The Idea Space System

Words as Handles to a Comprehensive Data Structure

Nicole SEGERS and Bauke de VRIES
Faculteit Bouwkunde, Technische Universiteit Eindhoven, NL

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Abstract: The Idea Space System is a CAAD system that supports an architect in the early phase of the design process, by reducing fixation in the process and enhancing the 'flow' of work. Mostly in the field of CAAD research, the emphasis lies on sketching or modelling. However the architect uses multiple representations in developing the design. In this research the focus lies on the use of words. The Idea Space System captures all design data and then uses the words to provide the architect with new associations and relations between words (real time), which stimulate the generation of new ideas.

Architecture students have used our first prototype of the Idea Space System in a small experiment. This gave us better insight in the ideas and relations made by the architect in the early phase of the design process and what kind of feedback preferred. Afterwards a study was done about the representation of the feedback. In this paper we focus on the textual input provided by the architecture students and the description of the Idea Space System, handling this textual input and providing the architecture students with the proper feedback.

1 INTRODUCTION

The Idea Space System is a CAAD system that supports an architect in the early phase of the design process, by reducing fixation (Purcell and Gero 1996) and enhancing the 'flow' of work. The Idea Space System captures all design data - being words, sketches, marks and images - and then uses the words to provide the architect with new associations and relations between words (real time). This stimulates the generation of new ideas.

In order to get better insight in the ideas and relations made by the architect in the early phase of the design process, we conducted a design experiment with architecture students, extensively described in a former paper (Segers 2002). The students had to point out which feedback, generated by our first prototype, was interesting for them and they had to state the consequential effects of this feedback in their design process. The representation of the feedback was examined in a small study. The system now generates graphs, based on these findings, which are

expected to be of interest to the architect.

In this paper we focus on how the results of this experiment and study influenced the data handling in the Idea Space System, and on the implementation of the prototype.

1.1 Related Research

Design is a creative activity. From the book 'Creative Cognition' we learn there are multiple methods for creativity (Finke et al. 1996). Conceptual combinations and metaphors are important for the architect. Witt speaks of a methodological power of language in the form of metaphor, the power of the imagination in mind experiments, and the power of story telling as a means for designers to develop new knowledge needed to design (Witt 2000). In the early phase of the design process there is room for wild ideas. Schön claims that the use of design ideas is constructive in nature and similar to a dialogue (Schön 1983). By means of associations, metaphors, analogies, etc. architects construct their design, in a dialogue with their sketches and writings.

Mostly in the field of CAAD research, the emphasis lies on sketching or modelling. However 'the use of words seems to be more flexible than pictures in sustaining multiple meanings, and are employed by many designers in conceptualising designs' (Lawson and Loke 1997). This research concentrates on the use of words in the early phase of the design process. The advantages that Suwa mentions for sketches are also applicable for writing (Suwa et al. 1998, 1999). Writing displays as much ambiguity and freedom in use - although in a different manner - as sketching.

It goes without saying, that the frame of reference, in which words are used, is a part that cannot be missed in language, associations and in creativity. Stahl recorded the whole design dialogue literally into a system called HERMES, including all drawings and sketches (Stahl 1992). Simoff and Maher also recorded their design data in a multi-representational manner. They have an extensive amount of design cases and they use ontology to retrieve it (Simoff and Maher 1998). Ontology defines the semantics of what is known about the design domain that the ontology covers. Thus design data is related in meaning. However, we feel as Lee states: 'A classification of the subject matter into a domain of discrete objects makes the system too rigid' (Lee 1995). Semantics play an important role though in indicating part of the associations that the architect makes, while (s)he expresses him/herself in natural language. The Idea Space System deals with the natural language for design content directly and in order to be able to find the relations and associations, which are present in the natural language, the system uses WordNet®. WordNet® is an online lexical reference system, developed at Princeton University, whose design is inspired by current psycholinguistic theories of human lexical memory (Miller et al. 1990).

