

Characterizing the visualization techniques of project-related interactions

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ABSTRACT: All construction projects can be considered as cooperative undertakings. Their strategic management as well as the daily operations causes numerous interactions to occur, either among persons or among persons and resources. These interactions have been studied from various viewpoints but few researchers have focused on their visualization. The graphical representation of the cooperation is however a powerful tool to help the project participants to get a correct understanding of the situation. This paper proposes thus a structuring framework (IVF - Interaction Visualization Framework) of the visualization techniques used to display such interactions. Three basic axes of classification are used to structure the study. Which objects are visualized? Why are they visualized? How are they visualized? For each axis, several properties have been identified and the admitted values have been specified. This work can be considered as a first step towards a structured view of the 'visualization of cooperation' domain.

1 INTRODUCTION

Any construction project projects can be considered as a cooperative undertaking. Indeed, considering that several persons join their efforts towards the project common goal, the three basic functions of cooperative situations, namely communication, co-production and sharing, and coordination (Lonchamps, 2003), are always present to a certain extent. In order to produce the promised deliverables, numerous interactions occur all along the project life cycle, either among persons or among persons and material or immaterial objects. These interactions can really be considered as the visible face of the cooperation. It is thus not very surprising that many researchers have studied them in different contexts.

In the Architecture, Engineering and Construction (AEC) industry, the interactions among the participants of a project have been studied from very various viewpoints such as supplier management (Clark et al. 1999), trust (Mohamed 2003), distribution of communication media (Howard & Petersen 2001), modes of information dissemination (Otjacques et al. 2003), influence of communication media on design performance (Kvan & Gao 2004), as well as distributed cognition (Perry 1997) or turbulence (Fyall 2002).

Nevertheless, notably fewer researchers have focused their work on the specific challenges associated with the visualization of these interactions, or in other words, on the visualization of the cooperation.

This viewpoint is, however, really worth being investigated. Indeed, human beings know for centuries how powerful may be a graphical representation of a problem for helping to solve it, which is usually summarized by the famous citation '*A picture is worth a thousand words*'. This paper proposes thus a global framework aiming to characterize the visualization techniques used to represent some interactions such as those arising during a project.

2 MOTIVATION OF THE RESEARCH

The intended result of this work is thus to propose a framework which could be used as a basic tool by researchers studying or designing some visualizations of interactions. Indeed, to the limit of our knowledge, no taxonomy especially dedicated to this kind of visualization techniques has already been proposed. Such a framework would, however, be clearly of prime interest as the following reflections point it out.

Herbert Simon stated some decades ago that '*the first step to understanding any set of phenomena is to develop a taxonomy*' (1969). In the information visualization domain, several researchers have also drawn the attention on the reasons why taxonomies, classifications or frameworks (these terms are sometimes used with quite similar meanings) are required. According to Lohse and his colleagues (1994), '*Classification lies at the heart of every sci-*



entific field. Classifications structure domains of systematic inquiry and provide concepts for developing theories to identify anomalies and to predict future research needs.' Wehrend and Lewis (1990) explain that, with a common conceptual framework, 'workers in any area can place their techniques, so that abstract similarities among problems in different application areas can be identified, and new techniques can be readily transported across application lines'. Gruia-Catalin and Cox (1992) mention that a taxonomy is a 'vehicle through which we carry out a systematic review of current systems, techniques, trends, and ideas ...'.

In any scientific domain, taxonomies are necessary for multiple reasons, among which the most important are probably:

- allowing a systematic and rigorous review of current techniques and ideas;
- positioning specific works in the whole research field;
- clarifying the concepts of the field, which is a required step before elaborating a new theory;
- identifying similarities and differences among the research findings;
- pointing out new research directions;
- highlighting lacks in research proposals.

This list is certainly not exhaustive but it is believed to include the most significant elements and it offers enough good reasons to reflect on a new taxonomy.

3 VISUALIZATION IN AEC RESEARCH

First of all, it may be useful to remind the scope of some scientific domains dealing with graphics and data. Card, Mackinlay and Shneiderman (1999), who are among the most renowned authors in this field, define 'visualization' as 'the use of computer-supported, interactive, visual representations of data to amplify cognition'. They also propose a list of working definitions aiming to clarify the relationships among the concepts related to information visualization. The most useful of them in the context of this paper are the following. 'Scientific visualization' concerns 'the use of interactive visual representations of scientific data, typically physically based, to amplify cognition'. 'Information visualization' deals with 'the use of interactive visual representations of abstract, non physically based data to amplify cognition'.

