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HARNESSING NON STRUCTURED INFORMATION IN INTEGRATED DESIGN TEAM

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Abstract

The aim of this paper is to focus on the use of draft and sketches in group understanding within Integrated-Team. We higlight the need of a communication tool that supports and structures numerical drafting and treatment for capitalisation of those drafts connected to messages. Then we show some interface of the tool that we have developped.

Keywords: Cooperative design, collaborative design tools, distributed design

1 Introduction

Concurrent Engineering approaches heavily rely on reliable and efficient shared information among people involved in the design: Engineering, industrialisation and even manufacturing. Concurrent Engineering (CE) takes into account the well-known QCD (Quality, Cost and Delay) objectives. This organisation of design activity is generally opposed to the sequential engineering approach These two design organisation introduce various ways of working: In the sequential methods, work starts from receiving results from upstream task, while carrying out concurrent tasks needs to exchange preliminary information. In that context of integrated design methodology, the nature of information exchanged by the design team changes.
Most of the information exchanged in sequential engineering are results of the different tasks. Actors who are responsible of the downstream task can trust it. In CE, actors of the design have to exchange preliminary information that allow the others to work simultaneously. Those preliminary information may be non validated, incomplete, uncertain and ambiguous. The actors have to discuss ideas, drafts of solutions etc… These information are partially true, and have to be updated often. The nature of information is then different and the role of Product Data Management (PDM) is therefore increasing. But the actual PDM systems that have to support this co-operation had been mostly designed for sequential design process. Preliminary information is not managed in these systems.
Many companies had first located design team in large office dedicated to the project to facilitate exchanges. These exchanges were mainly performed verbally face-to-face or on the phone or by e-mail. Furthermore nowadays the design teams are often world-wide distributed. And information is therefore poorly controlled. Sharing is not really managed and there is no capitalisation of problems treated during the design.

Taking into account these new requirements, we characterise the type of information exchanged in Integrated Team.[1] We focused on information Structuration model. In order to meet the rigour needs of companies without going down on a too fine level of granularity, we choose an instructional design of the information significance. We then consider that the construction of a sentence corresponds to combine instructions formulated in term of variables, which provide a sense to the statement. Exchanged information is then an abstracted entity, a theoretical object which consists of:

- Linguistic components which build the significance of information starting from instructions.
- Rhetoric components which bring a sense to information by addition of contextual information.

Thanks to this instructional design of the information significance, we characterise different types of information [1] :

- *Structured-Information* (*SI*), linguistic and rhetoric components of the *SI* are generally imposed.
- *Semi-Structured-Information* (*SSI*), linguistic components of the *SSI* are little formalised and rhetoric components could be parsimonious.
- *Non-Structured-Information* (*NSI*), the *NSI* are very little formalised and the rhetoric components can be very light if they ensure a sufficient degree of relevance for the comprehension of information by the receiver.

The MICA approach [2] (a specific interactive messaging system) has been developed and experimented in order to harness of *NSI* and to capitalise on relevant information exchanges. Also a Groupware tool called MICA, was created through an Intranet. It has been implemented and put into operation in an engineering team of twenty people in May 1998. Some return on experience has already shown improvement of the efficiency of the Integrated Team. Nevertheless, this kind of capitalisation from linguistic data is limited because of the graphical *NSI* lack. Sketching takes a large place in the group understanding of technical problems. Sketches could be considered as *Graphical Non Structured Information (GNSI)*. First version of MICA only takes into account linguistic data but does not take care of *GNSI* management.

In this paper we present how we implemented MICA-Graph. This tool based on web technology allows design team to exchange both textual and graphical *NSI*. In section 2, we emphasise on the theoretical and empirical bases of this work. From this analysis of the *NSI* flow in design activity, we propose requirements that the tool is based on. Then in section 3 we present the actual state of the tool.

