Published in the *Journal of Financial Information Systems* (http://www.shu.ac.uk/jfis/)

A GATEWAY TOO FAR? EXPERIENCES ON INTEGRATING ACCOUNTING INFORMATION SYSTEMS WITH STRATEGIC KNOWLEDGE

SIMON POLOVINA AND ADAM VILE
GRAPHICAL REASONING & NETWORK DESIGN GROUP (GR&ND)
SCHOOL OF COMPUTING, INFORMATION SYSTEMS AND MATHEMATICS
SOUTH BANK UNIVERSITY, LONDON, UK

EMAIL: S.M.Polovina@herts.ac.uk, vileawa@sbu.ac.uk
WEB: http://www.sbu.ac.uk/grand

Abstract. The paper brings together accounting and strategic planning through conceptual graphs; an advanced yet visual knowledge based formalism, suggesting that conceptual graphs are a suitable knowledge-based decision support tool for use by management accountants in strategic planning. This hypothesis is tested through a small-scale empirical study, using specifically developed software. The evaluations indicated that such first order logic oriented formalisms are inadequate for business knowledge modelling, thus highlighting that further efforts in this direction alone will be fruitless. Further work should be redirected towards fuzzy oriented modelling. Based on the experiences with conceptual graphs the paper offers some guidelines towards this aim.

Keywords: Knowledge-based Systems, Events Accounting, Cognitive Mapping, Conceptual Graphs, Strategic Complexity, Fuzzy Thinking

INTRODUCTION

To enable an organisation to have more control over its affairs, it would be very desirable to bring together into one positive framework two seemingly disparate yet important parts of business activity. The first area, accounting, essentially provides an established basis for controlling numerically based problems whereas the second, strategic planning, is characterised by fundamental but highly subjective problems that do not lend themselves to accountancy's quantitative techniques. The paper reveals the existence of a gateway between the two by examining an influential methodology in each area, and then restating them both in conceptual graphs. The first methodology, events accounting, is a significant attempt to capture the conceptual basis underlying accountancy. The second, based on cognitive mapping, is a leading knowledge-based strategic planning analytical tool. Our starting point is the accounting model itself.

THE DESIRABILITY OF AN ACCOUNTING MODEL

At its outset the major benefit of adopting a structured model of a problem is so that such a model draws out all the problem's relevant parameters from which a solution can be investigated fully. Contrast this with a written or spoken text discussion of the problem where it is well known that ambiguity and obfuscation can occur easily. This 'natural language' interpretation of problems may be the most flexible and easily followed, but without at least a basis in some structured form it can be dangerously erroneous. Hence the emergence of disciplines such as accounting that attempt to model the dynamics of economic activity in a structured way. The model, of course, must also be structured on a suitably principled basis. Otherwise it will omit or misinterpret the salient issues of the problem situation.

Arising from this need the traditional model of accountancy, the *bookkeeping model*, was developed in the Middle Ages. The principle behind this model is economic scarcity; for every benefit a sacrifice has to be made. The bookkeeping model is simple yet rigorous. Fundamentally, instead of recording one amount per transaction it records two: A 'debit' and a 'credit'. These amounts are complementary, thus 'balance' against each other. An accounting 'balance sheet' is merely the aggregate of all these debits and credits. Its rigorous nature derives from this principled ‘double entry’ structure so that each benefit is accounted for by a cost and vice versa. Every gain is thereby matched to a sacrifice.

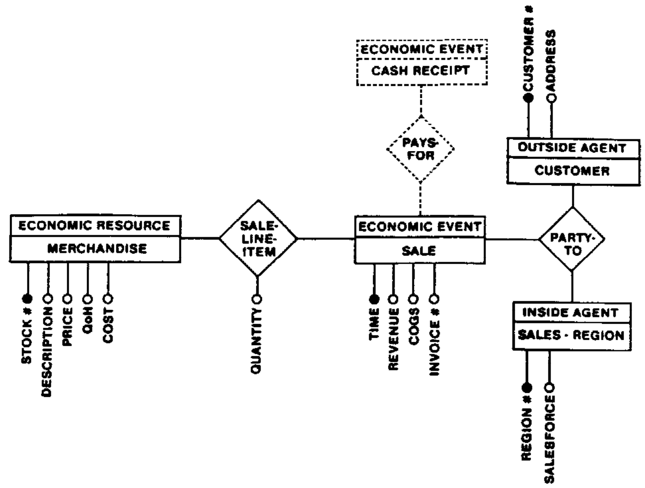


Figure 1: The events accounting model in ER form (Geerts and McCarthy, McCarthy).

