Presented at the Thinking with Diagrams '98 conference, http://www.aber.ac.uk/~plo/TwD98/

Thinking *of* or Thinking *Through* Diagrams? The Case of Conceptual Graphs.

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Abstract

This paper challenges a view, originating in psychological and philosophical foundations of conceptual graphs, that conceptual graphs in some sense are a map of conceptual schema in the mind. It suggests that a semiotic, social psychological, approach to the foundations of existential and conceptual graphs presents a more fruitful view of possible roles of these graphs in the meaning-making process, paving the way for a collaborative, distributed paradigm in conceptual graph applications and development.

Introduction

As an example of a community of practice in which diagrammatic thinking is the object of study one need look no further than the conceptual graph community. This community draws on the pioneering work of Sowa (1984) which in turn draws from linguistics, philosophy, psychology, object based methods, existential graphs (Peirce 1931-1958), knowledge engineering and cognitive mapping to produce an integrated graphical reasoning tool for the support of decision making and systems engineering. Conceptual graphs have found applications in obvious areas such as artificial intelligence and database development and less obvious areas such as management accounting and law (see Lukose, Delugach et al. (1997) for a collection of papers from the most recent conceptual structures international conference). Although a small community, the work that is done within that community clearly fits into the remit of "thinking with diagrams" and even though this paper explicitly concerns conceptual graphs and some of their foundational problems, many of the issues have relevance to diagrammatic thinking in general. This paper offers a position on conceptual graphs and, by extension, diagrammatic thinking, and hopes to generate analysis and discussion.

Foundations of conceptual graphs

The psychological and philosophical foundations of conceptual graphs reinforce a worldview of a subjective-objective, mind-body, division. There is the clear implication in Sowa (1984) that the conceptual graph is, in some sense, viewed as an external mapping of internal mental schema. In the very assumptions that underlie conceptual graphs (1984, 3.1.1, p 70) Sowa draws on the theory of Percepts and Concepts, in which sensory data is perceived and *conceptual relations* (interpretations) are formed; "a conceptual graph describes the way percepts are assembled" (p.71). This suggests that a conceptual graph represents an externalisation of a *schema*, a mental construction, a way of perceiving, understanding and thinking about the world (Hill 1997).

> "In diagrams, conceptual graphs are drawn as linked boxes and circles. Those links represent logical associations in the brain " (Sowa, 1984, p.70)

It is the notion that a conceptual graph in some way represents an externalisation of the mind, and that mental schemas can be reproduced on paper, that we term *radical* and want to challenge in this work. There is no suggestion that this radical view is explicitly championed by all in the conceptual graph community, but rather that to some degree such radical assumptions are implicit in much of the discourse. It will be more fruitful to address the extreme, (radical) view in this paper, as the contrast will help to make points applicable to conceptual graphs in general, more explicit.

Conceptual graphs are a special case of diagram, in that, along with cognitive maps (Eden 1991) they are named in such a way that they make explicit reference to mental processes, other forms of diagram do not seem to make such a claim. Nevertheless conceptual graphs take on board the cognitivist approach to learning and as such are seated in the information-processing view (Van Oers 1990). Any system of practice of diagrammatic thinking with cognitivist foundations may be subject to similar critique.

The purpose of this challenge is not to undermine the conceptual graphs (or for that matter any other diagrammatic thinking) paradigm, but rather to identify and address some of the problems in their foundations in a way which will provide impetus for possible extensions of conceptual graphs. As such, the challenge will take the form of a semiotic, social, reinterpretation of the foundations, which in turn will lead to an extension of the boundaries and role of conceptual graphs and suggest a paradigm shift in to collaborative meaning-making.

Dualism

Much of the original impetus and a fundamental logical structure of conceptual graphs are found in Peirce's existential graphs. It is not at all surprising that conceptual graphs are seen as, in some way, objective maps of

schema; as Peirce seems convinced of the possibility of objectivity in his representations. In the opening pages of the "Prolegomena" (Peirce 1906) he invites the reader to "construct a diagram to illustrate the general course of thought", by which he means "a System of diagrammatization by means of which any course of thought can be represented with *exactitude*" (p. 492, italics my own). Having constructed such a diagram, we are then in a position to treat it as an empirical object and conduct experiments on it, looking for changes in parts of the diagram in relation to others (*ibid.* p.493).