2 Role of Sketch in collaborative design

2.1 Sketches as intermediary objects

In order to understand *NSI* flow in design activities we had carried out empirical studies of design. [4][5][6]
We had studied limited situations, often only involving 3 or 5 people, for a limited period (one to several hours). An audio-visual recording device follows these actors. The materials submitted for analysis thus correspond to working sessions set up and instrumented for our

investigation. The sub-review design activities are distributed between several actors with varying know-how and action-based logic, belonging to different worlds.
The situation we mainly refer in this paper is a situation where a technical solution is being designed in response to a problem given at the start of the session. The actors are teachers specialised in what they do during the design session: two functional specialists, two manufacturing specialists and one structural analysis specialist. The session was recorded using a conventional video camera. It covers 6 hours of recording. The different A3 sheets used were recovered. Other field studies in industry allow us to have a larger view of the design activity and the information flow in design office. In these field studies in mechanical engineering design office, we could observe long term design projects and observe design reviews [5]

We are especially interested in the status and role of intermediary objects such as scribbled drawings or annotations on drawings made by several designers. In our investigations into innovation and design activities, intermediary objects are always present. We have already underlined their number and diversity, as well as the importance and multiplicity of interactions channelled by them. Depending on the case, they have various statuses: They are used to back up action, to bring information, to make intentions or compromises come true, to impose constraints on actors, to mediate between diverging logic-based actions, etc. When studied, they above all reveal actors, interactions, organisations and effective processes. In design processes, one can thus come across drafts and industrial drawings, assumed to be the vectors of communication between specialists. Identifying them, counting them and describing the area in which they circulate helps to visualise the design processes and underline possible differences from one process to another.

As revealing agents, these graphic objects help to describe the process and its timing: work periods of varying intensity, breaks in time. As mediators, they refer to changes in the nature of the job at hand and in exchanges between the actors. They also translate and constitute representations of the product during design. They are the product of this activity, of which they leave a partial trace. They are also resources mobilised by the actors to convince, explain, remember, revise, imagine, agree, etc. They thus mark the activity, the state of relations between the actors and the current representation of the future product [7].

2.2 Sketches as a process of building conventional support

The analysis of design sketch shows that the knowledge of their construction process is necessary to be able to understand the sketch. The actors created, during the process, some symbolic devices which were connected to semantic in a local convention. This allowed them to let some part of the device in a low definition level: fuzzy and partial. Sketches play a mediating role in a collective socio-cognitive process. They act, primarily, as individual and collective memory supports. They take the strain off the memory, and prevent actors from repeating what has already been said or demonstrated. They are therefore cognitive artefacts, according to Norman's definition of the term. For instance, the participants did not describe precisely what they were talking about, they showed the different elements they wanted to highlight with a finger or a pen and they used diectic words to point them. For example, an actor said: "that will be difficult to manufacture" (showing the elements concerned with his pen)

We want to highlight the fact that the sketches act as pragmatic conventional supports. Those conventional supports are negotiated in the interactions between actors, even if they can also use a higher level of convention as cultural ones, shared by the actors (the rules of industrial drawing in our case). The sense of the sketch is built in the action process and the conventions which allow this interpretation are quite local. Rhetoric components of sketches are specific and part of the linguistic components are built within the action itself. This suggest that the sketches are synchronous communication tool. This characteristic of *GNSI* is important in order to imagine design tool able to support *GNSI* in an asynchronous communication process, furthermore, in order to involve sketches in a knowledge capitalisation process. Indeed local conventions which allow interpretations are built in the interaction process. They won't be available for the actors that were not involved in the process itself. Our hypothesis is that we could trace building process of sketches by keeping historic dependencies. We claim that it could help the actor to understand the sketches. We would explain in section 3.4 implementation of this hypothesis.

2.3 Characterise different kinds of sketches

In order to help the actor to get context of interpretation of the sketches [8], we wanted to qualify the different types of sketch and to keep the drawer intention. This part is based on different typologies of sketches. Ferguson [8] identifies three kinds of sketches : thinking, talking, prescriptive. The situation of the experiment that we have carried out emphases on the second category of sketches. The collaborative activity involved many talking sketches. On the contrary, studies based on single designer activity mainly point out the thinking role of sketches. Industrial observations of design activity show that the three categories could occur. This typology define both intention of the emitter and the publication area. Observations show that a sketch could move from a category to another one during the unfolding of design activity. A thinking sketch could be published for assessment by the group and later, becomes prescriptive to transmit information to another actor.

