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The Drawing Process and Human Activity Problem Solving

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Abstract

The author of this paper is particularly interested in how the process of drawing and sketching helps human activity problem solving (e.g. decision making in meetings). From the literature, drawing and sketching are found to be very useful in various problem-solving activities such as information system development projects. However, many paper placed the focuses on the final products of drawing and sketching (e.g. pictures and diagrams). In this paper, the author tries to argue that the PROCESS aspect of drawing and sketching is also important for human activity problem solving, especially being "visually indeterminate" drawing helps idea generation. Moreover, this paper tries to suggest that the future decision support system research focus could be placed on how to help individuals to think instead of merely providing a means of drawing. In particular, a focus is placed on how to maintain the balance between a well-structured process and openness for creativity.

Keywords

Visualization, drawing, sketching, decision making and problem solving

1. Introduction

Drawing and sketching are two widely adopted techniques in many disciplines. For example, most Information System (IS) development methodologies require drawing diagrams during the system analysis and design stages (e.g. UML diagrams in object-oriented system development). Moreover, Kavakli (1998) indicates that drawing and free-hand sketching is very useful in architectural design. McGown and Green (1998) also indicate that the successful design and manufacture of complex engineering products relies on graphic representations as an information-rich means to distribute product descriptions. Furthermore, cognitive studies and empirical work about drawing and sketching are found across different disciplines including psychological and cognitive studies of human minds, the use of visual (graphic) representations and the process of drawing and sketching with a particular focus such as

in management science: Examples are Jarvenipaa and Dickson (1988), Stanwick (1996), Alder (1994)'s work of exploring the possible use of sketching and other forms of visual representations for creative thinking.

in architectural design: Examples are Purcell and Gero (1998), Medway and Clark (2003)s' efforts of addressing the need for sketching as a mental imagery manipulation process at various stages of architectural design.

in human computer interaction: Examples are MCENEANEY (2001), Jager (2000)'s researches into the design of software user interfaces and use of graphic methods for usability testing.
Or as broad as Goel (1995) and Goldschmidt (1991)s' paper which addresses sketching as a general method for thinking.

Apart from the final products of drawing and sketching (e.g. diagrams), the author of this paper is particularly interested in how the process of drawing and sketching help human activity problem solving, especially decision making in meetings. However, human activity problem solving is found to be very complex, because human problems include the following characteristics: there is no definitive statement of the problem; there is no definitive solution; and the problem solving process is dynamic (Robert (2000). The author of this paper follows Churchman's (1971) interpretation of human activity problem solving as a process of dealing with socially constructed, wicked and human related problems and tries to argue that the PROCESS of drawing and sketching is important for human activity problem solving (e.g. decision making in meetings). Moreover, this paper tries to place the focus on how to help individuals to think instead of merely providing a means of drawing when developing graphic decision support systems (e.g. whiteboard software).

2. Drawing and Sketching

According to Scrivener and M.Clark (1994), drawings are working material for paintings. The drawer usually follows a special rule or uses a special technique and equipment to draw. The final products are usually realistic and highly finished. The author further suggests that sketches are quite different from drawings because the sketcher is not required to follow any rules to produce the sketches as long as the sketches act as support for images in the mind of the creator (as an external framework for the imagination). Thus, sketching is also known as free-hand drawing. Nevertheless, both drawings and sketching are aimed at delivering a visual representation of a thing (either in the mind or in the real-world) with different aspects emphasised to the audience.

Lohse, Biolsi et al. (1994) suggest that visual representations are data structures for expressing knowledge. McCormick, Defanti et al. (1987) define visualisation as "*the study of mechanisms in computers and humans, which allow them in concert to perceive, use, and communicate visual information*". McCormick, Defanti et al. (1987) especially highlight that visual representations can facilitate problem solving and discovery by providing an efficient structure for expressing the data. Bronte-Stewart (1999) goes further to suggest that there are many situations where there is a desire to make explicit some appreciation of the "messiness" of a problem situation. In those cases, Forbus and Usher (2002) indicate that the combination of drawing and talking in sketching is a natural means of expression. Moreover, as one type of commonly used visual representations, diagrams are often used to develop, analyse and summarise ideas and can improve communication and collaborative understanding among the decision-makers. . Satzinger and Orvik (2001) suggest that each of the diagrams emphasizes some aspects of the "real-world thing" and diagrams are very helpful because "*they convey a great deal of information in a compact and precise form*".