These generic definitions can be instantiated in the specific case of the AEC research field. According to the above-mentioned definitions, the visualization of physical artifacts (e.g. steel structure, heat transfer properties of a building, building site spatial organization) belongs to the *scientific visualization* discipline. This domain encompasses most of the re-

search works on visualization in AEC. For instance, numerous papers can be found on Computer Aided Design, Virtual Reality, Building Rendering or Lighting Simulation (cf. for instance, ITCon 2003; eCAADe 2004).

The *information visualization* domain has a completely different purpose. It regroups the initiatives aiming to graphically represent abstract objects, such as meetings, document storage systems, e-mails or access to shared documents. This aspect has been notably less studied in the AEC research field. In fact, most of the time, this issue is tackled as a side effect of the study of information exchanges. For instance, project web sites (PWS) obviously include some *information visualization (InfoVis)* techniques but, in almost all the cases, PWS have been studied in terms of real usage, efficiency, or cost (e.g. Andresen et al. 2003) rather than in terms of *InfoVis* techniques. Similarly, project planning has been intensively explored with various techniques, such as Petri nets (Rueppel et al. 2004), knowledge base system (Castro & Dawood 2004), and *scientific visualization* techniques (e.g. adding temporal properties to a 3-D representation to show the state of the building site at a given moment of time). Few researchers, however, focused on the best manner to graphically represent the interactions between the actors. The choice of traditional representations, like Gant charts, is often taken for granted and is rarely questioned in order to assess the appropriateness of these *InfoVis* techniques to convey information in the situation under study.

The research work described in this paper relates to the *information visualization* field. It aims to study the visualizations techniques used to display the interactions occurring during a project. Therefore, the concept of 'interaction', which is a central element of the research work, has to be defined. In this paper, an 'interaction' is defined as 'any kind of communication or exchange among two or more actors, or between one or many actor(s) and some resources used in the project'. Typical examples of such interactions are phone calls between an architect and a contractor, e-mail exchanges between a project manager and the project members, face-to-face meetings between the project manager and the client, successive operations on a document located on a web site, or planning modification requests by some project participants.

4 IVF FRAMEWORK

4.1 General Approach

A global framework, called IVF (*Interaction Visualization Framework*), has been designed to underpin the analysis of the visualization techniques aiming to display some interactions (called *InterVis* techniques in this paper). The IVF framework is not



specific to the AEC industry but it is generic by nature and can be applied in any sector.

The IVF framework has been designed according to the following methodology. It was decided to study the visualization techniques from three viewpoints:

- which objects are visualized?
- why are these objects visualized?
- how are these objects is visualized?

Numerous papers have been collected about information visualization in general, about taxonomies of information visualization techniques, and about visualization of interactions. On the basis of this material, a set of properties was identified in each of the three above-mentioned aspects, and the values allowed for each property was specified. Some of the properties (e.g. *Retinal Variables*, *Entity Covering Level*) are derived from previous taxonomies in the information visualization domain (Bertin 1998; Card & Mackinlay 1997; Roth & Mattis 1990; Tweedie 1997). Other properties (e.g. *Interaction Media*, *Integration*) do not belong to these previous taxonomies. They result from the analysis of current visualization techniques and from conceptual reflections on the properties of interactions. It is also important to note that, most of the time, the property values are not exclusive, which means that a given *InterVis* technique can simultaneously take several values.

This generic framework has been instantiated in the AEC research context and has been applied to characterize some *InterVis* techniques.

4.2 Objects to be visualized: What?

First we have to discuss the objects to be visualized. In accordance with our previous definition, two kinds of objects are concerned: the interacting entities (persons and / or resources) and the interactions themselves. Very logically, the associated properties are thus grouped in two distinct sets: those qualifying the entities in interaction and those describing the interactions.

4.2.1 Entities in interaction

- Two kinds of entities are distinguished: ‘*persons*’ and ‘*resources*’. Obviously, in this approach, the persons are not considered as resources, which are limited to material (e.g. device) or immaterial (e.g. document) objects. Two values are allowed for the ‘*Interacting Entities*’ property, namely ‘*person-to-person*’ and ‘*person-to-resource*’.
- The ‘*Entity Visualized Objects*’ property allows specifying whether the visualization technique displays entities and / or attributes of these entities. It may take two values: ‘*entities*’ or ‘*entity attributes*’. For instance, in this context, a project participant is considered as an entity while the

role of this participant in the project (e.g. architect) is an entity attribute.