Goel [3] suggests another way to characterise the evolution of sketches in he design process: the transformations typology. He identifies two types of operations occurring between successive sketches in the early stages of design: lateral and vertical transformations. A lateral transformation movement goes from one idea to a slightly different idea. Vertical express a movement from one idea to a detail or an extract of it. The role of the sketches depends on their status and the evolution between two successive sketches. According to Fergusson and Goel typologies, we can identify six different categories of sketches that allow us to give to the designers elements of context to interpret sketches.

2.4 Allowing symbolic annotation

Sketches help to structure design activities and collective cognitive processes. They are used to clarify and compare opposing points of view expressed in different languages, thereby creating a meaning that can be understood by everyone. These interactions generate mutual understanding. Some objects thus become general references, and support common conventions. They act as conventional bases for action, created according to principles that everyone is familiar with and accepts. Specifications and engineering drawings are typical examples of conventional objects. When creating shared representations, such as sketches participants are involved in a process of creating local conventions that allow to build a basis for co-operating. Indeed, those conventions widely borrow from existing conventions such as industrial drawing or various standards. In sketches, it is generally easy to recognise some of the industrial drawing convention, but without the context it is difficult to go further on in the understanding of the sketch. We claim that developing co-operation implies systematising the creation of local conventions shared by a group and that can be reused. That means it is important to allow the designers to create symbols that support shared knowledge. They also could capitalise those symbols or use predefine symbols built in previous co-operation situation. That constitute elements of a learning process of co-operation within the design team. The designers have to define themselves the relevant type co-operating feature as defined by boujut [5].

3 Proposition of the tool

3.1 Principle of software architecture

To make concrete our specifications, we had programmed several MICA tool, for the last one, among the various possibilities of software architecture, our criteria of choice are mainly stability and the capability to use different customer machines, that is why we choose the servlets technology. An among the various types of engines of servlets, our choice is the external engines of servlets : the virtual machine turns outside the server. Of course requests sent to the Web server and which concern Servlets will be transmitted to the engine of servlets by using the TCP/IP protocol. This type of server is stable because a stopping of the Web server does not influence the engine of Servlets and vice versa. Moreover since the virtual machine is external with the Web server, it can turn on any machine, we will be able to even plan to install several virtual machines for a same Web server.
In particular we chose Tomcat of the Apache foundation, because it turns on a very significant number of different operating systems, which it is very well integrated into the server Apache, and that it is distributed in the terms of a license in free software. From these characteristics rises that it is very simple to be documented on this engine and that its development is very intense (http://java.apache.org).

3.2 MICA tool : specific interactive messaging system

As mentionned in the introduction : in the context of CE [9], the interactions between the members of the integrated team are carried out mostly via dialogues. We consider that the whole of the *INS* constituting the dialogues exchanged within Team-Integrated can be divided into topics of negotiation. Thus, it is possible to add some characteristics of structuration to an *INS* by associating contextual information to him specifying to which negotiation it refers [1]. However a negotiation can be made up many *INS*, not to repeat contextual information "refers to such negotiation" for each *INS*, we propose to gather them in a same document or "forms". with each form is associated an object with negotiation. To refine the knowledge history of the negotiation, the *INS* are gathered with their chronology of associated creation. Moreover, the general outline of the negotiation of Baker [10] highlights that a negotiation consists of three phases (Fig. 1) :

- "Initial State" which starts the negotiation by the means of a question, a report or a request,
- "State of negotiation", which is a phase where various people intervene in the negotiation,
- "Final State" at the time which a decision is made to close the negotiation.

The figure shows an interface of MICA form using the three states.

