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CONTEXT MODELING IN A COLLABORATIVE VIRTUAL REALITY APPLICATION AS SUPPORT TO THE DESIGN PROCESS

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1. Introduction

A virtual-environment, in which a multidisciplinary team will discuss modifications or developments in areas such as Design, Product Development, Plant layout, Maintenance and Production Planning is being developed with the participation of The Department of Industrial Applications at the Fraunhofer Institute for Computer Graphics. In this project, team members can bring their own ideas using different representing means (files, sketches, processes, etc.) and visualize them. The users will be also provided with the possibility to interactively modify the gathered information, or to separate from the group with newly acquired information and work on aspects relevant only to specific specialties and present the results again to the group.
Since the exchange of information between the participants takes place by means of direct manipulation of virtual objects on a shared area, the amount of inputs requested from the user is very restricted, and a great part of the outcome is dependant on the way participants manipulate such objects. It is desirable that objects within the virtual environment respond according to the context in which they are being used or they are likely to be used. Consequently, a means to identify and model the context in which a task is carried out is an imperative.
In this application, the main role of context is to provide the users with a much greater control over knowledge. Identifying context permits defining which knowledge should be considered, what are its conditions of activation and limits of validity and when to use it at a given time. Such a model of context will act as an adjustable filter for giving the right meaning and to present the minimal number of information pieces and essential functions that are necessary to the task at hand.
This paper discusses a set of relations that have to be elaborated in order to allow the system to create a model of the context in which a design task is being carried out. This will constrain the behavior of the objects within the VR environment and will be reflected e.g. in the way geometry, content or interaction is allowed or supported, the level of detail information is provided or graphs are displayed, etc.
In the next section, we present the motivation for this paper. After, we establish a definition of the concept of context. We then present a set of relations that help us to model context. Finally, the paper discusses the significance of the results and the steps for future work.

2. Scenario of the application

The department Industrial Applications of the Fraunhofer Institute for Computer Graphics participates in the project “Process and plant configuration for cooperative plant management”. The goal of the project is to develop technologies from the field of Interaction and Communications technologies for the optimization of industrial processes. This objective will be achieved through the development of a

workplace where an interdisciplinary group will discuss modifications or developments in areas such as Product development, Plant layout, Maintenance and Production planning.
This multidisciplinary user group should be able to present visually their ideas or concepts during the design activity. Therefore, it is necessary to provide tools that mimic, as much as possible, the way such a group will interact in a real-world meeting while providing tools that are not usually available [Slater, 2001]. This workplace considers a shared area where all users can discuss about the same artifacts and a separate area where the users can individually make modifications or work on a subject of their specialty during the meeting and then bring their results back to the shared area.
Among the technologies considered within the project is the use of Virtual reality environments to create a work environment where the user can design within a Virtual Environment. The use of VR often reduces design time and cost by examining a design in a more intuitive manner. There are applications, such as de VADeT [Hill, 1999] that incorporate design capabilities into a virtual environment. These capabilities usually include operation to model, display, or modify a design.

2.1 Domain of the application

Collaborative virtual reality applications allow users to experience immersive or semi-immersive experiences while sharing a virtual environment with other users either in the same geographical location or at a distant place. Examples are the Divercity Project [Christiansson 2001] or the Collaborative Cube Puzzle [Wideström, 2000]. Once a shared environment is provided, different interaction metaphors for object manipulation are needed.
There are two main reasons why this application should evaluate the relevance of the information to be presented. The first one is that a human being cannot process an infinite amount of information. Only relevant information will be taken into account. In other words, human cognitive processes are set up in such a way that maximum cognitive results should be obtained with minimum cognitive effort. This is only possible when the individual can focus his attention to relevant information [Sperber and Wilson, 1986]. This makes irrelevant information redundant and even undesirable since it can cause noise or side effects. Moreover, if the navigation in 3D is not perceived as natural, the user might have the sensation of not being (properly) supported by the tool. The second reason is that computational capacity is limited. The information to be fetched and the resolution of the graphics to be displayed, e.g., have to be adjusted as necessary sparing as much computational power as possible.