- The ‘*Entity Temporal Aspects*’ property specifies whether some time-related aspects (e.g. history) of the entities are displayed. Due to the very specific nature of time, a dedicated property has been added while time-related aspects might have been considered conceptually as attributes of the entities. This property admits two values: ‘*time sensitive*’ and ‘*not time sensitive*’. For instance, if the visualization shows only the presence of interacting persons, this property takes the ‘*not time sensitive*’ value, but if it also displays the moment when the persons joined the project the ‘*time sensitive*’ value is set.
- The next property, called ‘*Entity Covering Level*’, expresses the level of covering of the data space. It can take three values: ‘*one entity*’ (i.e. visualization of one specific object), ‘*some entities*’ (i.e. a specific subset of all objects) and ‘*all entities*’ (i.e. all objects). The example of project participants can still be used to illustrate this property. If one specific participant is displayed, the property takes the value ‘*one entity*’. If the visualization concerns the subgroup of all participants employed by a given company, the property takes the value ‘*some entities*’. Finally, if all participants of the project are showed, the property is set to ‘*all entities*’.
- The ‘*Entity Granularity*’ property refers to the level of data aggregation allowed by the visualization technique. If only individual entities can be displayed, the property value is set to ‘*individual entities*’ but if some groups of entities can be visualized as such, the property gets the ‘*aggregated entities*’ value. For instance, if the visualization technique only allows displaying documents as separate graphical objects, the ‘*Entity Granularity*’ property gets the ‘*individual entities*’ value. If it allows showing a group of documents as a single graphical object, the property is set to ‘*aggregated entities*’.

4.2.2 Interactions among entities

- The ‘*Interaction Visualized Objects*’ property allows specifying whether the visualization technique displays interactions and / or attributes of these interactions. It may take two values: ‘*interactions*’ or ‘*interaction attributes*’. For instance, in this context, an e-mail is considered as a basic object while the ‘*priority*’ of this e-mail is an object attribute.
- The ‘*Interaction Temporal Aspects*’ property specifies whether some time-related aspects (e.g. history) of the interactions are displayed. Due to the very specific nature of time, this dedicated property has been included but, conceptually, time-related aspects might have been considered



as attributes of the interactions. This property admits two values: *'time sensitive'* and *'not time sensitive'*. For instance, if the visualization shows the moment when each interaction occurred, it gets the *'time sensitive'* value but if it displays only that some interactions occurred, the *'time not sensitive'* value is set.

- The next property expresses the level of covering of the data space. The *'Interaction Covering Level'* property can take three values: *'one interaction'* (i.e. visualization of one specific interaction), *'some interactions'* (i.e. a specific subset of all interactions) and *'all interactions'* (i.e. all interactions). The example of e-mail exchanges can still be used to illustrate this property. If the technique permits to show a specific e-mail, the property takes the value *'one interaction'*. If the visualization concerns all the e-mails sent by a specific participant, the property takes the value *'some interactions'*. Finally, if all e-mails exchanged during the project can be displayed, the property is set to *'all interactions'*.
- The *'Interaction Granularity'* property refers to the level of data aggregation allowed by the visualization technique. If only individual interactions can be displayed, the property value is set to *'individual interactions'* but if some sets of interactions can be visualized, the property gets the *'aggregated interactions'* value. For instance, if the visualization technique visualizes each individual e-mail as a single graphical object, it gets the *'individual interactions'* value. If it allows representing all the e-mails exchanged between two project participants with a unique graphical object, the property is set to *'aggregated interactions'*.
- The *'Interaction Arity'* property is defined by the number of entities that take part in the interaction. Two values are allowed for the interaction arity: *'binary'* (i.e. interaction between two entities) and *'multiple'* (i.e. interaction between more than two entities).
- The *'Interaction Centricity'* property specifies whether the interactions that are visualized are relative to a given central person (*'egocentric'*) or concerns all interacting people without favoring a specific individual (*'sociocentric'*). For instance, an e-mail client is typically *'egocentric'* as it shows all interactions between the connected user and the other persons.
- The *'Interaction Media'* property refers to the tool(s) supporting the interactions. Some possible values are *'face-to-face meetings'*, *'e-mail communications'*, *'phone calls'*, *'video-conferencing'*, *'web site access'*, ...

4.3 Goal of the visualization: Why?

The goal of the visualization is the second aspect that we use to classify the visualizations of interactions. This aspect concerns the context of use for which the visualization is designed. Three properties are associated with this viewpoint.