However, the concept of visual representation is often used in a narrow way (Goel; Liddament (2000). For example, "visual representation" often refers to just the final outcomes (including pictures and diagrams). Purcell and Gero (1998) suggest that little attention has been paid,

until recently, to the function and ability that visual representations have during design or to the cognitive processes that are involved in their use. The authors found that the process of developing pictorial and diagrammatic representations has traditionally been treated "*as a skill or outcome rather than an essential part of the process of thinking*" about the problem situation. Therefore, this author believes that greater recognition of the process of picturing is critical to the development of appropriate computer-aided techniques.

3. The Process of Drawing

Newell and Simon (1972) suggest that "thinking" is fundamental in human problem solving. McKim (1980) defines the process of using diagrams and other visual aids for thinking as "visual thinking". The author suggests that "*visual thinking pervades all human activity from the abstract and theoretical to the down-to-earth and everyday*". He also notes that the thinking process requires interaction between seeing, imaging and drawing. In addition to the capability of drawing that allows individuals to compare ideas represented in the forms of diagrams or sketches side by side, McKim (1980) further claims that the process of drawing does not only help bring vague inner images into focus; but also provides a record of the advancing thought stream.

Moreover, the researcher has used McGown and Green (1998), Fish and Scrivener (1990)s' discoveries as a starting point to explore the connections between sketching and the problem solving activities. Many more details have been found from the literature. For example, Do (2000) suggests that drawing is important for problem solving because it is an external representation that helps in solving problems and generating ideas. More importantly, she asserts that drawing facilitates thinking and supports emergent ideas. Moreover, Newell and Simon (1972) indicate that human problem solving fundamentally is a thinking process. The authors further indicate that drawing and sketching fulfil the requirements of problem solving including a need of a common language for communication, a way to capture and record ideas, a brainstorming tool for idea generation and a process of reasoning and synthesising thoughts. By exploring the literature, the researcher finds that sketching is capable of satisfying these needs.

According to Do (2000), drawing is important for problem solving because it is an external representation that helps in solving problems and generating ideas. More importantly, she asserts that the process of drawing facilitates thinking and supports emergent ideas. From the review of various literature, it was found that Do's claim was supported by various authors (Goldschmidt (1991; Blaser and Egenhofer (2000). In particular, these authors believe that drawing or sketching fulfils the requirement of human problem solving that was proposed by Newell and Simon (1972) as discussed below.

I. As a process which uses a common language for communication: Blackwell (1997) suggests that diagrams can be seen as a notation system. The diagrams can "resemble", make "metaphors", and be used to "frame problems". The author further suggests that diagrams serve as a common language for problem solvers because diagrams provide information and intention in a visual form through simple shapes and their topology. Schon and Wiggins (1992) suggest that the conversation can potentially be perceived in different ways. The authors indicate that reinterpretations also often have unintended, as well as intended, consequences in terms of more abstract aspects of the problem. Therefore communicating

and clarifying these different interpretations using sketches and diagrams as a common basis will facilitate the idea clarification.

II. As a way to capture and record information (ideas) ongoing: Suwa and Tversky (1996) argue that the process of drawing provides visual cues for revision and refinement of ideas. The authors suggest that tracking visual representation of the problem domain during the problem solving process allows the problem solvers to review their ideas and even allows for self-reflection. Moreover Forbus and Usher (2002) claim that many concepts and situations are best explained by sketching. The combination of drawing and talking in sketching supports the expression of vague ideas. The authors also note that when interpreted by another participant on the basis of their background, and with misunderstandings clarified interactively, sketches (or diagrams) together with the derived narrative descriptions are most suitable for future references or distributions.