3. Context

3.1 Context in Computer science

To Brézillon [Brézillon 1999] context in computer science "can be thought of as a kind of expert system that would be expert in 'predicting' what the user would likely want/need to do next because of its knowledge of what had happened to either that user or other users with the same goals/needs". The main role of context is to provide humans with a much greater control over knowledge. Viewed like this, context permits defining which knowledge should be considered, what are its conditions of activation and limits of validity and when to use it at a given time (Bastien, 1992; cited in Brézillon, [Brézillon 1999]).
Contexts could be seen as adjustable filters for giving the right meaning in the current context and to present the minimal number of information pieces and essential functions that are necessary to the task at hand (Barthe, 1991; cited in Brézillon, [Brézillon 1999]). In other words, it is the context what defines the relevance of the available information.
Context is a commonly used term in computer science, especially in VR and AI, though there is not an agreement on its meaning and each discipline uses it differently. Context can be used to internally manage knowledge and to manage communication with a user. An appropriately designed user interface can play a role in establishing the context. For instance, by constraining some of the activities in the virtual environment, tasks such as navigation, object manipulation and object selection can be improved or at least be made user-friendlier. A multi-user interface should be provided which presents the shared objects and the progress of the joint work. The system should represent the shared context of group sessions. [Borghoff, 2000]

3.2 Context in Design

In design, the notion of context has a specific meaning. Products or artifacts cannot be defined from the mere perspective of their function. In fact, although an artifact might have the potential to support a function, such function cannot be performed by the artifact alone. Only when the artifact forms part of a bigger system, in which other elements like the humans and the environment appear, then the function can be performed.

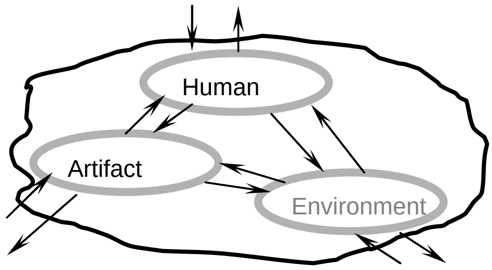

Figure 1. System Artifact-Human-Environment

The physical constitution of the product is set from the idea of what will happen to it with the lapse of time in its relation to the environment and to the humans. The subjects of this triad can change, and the purposes of the relations, as well as the function of the system and the function of the artifact. The function of the artifact with respect to the use does not change however. When we change the subjects, the relations also change and are particular for each circumstance. Consider the triads {User, Bicycle, Home}; {Manufacturer, Physical Artifact, Plant}; {Designer, Solution, Project}; {Distributor, Load, Goods}; etc. They would conform different settings like use, production, design, distribution, etc. This is what we call contexts (See fig. 2).

Not all the relations in all possible contexts can ever be defined. There is, however, a minimum set of relations that have to be defined to consider a design as complete. The minimum set of relations to be defined will depend largely on the type of project. Design is therefore understood, for the purpose of this application, as the definition of the minimum set of relations that will permit the construction of an artifact that will perform its intended function when put in the system [Artifact-Human-Environment].

4. Context Modeling

Context has been defined as a set of relations between the elements of the triad {Artifact-Human-Environment}. By observing the actors in a specific relation, it is possible to identify the context that is being discussed about. This is the basis for context modeling. There is only a finite number of possibilities for defining certain relation. For instance, when defining the relations artifact-plant in the triad {Manufacturer, Physical Artifact, Plant}, the possible relations are the ones allowed by the plant (available manufacturing processes, size of the machines, etc.) Table 1 shows some examples of characteristics that are to be defined for some relations. This set of allowed relations constitute the model of that specific context. When an element of the triad changes, the whole set of relations change as well. This means that the context changes and the system will have to react accordingly.

There are two visible ways in which the system would react. The first one is by changing the scope and the resolution of the information displayed. The second one is by limiting the design actions that are supported. Let’s take for example a case in which one of the participants in the collaborative environment changes. There is a manager among the group running the application. The system increases the resolution of the information relative to economic factors, timelines etc. The same manager could e.g. want to see a simulation of the manufacturing process. The resolution of the display does not have to show details like cutting speeds e.g., or any other non-relevant information.

According to a set of relations defined in a user database, the system chooses the relevant information to present to each user. This user profile is improved and increased accordingly to the information requested by the user and by his/her actions within the discussion.