- The *'Visualization User Role'* property specifies whether the technique is dedicated to be used by an actor which takes part in some of the interactions (*'participating actor'*) or by someone which is external to the interactions (*'external observer'*).
- The *'Visualization Purpose'* property indicates the essential purpose of the visualization. Two basic goals are identified: *'interaction support'* and *'interaction analysis'*. The first value concerns the cases when the basic purpose of the visualization is to support the user to interact with other entities and the second value applies when the visualization is used to analyze the interactions between some entities.
- The *'Visualization User Expertise'* property refers to the level of expertise, in terms of graphical representation reading, of the user for which the *InterVis* technique is designed. It can take three values: *'novice'*, *'normal user'*, or *'expert'*. For instance, a treemap can be considered to be designed for *'expert'* users while a pie chart can be dedicated for *'novice'* users.

4.4 Visualization techniques: How?

The last classification axis concerns the visualization techniques themselves. Intentionally, no property is defined to specify what might be called the *'visualization type'* (e.g. *pie chart*, *tree* or *parallel coordinates*). In fact, such a property would not be consistent with the framework philosophy that aims to characterize the *InterVis* techniques in a way as generic and lasting as possible.

- The *'Display Space Dimensions'* property is used to indicate how many space dimensions are used to represent the data graphically. Three values are allowed: *'1-Dimension'*, *'2-Dimensions'* and *'3-Dimensions'*. This property is defined as the number of coordinates necessary to position any data in the visualization display space. It may be useful to point out that it does not refer to the number of dimensions of the data. In Bertin's terminology (1998), this property refers to *'plan variables'*. It does not concern the retinal variables such as color or size. For instance, a timeline is *'1-Dimension'*, a planar tree is *'2-Dimensional'* and a virtual reality representation is *'3-Dimensional'*.
- The *'Entity Graphical Mapping'* property indicates which kind of graphical object is used to represent the entities in interaction. The possible



values are ‘point object’, ‘linear object’, ‘surface object’ and ‘volume object’. For instance, in usual ‘node-links’ graphs, this property takes the value ‘point object’ because the entities are displayed as point-like nodes.

- The ‘Interaction Graphical Mapping’ property indicates which kind of graphical object is used to represent the interactions among the entities. The possible values are ‘point object’, ‘linear object’, ‘surface object’ and ‘volume object’. For instance, in usual ‘node-links’ graphs, this property takes the value ‘linear object’ because entities are displayed as links.
- The ‘Retinal Variables’ property specifies which retinal variables are used to represent data values in the visualization technique: ‘color’, ‘grey level’, ‘shape’, ‘orientation’, ‘size’, ‘grain’, and ‘texture’. For instance, in a node-link graph, the frequency of the interactions can be represented by coloring the links (‘color’) or increasing the link width (‘size’).
- The ‘Display Space Boundaries’ property is used to specify whether the graphical representation uses a fixed (‘fixed’) or variable (‘variable’) display space, depending on the size of the data set. For instance, this property is set to ‘fixed’ for a treemap and to ‘variable’ for a classic node-link graph.
- The ‘Geometrical Distortion’ property specifies whether the visualization technique shows distorted views of the data (‘distorted’ vs. ‘not distorted’). In a distorted view, the values of the data are not all equally mapped with their geometrical representation within the display space. The fish-eye lens and the ‘Perspective Wall’ are some examples of distorted techniques.
- The ‘Abstraction Level’ property indicates whether the graphical elements used in the representation are purely abstract shapes (‘abstract’), remind some real objects via metaphors (‘metaphorical’) or mimic reality (‘pseudo-real’). To illustrate these values, representing e-mails by arcs takes the ‘abstract’ value; using expressive faces to display e-mail priority takes the ‘metaphorical’ value; and representing meetings within a virtual 3-D world takes the ‘pseudo-real’ value.
- The ‘Animation’ property indicates whether some movement or animation is included in the graphical representation of the interactions. Two values are allowed: ‘animated’ or ‘static’. In order to avoid confusion, it must be mentioned that this property does not refer to the dynamics of the interactions themselves.
- The ‘Interactivity’ property refers to the presence or absence of means for the user to interact with the graphical representation. A visualization technique will be called ‘interactive’ if the user can dynamically modify the selection of objects to be displayed, the displayed properties of these

objects, or a parameter of the graphical output used to display them. If the user cannot modify any aspect of the data representation, the visualization technique is called ‘not interactive’.

- The ‘Integration’ property explains whether the visualization technique is integrated with the interaction tool (‘integrated’) or not (‘independent’). For instance, an e-mail visualization module can be integrated within an e-mail client (‘integrated’) or it can be used to display an e-mail log file issued from an external application (‘independent’).

5 APPLICATION OF THE IVF FRAMEWORK

This section illustrates how the IVF framework can be applied to characterize and support the improvement of some current visualization techniques.