Peirce is well known as a semiotician as well as a logician. Throughout his work he drew connections between his semiotics and his logic. He reconceived logic as semiotic, and his representation of existential graphs is semiotically well founded (Zeman 1997). Developments of his semiotics have expanded into a thriving semiotic community and the Peircian preoccupation with thirdness has spawned an exclusively Peircian camp (Deely 1990). His "On a New List of Categories" (Peirce 1867), in which he introduces his categories of sign and the notion of thirdness must be set against the background of Kantian dualism, and is seen (Hoopes 1991) as a rejection and an attempt at extension of the Kantian theory (Boulting 1994).

This is interesting from the point of view of conceptual graphs because on the one hand Peirce considered a direct connection between the mind and the diagram (secondness), but on the other hand this connection is only made clear through the thirdness (interpretant), in interaction with the experimenter. So Peirce in his rejection of dualism and exposition of the trivium introduces a distinctly human aspect to logical reasoning. It is this aspect that will become a central part of our later discussion.

Sowa (1984) draws on Philosophy, Linguistics and Psychology for his formulation of conceptual graphs. In a comprehensive discussion of the relevant aspects of each of these theories he seems to rely on a primarily dualist assumption, and an information-processing approach to learning. This is not unusual, for a basic premise of Artificial intelligence is the "mind-body" duality, if it weren't AI would have little chance of success as a mind without a body would be unable to function. This simplification is only problematic in conceptual graphs when one begins to ask deeper philosophical questions. In terms of general applications the dualist approach proves fruitful and in general within the conceptual graph community is not questioned, conceptual graphs stand on their proven applicability in real world modelling.

Standard arguments against dualism centre on the question of communication between, or existence of other minds, and are primarily concerned with the *internalisation* process (Russell 1913). A dualist argument against conceptual graphs, on the other hand, is concerned with the *externalisation* process, and as such becomes a semiotic, or linguistic, field of inquiry. One problem concerns the multitude of ways that exist to express apparently the same idea or concept. One must reject the possibility of a single set of internal connections forming a schema, and as a result reject the certainty of an exact external representation of a given schema.

In order to express our thoughts, we need a system of signs (for example language, or conceptual graphs). It is generally understood that any system of signs is conventional (if not arbitrary) and thus the form of any expression is open to interpretation, both for an “author” of the form, and the “reader” (Derrida 1978), who of course may be one in the same. Peirce introduces the idea of an *interpretant* to address the very issue of the way in which something internal becomes external (and *vice versa*). By so doing he makes the implication that in the process of constructing a sign from an idea, or an idea from the sign, a fundamental transformation takes place.

Additionally, a current debate (Lerman 1997) throws doubt on the psychological underpinnings of conceptual graphs. This debate draws attention to a question of primacy, do thoughts give rise to language, or does language give rise to thoughts? In our opinion this question is non-trivial, and it seems that the former position (which is a *constructivist*, or Piagetian position) is fundamentally indefensible as a result of the following argument: if thoughts (schema) are constructed first mentally, before language, how then can we communicate these thoughts, for even if an individual were to think of a language, what is to guarantee that another will think of the same language, and so how may two people communicate. Constructivism is flawed because of the problems of *individualism*. This is a fundamental problem in conceptual graphs which at first sight (and, as we have shown, foundationally) attempt to map that which has been constructed internally to an external representation. Hence there are problems when thinking *of* diagrams, in communicating those diagrams to others.

As an exercise, and for the sake or irony, we decided to try to model, clarify and expose the above discussion of the problems of individualism and constructivism inherent in the foundations of conceptual graphs, by using a conceptual graph. Beginning with a list of IF-THEN statements (**Box 1**) drawn from the paragraphs above (which are an initial simplification and reduction of the discussion) we constructed the following conceptual

IF there exist a multitude of ways to express the same idea
THEN we must reject the possibility of a single set of internal schema
AND (as a result) reject the certainty of exact external representations
IF the form of expression is open to interpretation
THEN we cannot be sure of a shared understanding of the expression
IF language (diagrams) is constructed internally
THEN we cannot communicate our thoughts
THEREFORE: we cannot express our thoughts exactly, and HENCE there is no possibility of conceptual Graphs being an exact external representation of internal mental schema.