III. As a thinking tool to facilitate idea generation: Verstijnen (1997) claims that the process of sketching is particularly good for idea generation. The author names this method as "idea-sketches". He believes that these sketches are important in the creative process because the process of sketching allows individuals to interact with their ongoing mental images, helps deliver visual information and serves the functions of both analysis and synthesis. For example, an architectural designer will develop a series of sketches for a particular object and may merge various aspects together to create the final design solution. He / she will never be able to deliver a solution in one shoot.

McKim (1980) suggests that idea-sketching is a way to express visual ideas, to literally press them out into tangible form. Visual ideas (ideas represented in graphs or diagrams) can be expressed by acting them out, talking about them, writing them down, constructing them directly into a three dimensional structure – and drawing them out. The author goes on to suggest that graphic ideation has two basic modes: exploratory and developmental. In the exploratory mode, thinking and sketching are "adventurous". Each sketching action only captures one feature, not details. It aims at creating a road map of the concept for better understanding, by collecting perspectives to appreciate more fully the problem situation. In contrast, the development mode of graphic ideation aims at developing a more thorough understanding of a concept. The emphasis is on one idea. The sketching activity is less schematic and more concerned with concrete details.

Additionally, Lugt (2000) argues that visual expression may foster the group's idea generating process in several ways: (1) by providing a collective graphic memory for the group members; (2) by allowing the group members to not only be involved in conversations with their own drawings, but also to be involved in conversations with each others' drawings. Consequently, during problem solving meetings, visual expression may help to stimulate participants into building on each other's ideas.

IV. As a process that allows refinement of the ideas through the reasoning process: Goel (1995) argues that drawings are important because they are used as an "external symbol system" to represent real world artefacts which can be manipulated and reasoned with. This view has been widely accepted in many fields. For example, in the computer science discipline, workflow diagrams can be altered to indicate the process of change; even more, it allows the user to conduct a simulation using the diagrams, instead of practising in reality. Mackinlay and Genesereth (1985) also argue that a well-represented diagram is effective in presenting information in a way that makes it easier for humans to perceive and reason with.

Goldschmidt (1991) further suggests that freehand sketching is a common human activity. The sketching process is involved in the production of various kinds of sketches, such as road maps, diagrams and so on. This form of visual display is particularly helpful in certain kinds of reasoning. According to Goldschmidt (1991), in addition to problem solvers' gaining of direct access to explicit information contained in them, individuals may also see things which are not explicit. The inexplicit information contributes great value to the reasoning process.

McGown and Green (1998) try to summarise the role of sketching in problem solving by suggesting that a sketch is likely to be made for three reasons: (1). To communicate the physical nature of an entity conceived in the imagination; (2). To visually recall the physical nature of objects or environments from memory; and (3). To make a quick visual representation of entities or environments exposed to the naked eye. However, from the literature review, the author of this paper feels that when arguing the process of drawing for problem solving, the point of being "visually indeterminate" is critical for designing problem picturing software. It is found from the previous studies (e.g. Stanwick (1996), Alder (1994)) that modern drawing and sketching allows the drawer to start painting without the need of a clear idea in mind. The process of drawing serves as a means to stimulate the mind to invention. Hence, the final picture remains mysterious until the completion. Moreover, Purcell and Gero (1998) try to extend the meaning of being "visually indeterminate" and suggest that sketching presents a visual display which can potentially be perceived in different ways (different seeing); that is, the sketch can be reinterpreted. The authors point out that these reinterpretations also often have unintended as well as intended consequences in terms of more abstract aspects of the problem. For example, the overview of the implicit inter-connections between different entities can only be appreciated after the sketches are done. The authors consider these unintended consequences as giving individuals access to other domains of their knowledge that are relevant to the problem, but which were not a part of the thinking at time the sketches were made. Therefore, the arising question is that how to structure the drawing and sketching process, which facilitates thinking by applying simple rules but still remains to be open and non-restrictive to thinking. The answer to this question requires further exploration (a research design is being developed) and hopes to assist the design of new decision support systems.