5.1 Nodes-links diagrams

Sociograms, imagined by Moreno in the early 1930’s (Freeman, 2000) are considered as the most ancient example of visualization of social interactions. They are graph-like drawings in which individuals are represented by points and relations between them by lines. They became the most popular technique to display ‘interaction’ data and, for this reason, will be taken as example to illustrate the use of the IVF framework.

The Figure 1 is an example of a very simple sociogram that might be drawn by a researcher to study the interactions by e-mail between the members of a project. It will be considered as our reference of basic nodes-links diagram.

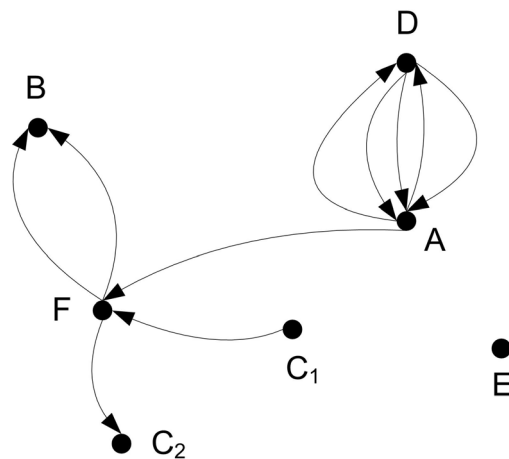


Figure 1. Reference nodes-links diagram

The IVF framework can be used to qualify this simple *InterVis* technique. Table 1 summarizes the values of the IVF properties for this sociogram.



Table 1. IVF properties of the reference ‘nodes-links’ diagram

What? Properties	
Interacting Entities	<i>person-to-person</i>
Entity Visualized Objects	<i>entities</i>
Entity Temporal Aspects	<i>not time sensitive</i>
Entity Covering Level	<i>all entities</i>
Entity Granularity	<i>individual entities</i>
Interaction Visualized Objects	<i>interactions</i>
Interaction Temporal Aspects	<i>not time sensitive</i>
Interaction Covering Level	<i>all interactions</i>
Interaction Granularity	<i>individual interactions</i>
Interaction Arity	<i>binary</i>
Interaction Centricity	<i>sociocentric</i>
Interaction Media	<i>e-mail communications</i>
Why? properties	
Visualization User Role	<i>external observer</i>
Visualization Purpose	<i>interaction analysis</i>
Visualization User Expertise	<i>normal user</i>
How? properties	
Display Space Dimensions	<i>2-Dimensions</i>
Entity Graphical Mapping	<i>point object</i>
Interaction Graphical Mapping	<i>linear object</i>
Retinal Variables	-
Display Space Boundaries	<i>variable</i>
Geometrical Distortion	<i>not distorted</i>
Abstraction Level	<i>abstract</i>
Animation	<i>static</i>
Interactivity	<i>not interactive</i>
Integration	<i>independent</i>

5.2 Diagram modeling with IVF

Node-link diagrams have been adapted in many ways by AEC researchers to represent some kinds of interactions linked to a construction project. These evolutions can be formalized by the modification of some IVF properties, as the following examples point it out.

5.2.1 Howard & Petersen: Sociograms

Howard & Petersen (2001) studied the information flows relative to four housing projects.

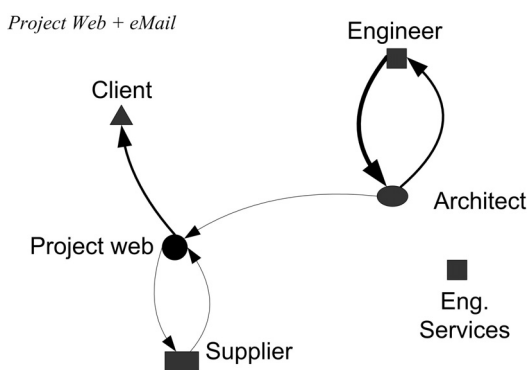


Figure 2. Adaptation of the reference nodes-links diagram to be similar to Howard & Petersen’s proposal.

They proposed to graphically represent communications with sociograms (cf. Figure 2). Neverthe-

less, the analysis of their proposal shows that the values of several IVF properties (cf. Table 2) are modified in comparison to the reference diagram (cf. Table 1).

The IVF characterization of Howard & Petersen’s work rapidly highlights in which sense it differs from our reference nodes-links diagram.