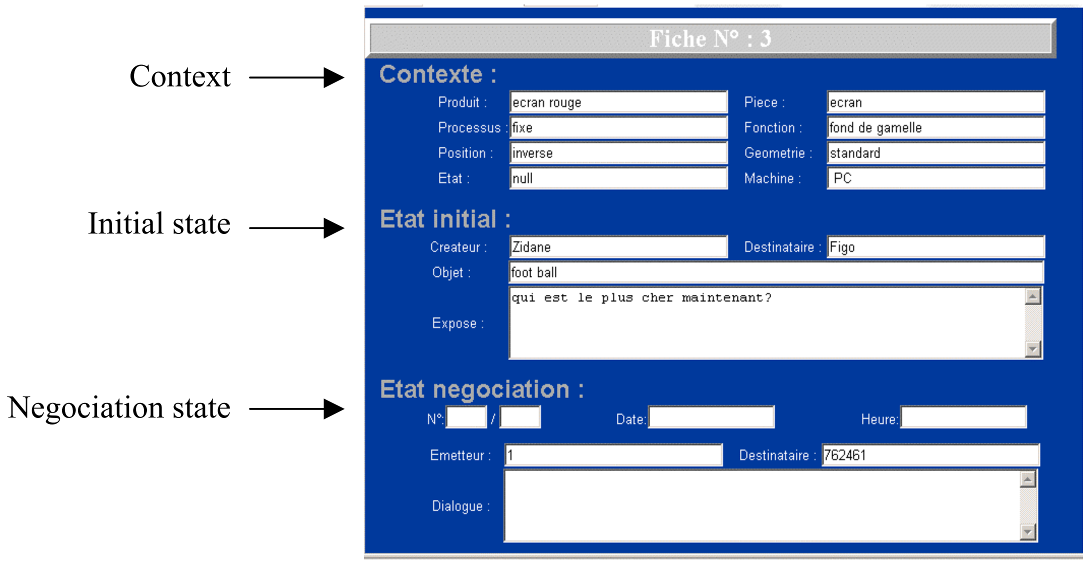

Figure 1. An example of MICA form

After having upgraded MICA form by a new negaciation state, the transmitter can attract the attention, on a form, of one or more members of Integrated-Team by sending an alert message. It does not prevent all the members from having access in reading all the forms. On the other hand they cannot modify existing data. This is state of the tool that was experimented in an industrial context during six months. We decided to add some functionalities relative to the sketches. They are described in the followed section.

3.3 MICA-Graph

The aim of MICA-Graph is to allow to associate sketches to the MICA form. We have highlighted in section 2 that it is important to follow the sketches modifications and steps present in the same final draft. We have developped a structure of layers in order track the process [2][6]. Indeed, if an actor wish to draw a sketch, he has the possibility to access to the interface (Fig. 2). First of all, the actor has the choice either to start with a blank paper or an existing visual document like an industrial design, a sketch , a picture, etc. Then the actor can use a sketching area where he can draw by "freehand" with his mouse or with an electronic pencil on a graphical table.

In this context, the actor has a pencil with different colors and different thickness of the feature. Then, he can express himself much more easily than in using textual information with predefined police (for instance : Times New Roman, Arial, etc.) or with actual design industrial software which hardly allow to draw with freehand. Obviously he can use different type of gum which make possible to erase only his production or also the initial sketch. The actor has at disposal several others functionalities such as zoom in or out, etc.