4. Computer-Aided Group Drawing and Sketching Tool

According to Blaser and Egenhofer (2000), people typically sketch by using paper and pencil. Paper is inexpensive and easy to use; however, sketches on paper are difficult to reuse and editing capabilities are limited. The authors found from their studies that the earliest use of sketching which interacted with computers was SketchPad (1963). More recently, many similar (but more functional) software packages were developed, such as Spartial-Query-by-Sketching. However the use of sketching in problem solving is still under-developed. For example, Forbus and Usher (2002) are currently developing a software tool named sKEA (sketching Knowledge Entry Associate), which is designed for knowledge capture via sketching. However both of these developers admit that making software that can contribute meaningfully to sketching is a difficult task.

Additionally, Broome and Chen (1992) argue that relevant computer assistance must be used in problem solving. Computer software support (e.g. the Group Decision Support System) will allow decision-makers to discuss and appreciate the different perspectives of a problem

situation through the sharing process. Gopal and Prasad (2000) also point out that the use of networked computer systems will allow the discussion of multiple-topics in both synchronous and asynchronous manners. Thus the availability of large numbers of ideas and information has the potential to enhance group problem solving. Further, the graphic capabilities of computer software give all decision-makers a common information base for discussion (Sambamurthy and Poole (1992).

Moreover, Blaser and Egenhofer (2000) indicate that people typically sketch by using paper and pencil. Paper is inexpensive and easy to use; however, sketches on paper are difficult to reuse and editing capabilities are limited. Ellen (1998) has explored the advantage to using computers to support sketching. She further suggests that a well-designed computer sketching package is capable of providing powerful editing, allowing the user to reshape lines, to delete, group, and duplicate figures, which are often hard to do in free-hand sketching. However, more sophisticated software packages such as Rational Rose (used for software engineering) are even capable of providing simulations on the users' drawings. For example, the software will firstly check whether or not the relationships between entities are valid. Secondly, it will generate a simulated task to test the design.

Furthermore, Fish and Scrivener (1990) assert that traditional media do not record or use the temporal information intrinsic to the flow of visual thoughts, and they make it difficult to represent and manipulate three-dimensional structures. The authors suggest that "computers have great potential to overcome these limitations, provided depictive metal imagery and semantic knowledge underlying sketch surface structure can be represented and passed between mind and machines". For example, by clicking an icon or a picture on the screen, the computer would display properties associated with this particular entity. The combination of graphical and textual explanations could enrich the understanding of the problem situation. In addition, the computer package has the ability to record the stream of thoughts by capturing the screen movement or implementing a version control on the sketches. This ability allows individuals to revise their thoughts at any time. Therefore, the researcher feels that computer support for sketching is highly valuable.

However a clear distinction should be made between computer-based drawing packages such as Paint and computer-aided picturing tools such as Decision Explorer. Paint is a simple drawing tool, while Decision Explorer has a built-in problem solving methodology, cognitive mapping (Ackermann, Eden et al. (1996), to facilitate structured and semi-structured decision-making. In particular, these packages provide a collaborative sketching environment and a log system that enables users to trace the thinking process during the process of the drawing.