- Most of the modification relate to the dataset to be displayed (cf. *What* properties). Indeed, a larger set of interactions is concerned. For instance, a given sociogram can be used to show both e-mail communications and interactions with the project web. Some attributes of entities, such as the role in the project, are also displayed.
- Howard & Petersen’s sociograms have a similar purpose as our reference diagram (cf. *Why* properties).
- Finally, the *InterVis* technique itself (cf. *How* properties) has been slightly modified. Among the adaptations, one may note the use of the retinal variable ‘size’ for making the line width proportional to the number of interactions. In the same context, the companies of the interacting people are represented by the shape of the associated node (e.g. circle, triangle...).

Table 2. Modified IVF properties in Howard & Petersen Sociograms (compared with the reference nodes-links diagram)

What? properties	
Interacting Entities	<i>person-to-person</i> <i>person-to-resource</i>
Entity Visualized Objects	<i>entities, entity attributes</i>
Entity Granularity	<i>individual entities</i> <i>aggregated entities</i>
Interaction Visualized Objects	<i>interactions</i> <i>interactions attributes</i>
Interaction Granularity	<i>aggregated interactions</i>
Interaction Media	<i>e-mail communications</i> <i>face-to-face meetings</i> <i>postal mail, phone calls...</i>
How? properties	
Retinal Variables	<i>size, shape</i>

5.2.2 Thorpe & Mead: Network Sociograms

Thorpe & Mead (2001) studied the communications within three projects that uses a project-specific web site. They represented the communication flows with network sociograms (cf. Figure 3). The IVF-based analysis of their work (cf. Table 3) points out to which extent it differs from the reference diagram.

- The data displayed are not identical. For instance, the visualization does not show some specific instances of interactions but rather the value of a specific attribute of the interactions, namely the frequency of occurrence (e.g. daily, weekly...).
- The goal of the reference nodes-links diagram and the network sociograms are similar.
- The visualization technique is quite similar to the reference nodes-links diagrams. Thorpe & Mead



propose, however, some adaptations, such as color coding to help the user navigate the diagram. Moreover, the length of the links is inversely proportional to the frequency of interactions.

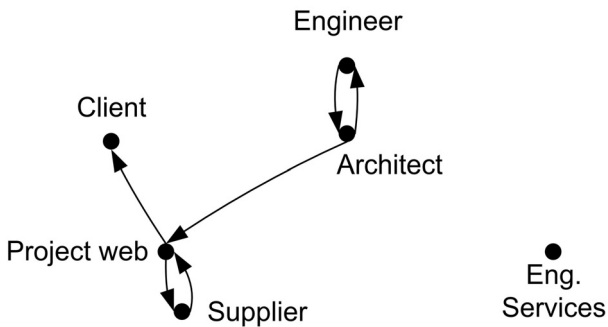


Figure 3. Adaptation of the reference nodes-links diagram to be similar to Thorpe & Mead's proposal.

Table 3. Modified IVF properties in Thorpe & Mead Network Sociograms (compared with the reference nodes-links diagram)

What? Properties	
Interacting Entities	<i>person-to-person</i> <i>person-to-resource</i>
Entity Visualized Objects	<i>entities, entity attributes</i>
Interaction Visualized Objects	<i>interactions</i> <i>interactions attributes</i>
Interaction Granularity	<i>aggregated interactions</i>
Interaction Media	<i>e-mail communications</i> <i>postal mail, phone calls...</i>
How? properties	
Retinal Variables	<i>color</i>

5.2.3 Halin et al.: Hypergraphs

Halin et al. (2004) studied cooperative tools in architectural design. They proposed to visualize the information about the project with hypergraphs (cf. Figure 4). In fact, this representation also appears to be an adaptation of the reference nodes-links diagram, which can be modeled as a modification of some IVF properties (cf. Table 4).

- The data to be visualized are different. For instance, the representation shows the interacting persons but also some project resources (e.g. documents, directories...) as well as the project activities. The temporal precedence of some interactions is also graphically represented.
- The purpose of the visualization basically differs from the reference diagram as it is mainly dedicated to the project participants (i.e. people being involved in the interactions).
- The visualization technique has been quite significantly modified. For instance, the interacting entities are represented by icons. Some retinal properties (*color, shape*) are used to convey some information. Another example is provided by the possibility for the user to add new entities and interactions directly in the representation.