Concluding, as in HERMES, the Idea Space System captures and relates all design information, but doesn't record it literally in a tree-like dialogue-structure. The system connects to the use of semantics as Simoff and Maher have done, but it makes no classifications nor defines cases. The Idea Space System uses associations,

natural language, and composes a comprehensive data structure that resembles a sort of frame of reference. If design is indeed about construction, dialogue, metaphor, and story telling, then a frame of reference forms the basis. All design content jotted down by the architect might prove useful, even the content that the architect crosses through initially. And while using all design content and finding relations and associations, the system also generates its own associations, being higher order concepts. Higher order, for the current prototype generates intermediary words in two types of relations: hypernyms ('the class') and holonyms ('the whole'). This might make it easier for the architect to shift viewpoint or reflect and then reframe the design problem at hand, as Valkenburg and Dorst speak of (Valkenburg and Dorst 1998).

Associations between concepts or ideas are not always based on semantics, but also on co-occurrence of these concepts or ideas in time and space. Therefore an episodic association is a subjective experience. These associations are called episodic associations (Silberman et al. 2001). The Idea Space System is not able to find these episodic associations. These episodic associations are many and are dependent on the architect's interests, personal history and experiences, the country and culture (s)he is living in. However the architect can notify the system of such a relation, namely by making marks (for instance lines, arrows, and frames). In doing so, the architect defines the episodic associations for the system, making a personal thesaurus. From Silberman's research, we learn that a semantic relationship between words facilitates forming episodic associations between them. So in showing the semantic or lexical relations between words to the architect, we stimulate him to have extra episodic associations as well.

2 SYSTEM IMPLEMENTATION

2.1 Method

In order to get better insight in the ideas and relations made by the architect in the early phase of the design process, we conducted a design experiment with architecture students (Segers 2002). The results of this experiment greatly influenced the implementation of the Idea Space System. Briefly stated, the assignment given to the architecture students was to design a chair, which could be used for lounging and surfing the Internet as well. The products of their design-process were processed with our first prototype. The students had to point out which feedback - generated by our first prototype - was interesting for them and the consequential effects of the feedback in the design process. The words that were found most interesting were often those with a hypernym-relation and having one intermediary word generated by the system (a so-called Hyp^2 relation). For example, if the architecture student wrote down "chair" and "table", the system generated "furniture". With the feedback of the system, the student could then release the idea of designing a chair and reframe the assignment to making a piece of furniture. This reframing gave the

student more freedom in thinking.

The first prototype generated a graph-based representation of the words by the students and the words found by the system. We found in our experiment that it produced too much feedback: only about ten percent was found interesting. We took the answers of the students to try and statistically determine filters, which enabled us to further develop the Idea Space System. We did not find statistically valid differences in interestingness for the place and time of writing the words, nor for the type of relation found between the words. However, we did find that some generated words from the Hyp^2 relation were too general. These were not found to be interesting. We found further that large graphs of feedback were found to be useless. Probably when graphs grew too large, there was a lack of an easy overview of the feedback. Based on these findings, we defined two filters. With these filters, graphs are generated which are expected to be of interest to the architect.

In the same experiment, we discovered that the use of marks is important in interpreting the design content and the graphs: marks indicate relations between design data. These relations are not necessarily semantic of lexical. For this reason we introduced 'episodic' associations to the system. The architect makes these relations him/ herself. There was diversity in interpreting the marks and therefore we found it necessary to conduct a small study, which we did on the Internet. In this study, we asked architects and architecture students to state what is the meaning of seventeen different marks between words. Included were lines, arrows, braces, brackets, encircling and frames. For some marks there was absolute consensus about the meaning. Single headed arrows for example all indicated the meaning 'leads to' or 'comes from', the symbol '=' indicated 'equal', the symbol '|' indicated separation, and encircling or framing always indicated 'belong together or group'. Most people thought that colour didn't matter in indicating what kind of relation between words is at hand.