Box 1: The argument in IF-THEN Form

graph (**Figure 1**[1]). This graph serves to illustrate both the nature of conceptual graphs and the logical complexity of the argument. This is not the only way to model the dimensions of this argument and a considerable degree of negotiation, redrawing and communication took place to arrive at this version. The process of constructing the graph will feature in our later discussion.

The validity of conceptual graphs in providing a toolkit for consistent reasoning is well established and is not in

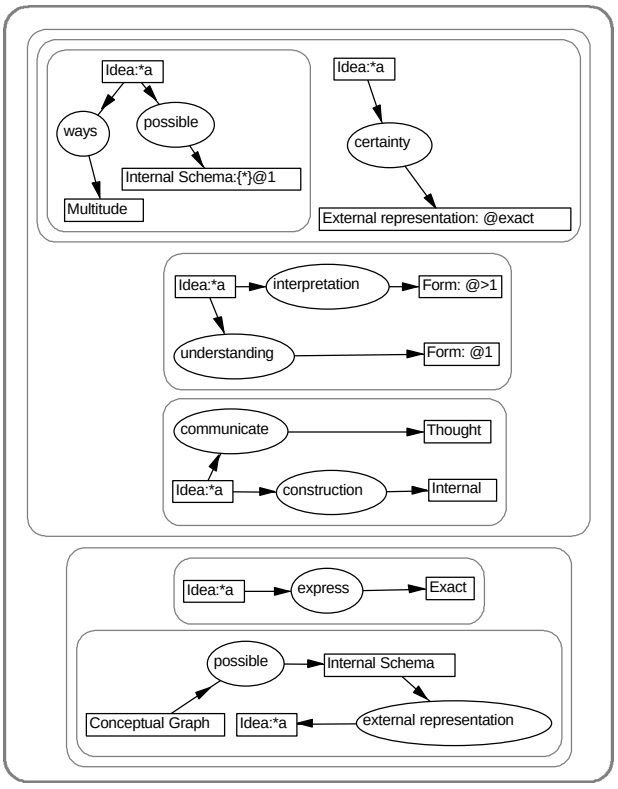

Figure 1: The argument in CG form

question. Both Peirce's existential graphs and Sowa's conceptual graphs are based upon a premise of iconicity, that is perspicacity in representation. As the graph above illustrates, this can lead to complexity yet once relationships and concepts are defined and mapped then inference (through Peirce rules) can proceed to consistent and reliable conclusions. The reasoning process can be considered to be exact, and the diagrammatic approach is particularly appropriate in this context for all sorts of reasons (Allwein and Barwise 1996); not least by semiotic virtue of its iconicity.

Effability

Connections between thought and representation are expressed in the *principle of effability* "according to which natural language can express anything that can be thought" (Eco 1997, p. 24). The underlying assumptions of conceptual graphs seem to be based upon a strong principle of conceptual graph effability, in which conceptual graphs replaces "natural language" in the statement above. We have cast doubt on the fundamental underpinnings of such a principle and in the following section we will attempt to formulate a weak version of the above principle in order to reconstruct conceptual graphs from that perspective. In the final section we will explore ways in which this new principle may provide a context for augmenting the conceptual graph approach, and some general implications for diagrammatic thinking.

The weak principle(s) of conceptual graph effability: towards a social-psychological reconstruction

The psychological foundations of conceptual graphs are based upon a cognitivist perspective that suffers from the fundamental difficulties embodied in individualism and constructivism. It is also clear that no one from the conceptual graph community would be able to defend, nor would necessarily want to, the exactitude of expression in a strong version of this principle. They may on the other hand want to argue of the connections between the external conceptual graph representation and the mental concept encapsulated in a proposal of a "weak" effability principle:

Conceptual graphs are an inexact, incomplete, model of anything that can be thought.