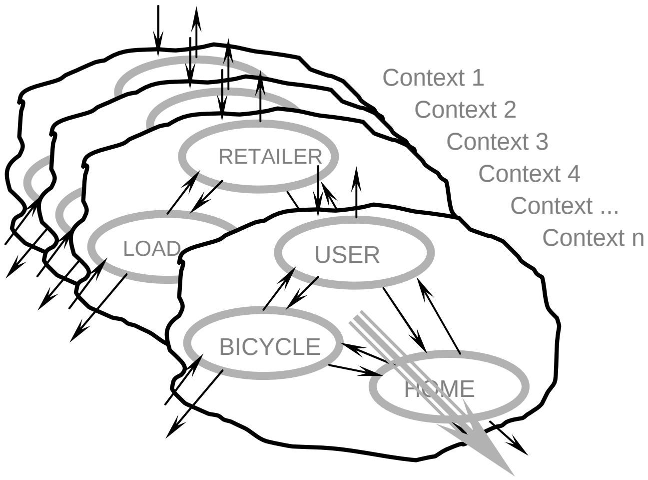

Figure 2. Contexts

Table 1. Some possible relations that will define the context model

Artifact	Human	Environment	Characteristics	Example
Body			Geometry	Length, width, depth, diameter, area, volume, distribution, connection, order, disassembly, needed space.
Body, flow			Kinematics	Displacement, speed, acceleration. Type of movement: stable, oscillatory Direction of movement. Number of movements. (Inertia, stability)
Energy flow			Energy	Electrical: Voltage, current, power. Thermal: Heat, temperature, warming, cooling, transformation, work, state. Mechanical: Cinematic, Potential, Pressure, friction (efficiency, loses)
Flow of matter			Matter	Flow of material: transport, transformation, position, storage. Properties: Physical, chemical, etc. State: Solid, liquid, gas. Response: ductile, fragile, plastic. Composition: Uniform, compound. Form: powder, grain. Input and output system products, Additional row materials Other characteristics i.e. (toxicity, etc.)
Information flow			Signal	Type: Mechanical, electrical, optical, etc. Form: Analog, digital Function: broadcast, keep, locate, modify, amplify. Carriers: indicators, regulation devices, measure and control devices, security devices.
Relation Human	Relation Artifact		Ergonomics	According to Men-machine relations. Starting with manufacturing, marketing, use, maintenance (operation altitude, operability, type of operation, ease of use) refer the life cycle Manufacturing: easy to handle, easy to assemble, easy to recognize or to find. Marketing: easy to transport, easy to grab, size of doors and circulation areas. Use: Security, controls and unambiguous signals, easy to grab, easy to pull, that don't produce noise or vibration. Maintenance: easy to assemble and disassemble, parts and positions recognition, easy to manipulate.
Relation Environment		Relation Artifact	Production Manufacturing	Limitations of production (available machinery, supplies, assemblies) available processes, ranges, finishes and possible tolerances.

Artifact	Human	Environment	Characteristics	Example
Relation Human	Relation Artifact		Control	Availability for measurement and execution of tests, norms and actual standards. (DIN, ISO, AGMA).
Relation Environment		Relation Artifact	Assembly	Assembly instructions, availability of cranes and assembly tools.
Relation Environment Relation Human	Relation Artifact	Relation Artifact	Transport	Limitations due to product's weight, size or condition for its transport indoors or outdoors. Form of delivery (parts, assembled units, etc.) routes.
	Relation Human Relation Artifact		Maintenance	Guarantee, number and periodicity of maintenance, parts replacement, cleaning.
			Costs	Maximum cost of production, tool cost, investment, amortization(show the costs in different stages of the life cycle of a product)

5. Conclusions and future work

A system to support collaborative work should be more than a tool to support communication among the participants. In this case, the idea is also to provide them with a platform in which they can visualize, share, etc. their designs, but more importantly, one in which they can simulate important aspects like plant planning, manufacturing and assembly processes. This requires an extensive database with information about processes, machinery, floor layout and so on. Moreover, the system must allow the interaction with stakeholders from different backgrounds (managers, engineers, etc). This makes especially important the selection of the exact amount of information to be displayed and the exact extent to the interactions to be allowed during a particular situation.
A definition of the context in which that situation is happening can help in the judgment of the relevance of the information and or the interactions supported. A comprehensive model of the context can never be achieved, and this has implications for the development of the software. The continuous generation of new models of context can be a computer intensive labor that might be bigger than that we want to prevent by having it. However, if we can spare the users the burden of having an overload of information displayed at the same time in the environment, this might be a price worth paying. That is something that can only be found out once the software is finished and tested.
Besides the technological challenges, this project raises important methodological questions. For instance, how to recognize the elements in a design process that will allow the system to identify in which stage of the design process the designers are? Are there any explicit indicators of the tacit knowledge of the designers that can be used to make the model of the design setting? If that is the case, has the relation between tacit and explicit knowledge any methodological relevance?

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