2.2 Input

From the experiment we found that most architecture students write rather much in designing, from the brief to the first ideas (Figure 1). The amount of sketching and writing differs with each student, but all of them had a combination of the two representations. Occasionally a reference to a picture was made. As indicated by Lawson, the words seemed to be quite useful indeed in vaguely describing ideas (Lawson 1997). The advantage is that no geometry is drawn yet, no shape, which may sometimes lead to fixation in the appearance of (part of) the design.

All that is jotted down by the architect is recognised and processed by the Idea Space System. The design support we envision with the Idea Space System integrates and inter-relates textual, graphical, and other information into one comprehensive data structure for design information: the Idea Space.

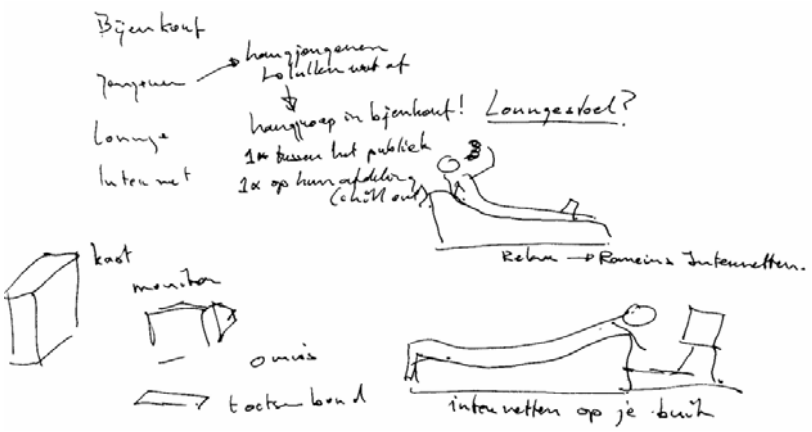

Figure 1 Input of Architecture Student

2.3 Platform

The platform of the Idea Space System is VIP3, which is the Visual Interaction Platform, developed by Aliakseyue et al. (2000). The VIP3 interface consists of a horizontal working field - both action and perception space - and a vertical screen - perception space only. The input devices are pens. Using VIP3 feels like working on real paper, that the real paper being used is augmented with a projection of virtual objects. All elements that are presented on the horizontal working field are part of the Idea Space created by the architect. Since the action and perception spaces coincide, there is no interruption of the design process. The architect writes things down, makes marks, sketches and performs search in the Idea Space. The architect has the same advantages of using pen and paper, but on top of that there are additional tools included. A mixture of computer aided design and design by the old means can be made. All information jotted down on real or 'virtual' paper is captured by the system: the Idea Space consisting of objects and relations is being constructed on the fly.

2.4 Recognition

The input of the architect needs to be recognised. In order to do so, the Idea Space System collects strokes, i.e. a collection of points (from where the architect puts the pen on paper until (s)he releases it again). With each stroke an attempt is made to first recognize the stroke or the collection of strokes as a letter, word or symbol. For this purpose (natural handwriting recognition), we are now looking at PhatWare® Corporation's commercial product, **PenOffice™ for Microsoft Windows®. This program** analyses pen strokes written in any application window, converts the pen strokes into text and sends the recognized text to a target application (VIP3 and the Idea Space System). Employing advanced fuzzy logic and neural net techniques,

PenOffice™ recognises arbitrary alphanumeric strings as well as words from its integrated dictionary. If a group of strokes is not recognised as words or some other kind of strings then the mark-recognition-component of the Idea Space System is set to work. This component of the Idea Space System contains a limited set of marks that can be recognised. What remains is the group of strokes that is not recognised as a word or mark; in this case the group of strokes is recognised as (part of) a sketch.

2.5 Structure of the Idea Space

In Figure 2, a description is given of how design-data is structured as objects, classes, and attributes to form the Idea Space. Most of the objects are ISobjects; some are relations between ISobjects. ISobjects and Mark-Relations are the super-types in the class diagram. As can be seen in the diagram, each project in the Idea Space is composed of one or more pages. On each page are multiple objects, like containers such as papers and images, and contents like words, marks, and sketches. For each representation holds that a new time-and-place-stamp attribute is assigned to the object with each design-action i.e. an object was created, moved, related, or re-used. In this attribute, it also stated what kind of action was performed.