Advances in social psychology and semiotics present alternative views of the interaction between mind and language, in order to reconstruct conceptual graphs through the weak principle of effability, we will look to a particular social psychological position, that of Vygotsky (1978). The Vygotskian position gives primacy to language (semiotic system) and draws (independently of Peirce) on a principle of thirdness in which language and thought are linked through semiotic mediation. One of the added advantages of adopting a Vygotskian perspective, quite apart from its success in the current debate, is because of the similarities between a Vygotskian and Percian conception of semiotic (Maffiolo 1993).

Vygotsky saw thought and language as a developmental dialectic. Action, and language emerged first and then thought, mediated through tool use (in his definition of tool he eventually included words as well as physical tools) until both thought and language join into one strand of development. The Vygotskian triangle has subject and object connected through mediational means, which compares with the sign-object-interpretant triangle of Peirce. Additionally Vygotsky states clearly his belief that any function of development (i.e. any meaning) first "appears on the social plane and then on the psychological (Vygotsky 1978, p. 163), which provides us with an explicitly social view of the role of a semiotic system. Peirce does not explicitly give primacy to the social, but he does foreground the human place in semiotic acts.

Adopting a Vygotskian view, and bearing in mind the identified theoretical problems with conceptual graph

[1] The mechanics of constructing conceptual graphs from logical or linguistic statements will not be discussed here, for an introduction to conceptual graphs see (Polovina and Heaton 1992).

foundations, we may reconceptualise the weak effability principle to take account of the social and the mediational means. Thus the weak effability principle (II) may be thought of as:

Conceptual graphs are an inexact, incomplete model of social and cultural contexts, these graphs may provide a vehicle, or toolkit that mediates internalisation, hence generate thought.

Building from this principle, we see conceptual graphs as a semiotic system, a toolkit for aiding thought rather than mapping it. Indeed Sowa (1997) implicitly adopts this position when he champions conceptual graphs as an expressive model of natural language, although he does not see this as contradictory to his original position, nor does he explore the consequences of such a position. Earlier, in his original work (Sowa 1984) he does identify "conceptual relativity" (7.3) as problematic in his theory, as this seems to demonstrate an opposition to the notion of conceptual graphs as a map of mental schema. At this point he relaxes conditions, admitting that, pragmatically, conceptual graphs provide at best a "workable approximation" of the world. But accepting that conceptual graphs are discrete simple models of complex continuos worlds is not contradictory to an idealist, schema based view of the nature of these graphs. For one may contend that conceptual graphs are but a subset, in external form of the interconnected concepts and precepts in the mind. This does not exclude isomorphism of representation through externalisation. In general the conceptual graphs community has not concerned itself with this question, preferring to work with graphs as if they were exact representation, for reasons of functionality. Here we are arguing for a more dynamic, social view of conceptual graphs grounded in a social semiotics.

Semiotic systems are designed for communication, thus conceptual graphs are no exception. Adopting the weak conceptual graph effability principle (II) leads us to a conception of conceptual graphs not only as signs for communicating concepts, but as a toolkit for the joint construction of knowledge. From this perspective the conceptual graph can never exactly represent a concept, rather the process of constructing the graph helps the constructors to get a better “idea” of the concept and its’ context. This is seen as a collaborative, iterative procedure in which these individual ideas are then externalised, and shared, in the form of modifications of the existing Graph. That is, thinking *through* diagrams.

From this point of view the *process* of constructing a conceptual graph may be considered to be more important than the *product*, the final graph. Individual subjectivities and the shared objectivity are linked through the construction process. That is, the construction of a representation in the *intersubjective* plane, gives rise to a meaning in the *intrasubjective* plane (Vygotsky 1978) through the toolkit of conceptual graphs. This provides support for the use of conceptual graphs as analysis tools in which analyst and "user" carve out meanings and concepts *together*, and as tools that could become central to decision making and strategic planning.

It is clear that similar claims could be made, and indeed have been made, about text and language in general. This is true, yet here we are explicitly championing diagrammatic thinking in particular the iconic nature of conceptual graphs. Language is more arbitrary, consisting of symbolic rather than iconic connections[2] and less "clear" and "expressive". This has been convincingly shown in an earlier pilot study by Polovina (1993).