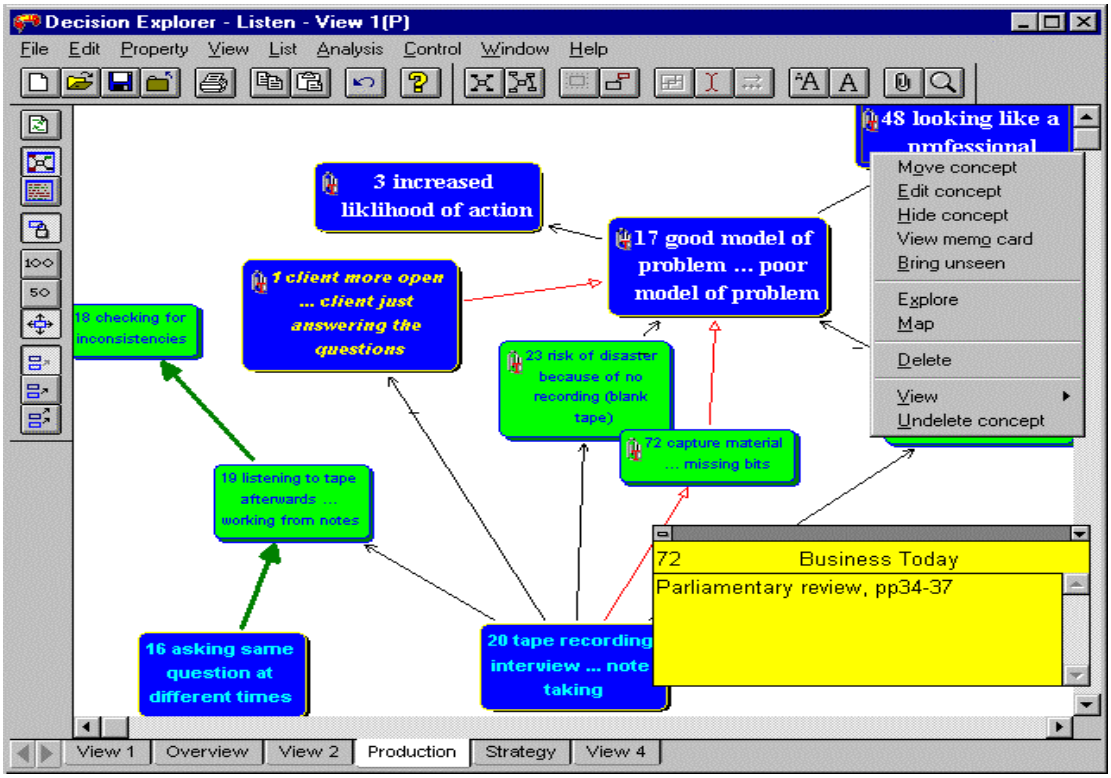

Figure 1: Decision Explorer in action

It is also important to distinguish between graphic communication software packages such as white-boarding system (e.g. in Microsoft Net-meeting) and decision-making support systems. For example, Compendium (known as QuestMap in its early versions) is a software package developed originally by Verizon Communications. Selvin, Buckingham et al. (2002) suggest that Compendium consists of three key elements: a shared visual space where ideas can be generated and analysed, a methodology that allows the exploration of different points of view, and a set of tools for quickly and easily sharing data both within and beyond the boundaries of the group. The authors further assert that the backbone of this software is the use of argument-map for problem solving, which is not provided by any other white-boarding systems.