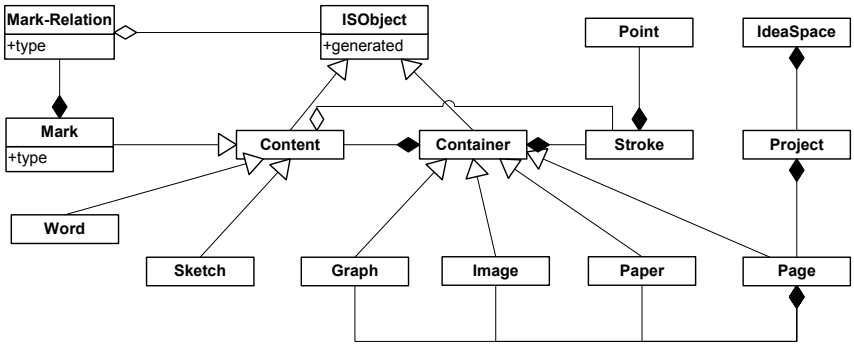

Figure 2 The Idea Space Structure

A special type of content is the mark, for it is always part of a Mark-Relation. The type of mark determines in what way the ISobjects are related. A relation might be for instance ‘belongs together’, ‘is opposite to’, or ‘leads to’. As discussed above, there are other relations possible: semantic and lexical. These relations apply only to words. A component of the Idea Space System, named WordGraph, determines which relations exists between words, and generates graphs. A graph consists of two words at least.

2.6 The WordGraph Process

The relations determined by WordGraph (Figure 3) - the component of the Idea

Space System that determines the lexical and semantic relations between all words - provide the Idea Space with extra links and properties added to these links. It searches for synonyms, antonyms, hypernyms, Hyp^2 (hypernym with one intermediary word), holonyms, Hol^2 (holonym with one intermediary word), and entailment. These relations are found on our application of WordNet® in the form of WordGraph.

