argumentative process was a mix of domain specific knowledge and "*boundary knowledge*", that was created during interaction and that cannot be classified in one or the other specific domain. For example, figure 3 shows a blue symbol that is a kind of boss on the forged part (see figure 1). This boss has been invented by the participants in order to deal with a technical problem that they were facing. This technical problem led them to invent this symbol that is more than a mere representation but refers to a modification of the part's geometry and has a real impact on the manufacturing process. This symbol has been reused in other projects together with the knowledge associated.

5. Conclusion

This paper must be considered as a basis for discussion. Our goal was to provide an unusual view upon co-operative processes. More precisely, we wanted to show the importance of annotative processes in the dynamics of co-operation. Our field studies led us to discover the importance of this kind of objects, within the frame of design offices working on CAD systems dealing with complex models, and involving deeply interwoven process constraints. Our approach is centred on human interactions and we considered the tools as instruments of the design action.

We want finally stress here that annotations are more than mere geometrical pointers or stickers but have a definitive action on the co-operative process itself. An annotation are firstly an *object* (mostly numerical), but it also makes sense and therefore it is secondly the materialisation of *contextual knowledge*; thirdly an annotation is a *convention*, exactly as industrial drawing is a convention for designers. This level of convention is of course far more local but still, as far as the meaning is shared among a group and remains persistent we consider these symbols as convention among the group. This point is fundamental when we think of design reuse.

Of course many further work remains to be done, especially in the direction of the dynamics of annotations and particularly the argumentative processes involved. Argumentation is an important research field in linguistic and cognitive sciences, and we think there is much to do with understanding the relations between annotative processes and argumentative processes. Another research challenge relies in the production of computer tools that could deal with either annotation, complex information storing/retrieving and the link with commercial CAD tools, above the simple cosmetic arrangements we find today on the market.

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