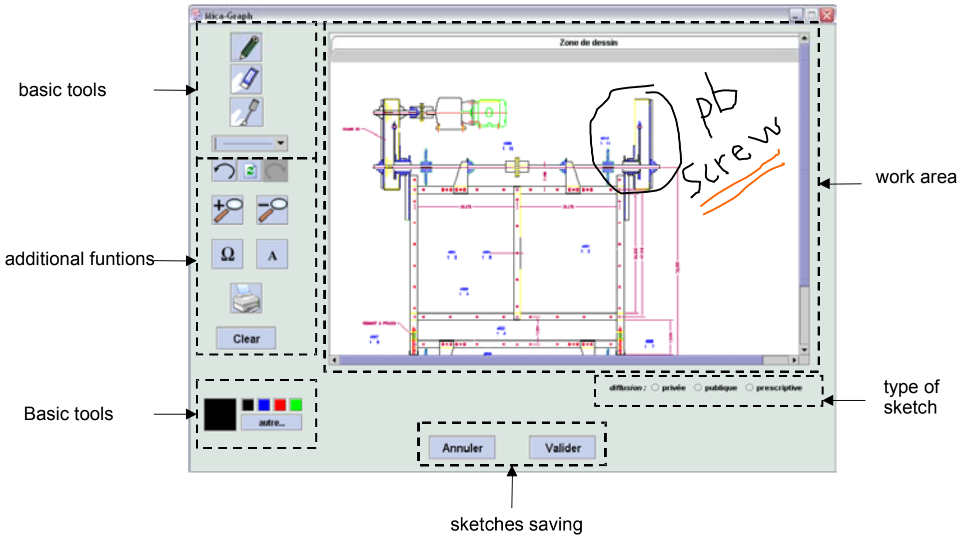

Figure 2. An interface of MICA-Graph : view of the sketching area of MICA-Graph

To add information to the sketch drawn, with the Fergusson point of view [8] : thinking, talking and prescriptive, we have slightly modify his proposition in respectively private, public and prescriptive because these last words are instantly more understandable by users. So if the actor assess that his production worths well, he can save it for himself to keep this idea in mind, he saves it in its private area. Otherwise, he can choose to offer his contribution to the team in order to debate of his proposition. Then each actor of the team can give his opinion with textual information. He can also modify the sketches with added design information thanks to the sketching area. His last possibility is to characterize his production with a prescriptive statut. In this case, his proposition can not any more be modified and each member of the team has to follow his prescription. If the layer has a public or prescriptive statut, then a small representation of the sketch is added on the negociation state as an icon. (Fig. 3).

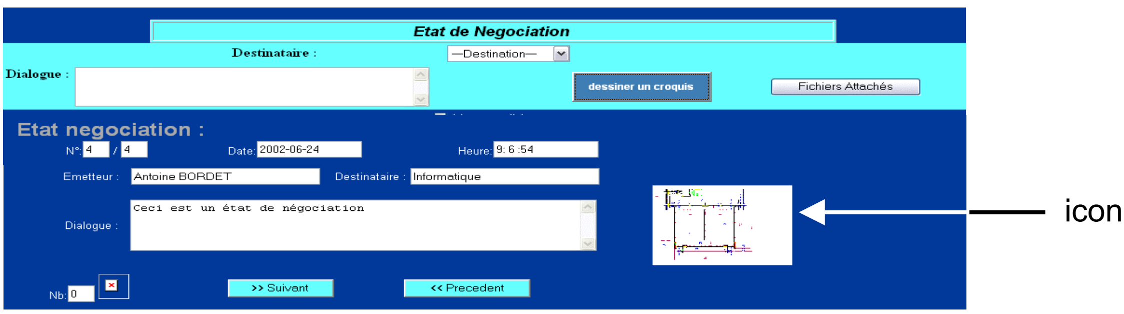

Figure 3. An interface of MICA-Graph : view of negociation state with associated sketch ico

3.4 Historical tree structure of sketches

We have highlighted the difficulty to track the different steps of a sketch out of the drawing process. It is also impossible to identify in an actual papper sketch the valid elements from the aborted solutions. It is important to follow the sketches modifications and to track the different sketch levels and steps present in the same final draft. We also want to know who had drawn on it. So we choose a tree structure with two more way of characterisation of the sketches wit the Goel point of view [3] : lateral transformations (one idea to a slightly different idea) and vertical transformations (from one idea to a detail or an extract of it). And we adopt the following structure : to show a small representation of the sketch and to place the new sketch with a link with the old one : under the old one in the case of a vertical transformation or on the right in the case of a lateral transformation (Fig. 4).

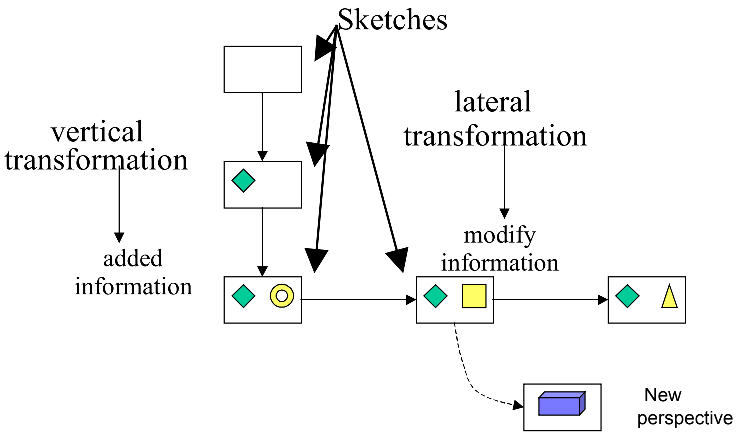

Figure 4. Historical tree structure of sketches : representation of steps of the sketch building process