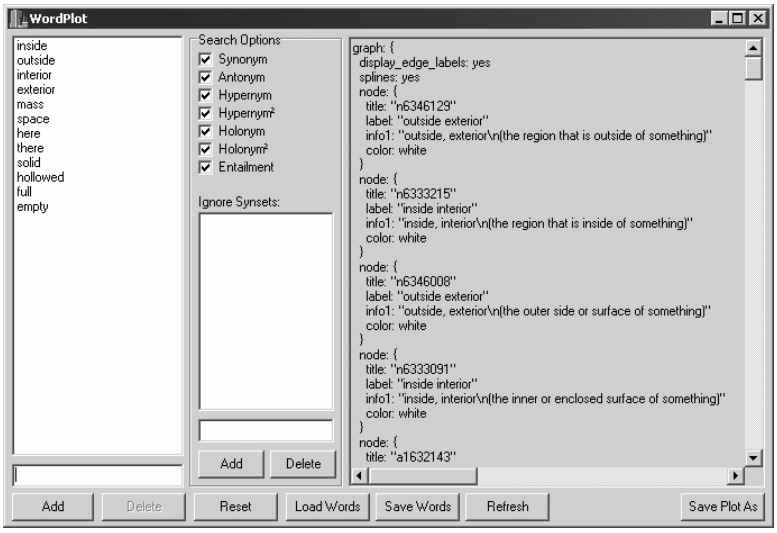

Figure 3 WordGraph Component

The first prototype produced way too much feedback; now two filters are applied: the exclusion of too general words and preventing too large graphs. Too general words are mostly generated by the system with the Hyp^2 relation. In the experiment, the architecture students found some generated intermediary words useless. Only general system-generated words are being filtered out, not the design content that the architect writes down. The reason for this, is that it could well be the architect is thinking on a high abstraction level. An example: WordGraph finds that “computer”, “link”, “black”, “round”, “lounge” and “fabric” are “artefact”. However, the architect did not write down the word “artefact”, it was generated by the system. From the results of the experiment we know, that “artefact” was not found interesting. WordGraph contains a list of twenty-four words that have to be excluded from the search and one of them is “artefact”. Thus the graph connecting all the words via artefact is not shown as feedback. Examples of other too general words are “object”, “entity”, “activity”, “state”, “knowledge”, and “human being”. Remarkable was, that students found the general word “to be” interesting. Two of the subjects indicated that “to be” in relation with their own words reminded them of philosophical issues and they were triggered to think at a higher level. With the exclusion of these twenty-four words, too large graphs are also less likely to occur. The remaining large graphs are simply split up into smaller ones, by removing the computer-generated words that have more than seven relations to other words.

2.7 Feedback

The architect writes things down, makes marks, sketches, and performs search in the Idea Space. All information is jotted down on real or 'virtual' paper. What is written on real paper, also is captured and made digital. The horizontal working field serves as a table filled with sketches, images, and other items. It is augmented with projected paper, images, sketches and text as well (Figure 4). The advantage of VIP3 is that all projected objects can be scaled, altered in colour, and easily edited.

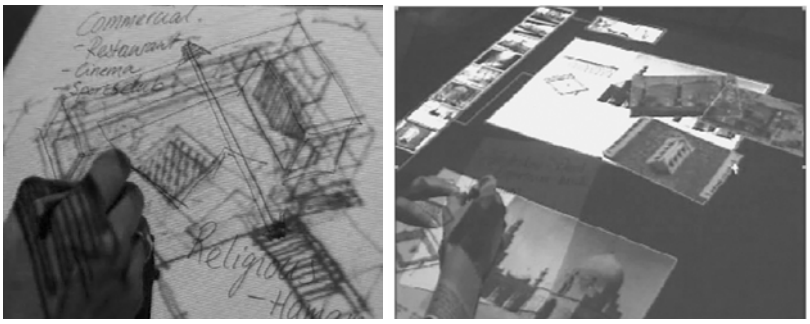

Figure 4 Horizontal Working Field

The WordGraph component searches real time for interesting relations among words. These relations are displayed in a graph representation on the vertical screen, but there is also a hint on the horizontal working field that some things are happening on the vertical screen. The relations found by WordGraph are emphasised, by gradually increasing the contrast of the words (that are included in the graph on the vertical screen) on the horizontal working field. This way it is clear that the system found something that is perhaps of interest. The architect then can decide for himself if the information is interesting. The words included in the graph can be selected on the horizontal working field with the pen, inducing the whole graph to be moved onto the horizontal working field. In this way the graph becomes part of the Idea Space.

The words in the graph on the vertical screen are no longer handwritten. This distinguishes what the architect has written him/ herself and what words are parts of a graph, generated by the system. The representation of the graph is simple: words, arrows and lines connecting the words. An example of a graph is shown in Figure 5. In this graph the architecture student thought it interesting that sitting behind a computer and using the mouse (in his interpretation of the words) was associated with moving (Hyp^2 relation).

Information of the sense of the words and the full meaning as the system interpreted the word could be asked for as well in the first prototype, but were not shown by default, for that might distract the architect from the 'flow' of work.

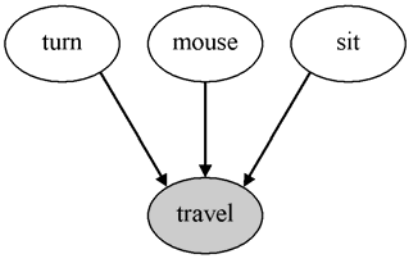

Figure 5 Example Feedback Graph

3 DISCUSSION AND CONCLUSION

The Idea Space System generates associations and relates words. It is implemented in the VIP3-interface, which has a natural feel to the architect. The relations and extra associations generated must stimulate the generation of new ideas. We believe the Idea Space System reduces fixation and enhances the 'flow' of work.

We thus far experimented only with architecture students while from the work of Kavakli et al., it becomes clear that there is a difference in how experts and novices design (Kavakli et al. 1999). The prototype needs some further developing before testing it with professional architects.