Towards a collaborative paradigm

So what does this mean about the conceptual graph paradigm? And what does it say about thinking with diagrams? Let us say first what it doesn’t mean; it doesn’t mean the rejection of conceptual graphs as tools for mapping concepts, and it certainly does not mean the rejection of diagrams as an aid to thinking (in fact this discussion supports the case for collaborative thinking *through* diagrams). How indeed could it? Especially when one considers all of the successful applications of conceptual graphs in numerous areas. The semiotic system, iconicity, logical consistency, expressive power and pragmatic functionality of conceptual graphs are not in question, only a foundational issue, and a radical one at that. Consideration of this issue, which results in the weak principle (II) leads only to the relaxation of some absolutist expectations and the expansion of the conceptual graph paradigm into a social and cultural arena.

As an example consider the process that the authors went through in the construction of the graph in **figure 1**. This graph is complex yet it represents on one page a highly involved argument. But does it represent it exactly? Almost certainly not. The graph was constructed initially by one of us, and then explained to the other. At this point there was some disagreement and negotiation until after an iterative process consensus was reached that the graph adequately illustrated the dimensions of the argument. In fact what this graph represents is the representation of a *collective intelligence*, a socially, and externally, constituted representation of two peoples views of a course of thought. For the authors the process of constructing the graphs forced choices (such as the focus on an "idea") and illuminated parts of the argument through the need to clarify and structure. It is in this type of activity, thinking *through* diagrams, that we see the future of conceptual graphs, and indeed many other diagrammatic forms of concept representation and inference.

This expansion of the conceptual graph paradigm may be effected through attempts to increase the possibility of multiple users of a single conceptual graph environment, and would be essentially pragmatic. Accepting that the real potential of conceptual graphs extends beyond the individual to mutual, social production leads us to think of ways to enhance collaborative conceptual graph production through interactive, distributed toolkits. Networked PC’s and Internet are obvious choices for this,

[2] Here we use *symbol* and *icon* in the sense of Peirce (1931-1958) in which symbol has conventional and icon has concrete connections with the object that they signify.

as they allow graphical interfaces and interactions, they are accessible from all remote locations and most importantly they allow sharing.

This socialising of conceptual graphs extends to a socialising of diagrammatic thinking in general, from an individual thinking *in* or *of* diagrams to a mutually shared, intersubjective space for thinking mediated *through* diagrams, in which mutual construction of representations facilitates mutual meaning-making. This is quite different to the case of language where an unbalanced power relationship exists between the utterer (owner) of a sentence and the receiver, the receiver must struggle to get even a belief in a sense of shared understanding of meaning. In mutually constructed diagrams, thought is constituted in mutual inter*actions*, that is no one is passive in the meaning making process.

Conceptual graphs in the future?

We may see in the future the scope of conceptual graphs expanding into more disciplines. Perhaps as research instruments in fields such as marketing, media, or more main stream psychology, or as teaching and learning instruments in which students are encouraged to build, individually or collaboratively, conceptual graphs representing historical, political or mathematical concepts. As we have already suggested, there may be applications in information systems, in which the user and analysis join in the process of concept construction (the interaction of user and analysis is discussed in great detail by Checkland (1981)). In fact conceptual graphs have great potential in all areas in which collaborative thinking, concept mapping or analysis is a possibility. There is, however, a danger that as conceptual graphs become a collaborative meeting of minds there may be just too much knowledge to be represented. We have discussed this issue elsewhere (Polovina and Vile 1998). And so care must be taken to avoid needless complexity that obviates any iconicity through a high order of interconnectedness.

Nevertheless there will be value in conceptual graphs as a toolkit for collaborative concept construction in many non-trivial cases. It is clear that socially conceptual graphs can be of benefit, and whether constructed on paper or with technological tools their degree of clarity will encourage meaning making and lead to problem solution. Although conceptual graphs found inception in a cognitive paradigm, they are well suited to a more socio-cultural view, and could have almost been designed for that purpose.

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