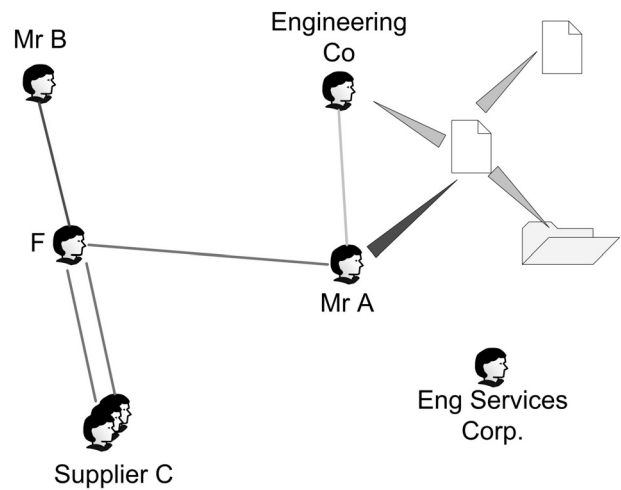


Figure 4. Adaptation of the reference nodes-links diagram to be similar to Halin et al. hypergraphs.

Table 4. Modified IVF properties in Halin et al. Hypergraphs (compared with the reference nodes-links diagram)

What? Properties	
Interacting Entities	<i>person-to-person</i> <i>person-to-resource</i>
Entity Visualized Objects	<i>entities, entity attributes</i>
Entity Temporal Aspects	<i>time sensitive</i>
Entity Granularity	<i>individual entities</i> <i>aggregated entities</i>
Interaction Visualized Objects	<i>interactions</i> <i>interactions attributes</i>
Interaction Temporal Aspects	<i>time sensitive</i>
Interaction Granularity	<i>individual interactions</i> <i>aggregated interactions</i>
Interaction Media	<i>web site access</i> <i>face-to-face meetings ...</i>
Why? properties	
Visualization User Role	<i>participating actor</i>
Visualization Purpose	<i>interaction support</i>
How? properties	
Retinal Variables	<i>color, shape</i>
Abstraction Level	<i>metaphorical</i>
Interactivity	<i>interactive</i>
Integration	<i>integrated</i>

5.2.4 Remarks

In the previous sections, three examples of interaction visualization techniques were examined with the IVF framework. They were chosen for illustrative purpose but the reader should be aware of the fact that other approaches have been proposed in the literature. For instance, Lottaz et al. (2000) proposed a 3-D view of the interactions on documents in a collaborative authorship context. Moreover, the IVF framework can be used to describe other diagrams than nodes-links diagrams. For instance, completely different techniques, such as smartmaps (Prinz et al. 2004), can also be characterized with this method.



6 CONCLUSIONS

The IVF framework described in the paper allows classifying the *InterVis* techniques, i.e. graphic representations of interactions, such as those occurring during a construction project. It offers three main advantages. First, it allows characterizing the *InterVis* techniques in a structured and standardized way. Second, it helps to identify similarities and differences among the proposals. Finally, it highlights some possible enhancements to the techniques encountered in the literature. Further works will focus on refining the list of allowed values for each IVF property, in order to achieve a greater precision for describing each technique.