What is lacking is the inclusion of jargon. The architect mainly expresses him/ herself in natural language. However, with the use of WordNet® in WordGraph to find semantic and lexical relations, we exclude specific architecture-related terms. Therefore these words are not included in making relations among words. This aspect of the system needs still improvement, by including these terms in an additional thesaurus.

REFERENCES

Aliakseyeu, D., J.B. Martens and S. Subramanian, et al. 2001. Visual Interaction Platform. In *Human-Computer Interaction - INTERACT'01*, ed. *M. Hirose,* 680-681. Tokyo: IOS Press.

Finke, R.A., T.B. Ward and S.M. Smith. 1992. *Creative Cognition*, Cambridge MA: MIT Press.

Kavakli, M., M. Suwa and J.S. Gero et al. 1999. Sketching Interpretation in Novice and Expert Designers. *Visual and Spatial Reasoning in Design '99*, ed. J.S. Gero and B. Tversky, 209-220. Sydney: Key Centre of Design Computing and Cognition.

Lawson, B. and S.M. Loke. 1997. Computers, Words and Pictures. *Design Studies*, vol. 18, ed. H. Sanoff, 171-183. Birmingham: Design Research Society.

Lee, J.R. 1995. Graphics and Natural Language in Design and Instruction. *Dialogue and Instruction*, vol. 142, eds. R. J. Beun, M. Baker and M. Reiner, 72-84. Berlin: Springer-Verlag.

Miller, G.A., R. Beckwith and C. Fellbaum, et al. 1990. Introduction to WordNet: An On-line Lexical Database. *International Journal of Lexicography (special issue)*, vol. 3 (4), 235-244. Oxford: Oxford University Press.

Purcell, T.A. and J.S. Gero. 1996. Design and Other Types of Fixation. *Design Studies,* vol. 17, 363-383. Birmingham: Design Research Society.

Schön, D. 1983. *The Reflective Practitioner*, New York: Basic Books.

Segers, N.M. 2002. Towards a Data-structure that can Handle Ambiguous Information in a Computer-aided Tool for the Early Phase of Architectural Design. *Design & Decision Support Systems in Architecture*, eds. H.J.P. Timmermans and B. de Vries, 339-351. Ellecom, The Netherlands.

Silberman, Y., R. Miikkulainen and S. Bentin. 2001. Semantic Effect on Episodic Associations. *Proceedings 23rd Annual Conference of the Cognitive Science Society*, ed. J.D. Moore and K. Stenning. Edinburgh: Cognitive Science Society.

Simoff, S.J. and M. Maher. 1998. Ontology-based Multimedia Data Mining for Design Information Retrieval. *Proceedings of ACSE Computing Congress*. Cambridge.

Stahl, G. 1992. *A Computational Medium for Supporting Interpretation in Design,* Technical Report CU-CS-598-92, 1992.

Suwa, M., J.S. Gero and T. Purcell. 1999. Unexpected Discoveries: How Designers Discover Hidden Features in Sketches. *Visual and Spatial Reasoning in Design*, eds. J.S. Gero and B. Tversky, 145-162. Sydney: Key Centre of Design Computing and Cognition.

Suwa, M., J.S. Gero and T. Purcell. 1998. The Roles of Sketches in Early Conceptual Design Processes. *Proceedings of Twentieth Annual Meeting of the Cognitive Science Society*, eds. M.A. Gernsbacher and S.J. Derry, 1043-1048. Hillsdale: Lawrence Erlbaum.

Valkenburg, R. and K. Dorst. 1998. The Reflective Practice of Design Teams. *Design Studies*, vol. 19 (3), ed. D.G. Ullman, 249-271. Birmingham: Design Research Society.

Witt, T. 2000. Indecision in Quest of Design. *Proceedings of the 5th International Conference on Design and Decision Support Systems in Architecture and Urban Planning*, eds. H.J.P. Timmermans and B. de Vries, 423-431. Eindhoven: Design Systems GrouSp.