To create a new sketch, the actor has the possibility to choose among any of the sketches in the tree structure the more suitable in his context for his purpose. To facilitate this use in the MICA-Graph, the interface is split into two areas on the screen (Fig. 5), one with sketch structure tree and the other one with selected sketch. If the actor validate his choice, the interface of sketching area appears (Fig. 2). Then he can produce new inscription using this sketch as a background. This new production will be saved as a sketch entity. Then it will appear in the historical tree as a vertical or latteral transformation of the background sketch according to the choice the actor.

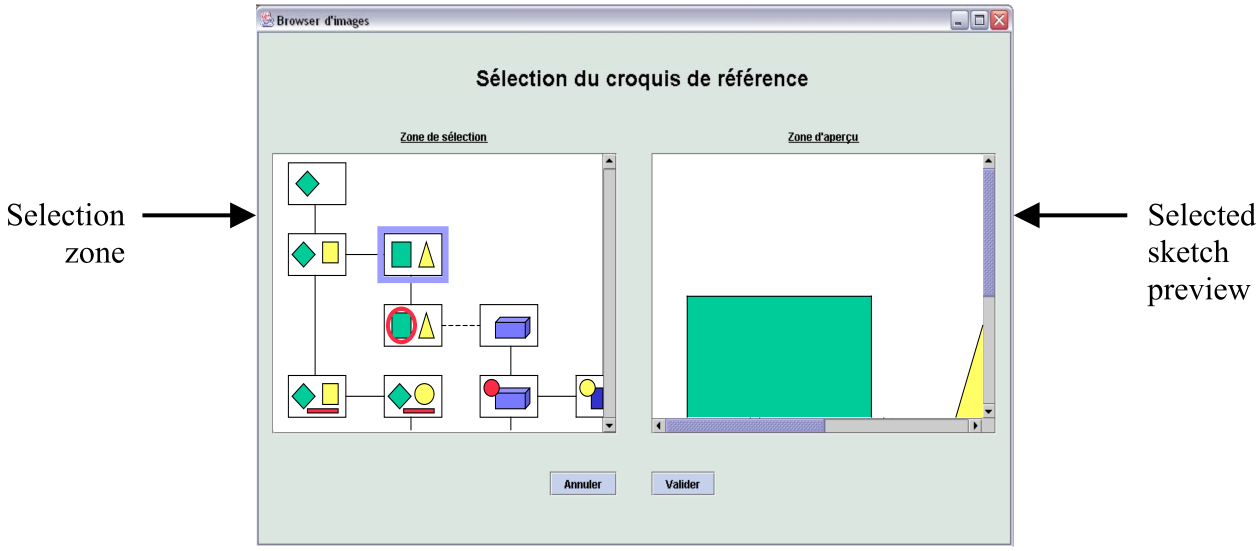

Figure 5. An interface of MICA-Graph : screen of sketch selection

3.5 Symbols library and annotations

During the design, in the context of specific knowledge domain, some local conventions were embedded in the sketches and remainly mainly tacit, therefore they carried no memory of the knowledge involved in their production. An important issue is the creation of local conventions that are explicit and shared by the group. To fulfil this need, we offer the possibility to use symbol . This symbol can be created during the exchange. This way, the co-operation with MICA-Graph intends to increase the creation of local convention, that is to say symbol wich could create a core of shared knowledge within a group of designer or expert. The symbol created could be capitalised in a symbol library. Iit is a kind of predefined vocabulary. Obviously if this kind of vocabulary is not enough accurate, the actor can use the annotation and add texte to specify more precisely his meaning.

4 Conclusions and perspectives

MICA is a groupware tool used to track all interactions and information exchanges between members of Integrated Teams in solving an engineering problem. This tool is able to structure, share, have access and capitalise information through an Intranet. Some return on experience has already been extracted. We added sektching functionalities to allow designers to share GNSI. The exchange of sketch produce are organised and capitalised in order to track the different step of the exchange.