REFERENCES

- Andresen, J.L., Christensen, K. & Howard, R.W. 2003. Project Management with a Project web. *Electronic Journal of Information Technology in Construction*, Vol. 8, 2003, <http://www.itcon.org/2003/3>, accessed 21 March 2005.
- Bertin, J. 1998. *Sémiologie graphique*, 1998 reprint of the 2nd édition of 1973, Paris: Editions des hautes Etudes en Sciences Sociales.
- Card, S. & Mackinlay, J. 1997. The Structure of the Information Visualization Design Space. In *Proceedings of the IEEE Symposium on Visualization (InfoVis '97)*, 18-25 October 1997, Phoenix, Arizona, USA, pp. 92-100.
- Card, S., Mackinlay, J. & Shneiderman, B. 1999. *Readings in Information Visualization, Using Vision to Think*. San Francisco: Morgan Kaufmann Publishers, Academic Press, pp 6-7.
- Castro, S. & Dawood, N. 2004. Roadsim: an integrated simulation system for road construction management. In A. Dikbas & R. Scherer (eds), *eWork and eBusiness in Architecture, Engineering and Construction; Proceedings of 5th European Conference on Product and Process Modelling in the Building and Construction Industry*, September 2004, Istanbul, pp. 237-243.
- Clark, A.M., Atkin, B.L., Betts, M. P. & Smith, D.A. 1999. Benchmarking the use of IT to support supplier management in construction. *Electronic Journal of Information Technology in Construction*, Vol. 4, 1999, <http://www.itcon.org/1999/1>, accessed 21 March 2005.
- eCAADe 2004. *Architecture in the Network Society. Proceedings of the 22th Conference on Education and Research in Computer Aided Architectural Design in Europe*, September 2004, Copenhagen, Denmark.
- Freeman, L.C. 2000. Visualizing Social Networks. *Journal of Social Structure*, Vol. 1, 2000.
- Fyall, M. 2002. When Project Information Flow Becomes Turbulent: Toward an Organizational Reynolds Number. In *CIFE Technical Report #138*, August 2002, Center for Integrated Facility Engineering (CIFE), Stanford University, California.
- Gruia-Catalin, R. & Cox, K. C. 1992. Program Visualization : The Art of Mapping Programs to Pictures. *Proceedings of the 14th International Conference on Software Engineering*, 1992, Melbourne, Australia, pp. 412-420.
- Halin, G., Hanser, D. & Kubicki, S. 2004. Towards an integration of the cooperative design context in collaborative tools. In F. Feltz, A. Oberweis & B. Otjacques (eds) *Informationssysteme im E-Business und E-Government; Proceedings of EMISA 2004*, Lecture Notes in Informatics – Gesellschaft für Informatik, Luxembourg, October 2004, pp. 175-186.
- Howard, R. & Petersen, E. 2001. Monitoring communications in partnering projects. *Electronic Journal of Information Technology in Construction*, Vol. 6, 2001, <http://www.itcon.org/2001/1>, accessed 18 March 2005.
- ITCon 2003. *Special Issue on Virtual Reality Technology in Architecture and Construction of the Electronic Journal of Information Technology in Construction*, Vol. 8, 2003.
- Kvan, T. & Gao, S. 2004. Frames, Knowledge and Media, An investigative Study of Frame Systems within Computer and Paper Supported Collaborative Design Process. *Proceedings of the 22th Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe 2004)*, September 2004, Copenhagen, Denmark, pp. 410-417.
- Lohse, G. L., Biolsi, K., Walker, N. & Rueter, H. H. 1994. A Classification of Visual Representations. *Communications of the ACM*, Vol. 37, N° 12, December 1994, pp. 36-49.
- Lonchamps, J. 2003. *Le travail coopératif et ses technologies*, Paris: Hermes Science Publications, pp. 27-28.
- Lottaz, C., Stouffs, R. & Smith, I. 2000. Increasing understanding during collaboration through advanced representations. *Electronic Journal of Information Technology in Construction*, Vol. 5, 2000, <http://www.itcon.org/2000/1>, accessed 18 March 2005.
- Mohamed, S. 2003. Determinants of Trust and Relationship Commitment in Supply Chain Partnerships. In *Proceedings of 2nd International Conference on Innovation in Architecture, Engineering and Construction*, June 2003, Loughborough, UK, pp. 617-625.
- Otjacques, B., Post, P. & Feltz, F. 2003. Management of Information Flows during Construction Projects. *Proceedings of the 20th CIB W78 International Conference on Information Technology for Construction*, April 2003, Auckland, New Zealand, pp. 278-285.
- Perry, M.J. 1997. *Distributed cognition and computer supported collaborative design: the organization of work in construction engineering*. PhD Thesis, Brunel University, UK.
- Prinz, W., Pankoke-Babatz, U., Gräther, W., Gross, T., Kolvenbach, S. & Schäfer, L. 2004. Presenting Activity Information in an Inhabited Information Space. In Snowdon D., Churchill E, and Frécon E. (eds), *Inhabited Information Spaces*. London: Springer, pp. 191-194.
- Roth, S. F. & Mattis, J. 1990. Data Characterization for Intelligent Graphics Presentation. In *Proceedings of Conference on Human Factors in Computing Systems (CHI'90)*, April 1990, Seattle, Washington, USA, pp. 193-200.
- Rueppel, U., Meissner, U.F. & Greb, S. 2004. Modeling processes and processing product model information based on Petri Nets. In A. Dikbas & R. Scherer (eds), *eWork and eBusiness in Architecture, Engineering and Construction, Proceedings of 5th European Conference on Product and Process Modelling in the Building and Construction Industry*, September 2004, Istanbul, pp. 291-296.
- Simon, H. 1969. *The Sciences of the Artificial*, MIT Press.
- Thorpe, T. & Mead, S. Project-Specific Web Sites: Friend or Foe? *Journal of Construction Engineering and Management*, Vol. 127, No 5, September/October 2001, pp. 406-413.
- Tweedie, L. 1997. Characterizing Interactive Externalizations. In *Proceedings of Conference on Human Factors in Computing Systems (CHI'97)*, March 1997, Atlanta, Georgia, USA, pp. 375-382.
- Wehrend, S. & Lewis, C. 1990. A Problem-oriented Classification of Visualization Techniques. In *Proceedings of the 1st IEEE Conference on Visualization*, October 1990, San Francisco, California, USA, pp. 139-143.