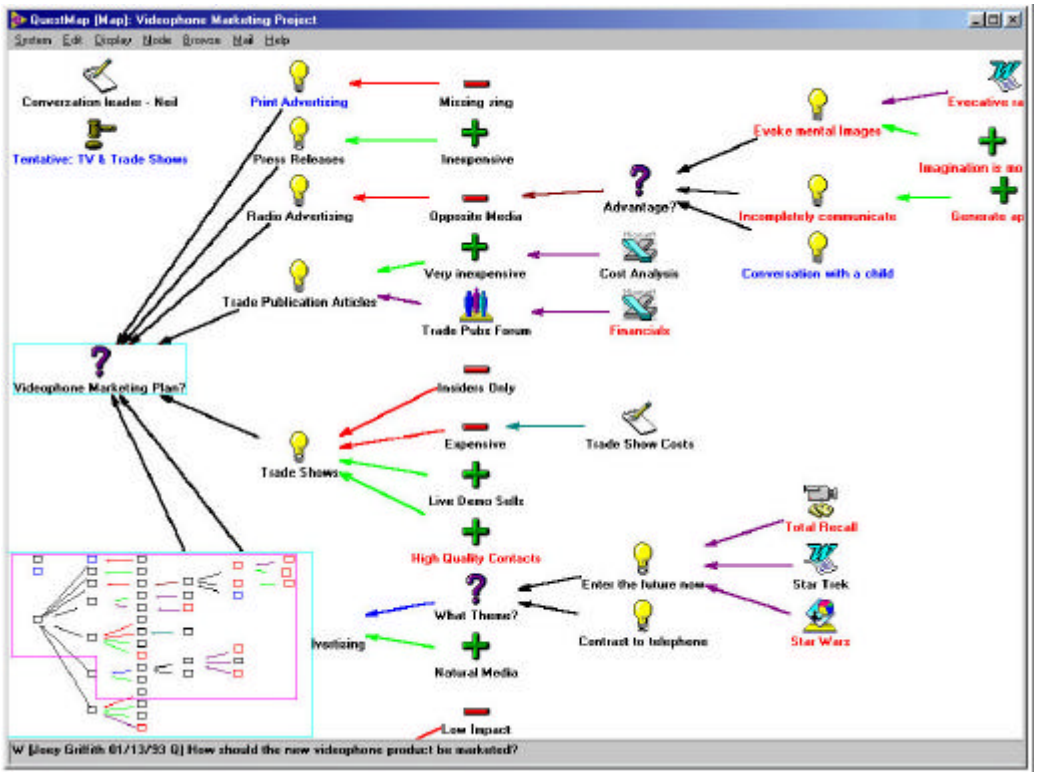

Figure 2: Compendium (QuestMap) in action

However, whether the process of these software packages' drawing capabilities should be well structured, still remains as an issue of debate. Jarvenipaa and Dickson (1988) address the need for guidelines in the use of graphics for managerial decision-making. The author asserts that flexible graphics software makes the problem solving exercise more difficult for an inexperienced end user to decide what is an effective display due to the large number of choices available. Moreover, guidelines are needed to reduce misuse and abuse of graphics. Kavakli (1998)'s cognitive study on sketching also reveals that structure in the process of sketching is an important consideration, which makes a drawing software packages successful. For example, in the two systems mentioned above, it is found that Decision Explorer employs cognitive mapping theory and follows the steps that are outlined in the theory in order to fulfill the needs of problem solving. Similarly, as a step-driven software, Compendium achieves the same objective by adopting the argument map theory for problem solving. Although in this study, Kavakli did not make an explicit statement about whether or not structured sketching is effective for design, it is found from other literature that it is an area of debate. For example, Fish and Scrivener (1990) claim that sketches contain deliberate or accidental indeterminacies which help brainstorming. Since a structured process may restrict thinking, whether or not a structured sketching process still has the same functionalities remains uncertain at this moment. For example, applying problem-solving methodologies such as soft system thinking to the drawing software often results as a step-driven process. For example, the use of Checkland's soft system methodology will inevitably introduce a seven steps process and a CATWOE framework. Thus, whether the virtue of sketching that is being "visually indeterminate" could still be retained after applying these methodologies and theories, needs further exploration.

5. Implication

Fish and Scrivener (1990) assert that traditional media do not record or use the temporal information intrinsic to the flow of visual thoughts, and they make it difficult to represent and manipulate three-dimensional structures. The authors suggest that "computers have great potential to overcome these limitations, provided depictive metal imagery and semantic knowledge underlying sketch surface structure can be represented and passed between mind and machines". For example, by clicking an icon or a picture on the screen, the computer would display properties associated with this particular entity. The combination of graphical and textual explanations could enrich the understanding of the problem situation. In addition, the computer package has the ability to record the stream of thoughts by capturing the screen movement or implementing a version control on the sketches. This ability allows individuals to revise their thoughts at any time. Therefore, the researcher feels that computer support for sketching is highly valuable.

According to various IS and Computer Science conference proceedings, many attempts have been made towards the development of group based decision support systems. However the successful design of these systems still relies on the effective use of theory, which is the foundation of IS development. The process of thinking is essential in problem solving; therefore designing a successful decision support system or any problem solving tool, requires the exploration of theories of idea generation and thinking facilitation. However, while applying various methodologies to the design of graphic based decision support systems, the balance between a well-structured process and openness for creativity requires extra considerations. In this case, how to retain the virtue of sketching that is being "visually indeterminate" could be a valuable research project in future.

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