Then one of the main hypothesis of this work is to be able to move the sketches from a synchronous local support of co-ordination to an asynchronous and distant use. However, this challenge as to be improve by use of designers in an industrial environment, that should be the case in the next few months. Indeed, the MICA-Graph tool should be experimented in an industrial way in the context of a design project. So the communication tool should be ergonomic . The return on investment should be positive in term of time spent by designer and in term of financial point of view. So the MICA-Graph tool should be efficiente immediately. And if the experimentation is positive in the day to day life of the designer, then we will have a sketch data base with all the sketches tracked during the building of the design with the use of MICA-Graph.

The next step will be to "rebuild" the decision making of the different choices which took place in the life of design. This, in order to partly identify the reason or the criteria of the choices done. With this aim in view, we have already experimented content-based sketch retrieval [11]. Given tehnical sketches and drawings, we have used invariant shape descriptions that can be utilised for content-based sketch retrieval. We have experimented a novel method of browing images which are organised into a tree of subclusters using relevance feedback by the user. Indeed Fourrier descriptors achieved the best evaluation results with average precision values of up 68%. We implemented a genetic algorithm to determine the optimum weight set for this particular sketch base and found that performance can be increased by another 10% by simply combining Fourrier descriptors and difference chain codes with a weight ratio roughly 3 : 1. Futher studies are currently undertaken to evaluate the robustness of these results under different datasets.

This last experimentation incites us to follow in this direction, indeed :

- if the designer could retrieve a sketch thanks to similarity between sketches,
- if he is able to understand the sketch with added predefined symbol and annotation,

- futhermore, if he is able to access to the construction of the design, it could be very usefull to reinterpret and extract the knowledge of sketch.

If the three points above are confirmed, that would allow actors to synchronise their point of view, their context, their understanding, etc. asynchronously to be more efficient during the face to face interaction.

References

[1] Gardoni M., Spadoni M., Vernadat F., Harnessing non structured information and knowledge and know-how capitalisation in integrated engineering, case study at Aerospatiale Matra, *Concurrent Engineering : Research and Applications*, vol 8, n° 4, 2001

[2] Gardoni M., Blanco E., Taxonomy of information and capitalisation in a Concurrent Engineering context 7th ispe international conference on concurrent engineering (CE'2000), Lyon, France, July 2000

[3] Goel V, *Sketches of thought* MIT press Cambridge, MA 1995

[4] Blanco (2003) Rough Drafts. Revealing and mediating design. Everyday engineering. An ethnography of design and innovation. D. Vinck. Cambridge, MA, MIT press**:** 181-201.

[5] Boujut J.F., Blanco E., "Intermediary Objects as a Means to Foster Co-operation in Engineering Design", Journal of Computer Supported Collaborative Work, 2003 V12 2003 issue 2

[6] Blanco E., Gardoni, M., Supporting Graphical Non Structured Information in integrated design team, International Conférence on Engineering Design, ICED 01, Glasgow, August (2001)

[7] Finger S., Konda S.L., Subrahmanian E., "Concurrent Design Happens at the Interfaces", Artificial Intelligence for Engineering Design Analysis and Manufacturing, Vol. 9, 1995, pp. 89-99.

[8] Fergusson E,S, *Engineering and the Mind's Eye* MIT press Cambridge, MA 1992

[9] M. Gardoni, M. Spadoni, F. Vernadat, "Information and Knowledge Support in Concurrent Engineering Environments", 3rd International Conference on Engineering Design and Automation, EDA'99, Vancouver, B.C., Canada, August 1-4, 1999

[10] Baker, M. A model for negociation in Teaching-Learning Dialogues, *Journal of Artificial Intelligence in Education*, n.5.(2), pp.199-254, 1993

[11] Heesch D., Hoare J., Gardoni M., Duncan G., Ruger S, Content-Based Sketch Retrieval and Relevance Feedback, Proceedings of Scuola Superiore Gugliemo Reiss Romoli, Aug 06 - Aug 12 2001

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