The double entry bookkeeping model however is unlikely to capture all these economic value trade-offs, as many accountants, well aware of the difficulties in attaching a monetary value to ‘intangibles’ such as product brand names, would testify. Recognising that many transactions are thereby too qualitative to be recorded, Geerts and McCarthy (1991) and McCarthy (1987) have proposed the *events accounting* model. Unlike the bookkeeping paradigm, events accounting attempts to capture the qualitative dimensions of economic scarcity. The model is shown by **Figure 1**.

Figure 1 shows the events accounting model as an *entity-relationship (ER) diagram* (Chen, 1981). Chen (1985) argues that the pictorial nature of ER diagrams are particularly useful in structuring problems qualitatively stated in natural language.

Given this actuality, events accounting represent a powerful means of recording scarcity as more than a monetary measure. Setting aside its ‘dotted’ part for now, **Figure 1** reveals the fundamental links between an ‘economic resource’, which means some exchangeable item of value, and the parties which create the ‘economic event’ that causes the economic resource to be exchanged.

THE EVENTS ACCOUNTING MODEL AS CONCEPTUAL GRAPHS

Conceptual graphs are an advanced knowledge-based representation formalism first conceived by Sowa (1984) from philosophical, psychological, linguistic, and object-oriented principles. Polovina and Heaton (1992) provide a succinct explanation of conceptual graphs, including its ‘Peirce logic’ inferencing capabilities. Conceptual graphs can structure the dimensions of natural language-based problems beyond that of ER diagrams Sowa (1985), and Sowa (1990) further demonstrates that conceptual graphs also extend ER diagrams by adding, to begin with, the capacity of first-order logic in a pictorial way. On this basis we enhance the events accounting model by transforming it into conceptual graphs form. The conceptual graph of **Figure 2** represents this transformation.

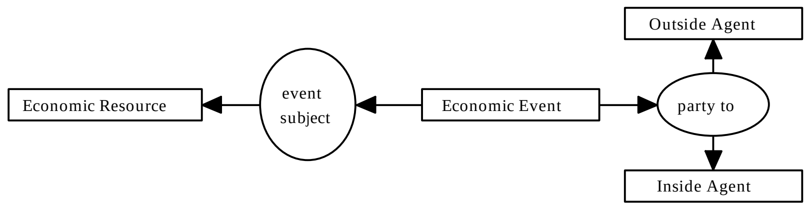


Figure 2: Transformation of the events accounting model into supertype conceptual graphs.

Figure 2 is essentially a conceptual graphs reproduction of the general supertype parts of the earlier entity-relationship events accounting diagram, **Figure 1**, except that the arguably more definitive term ‘event subject’ is substituted for ‘sale line item’. The *triadic* relation ‘party to’ in the figure also illustrates where it is convenient to employ a relation that is linked to three concepts instead of the previously discussed two concept linked, or *diadic*, relations.

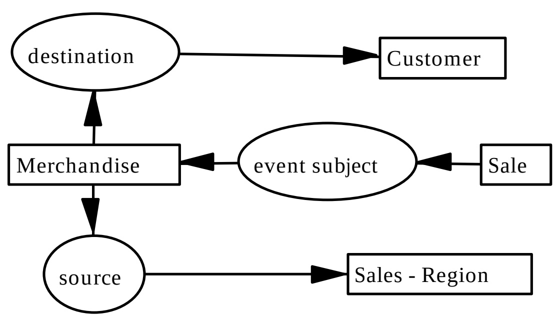


Figure 3: Transformation of the events accounting model into subtype conceptual graphs.

Figure 3 similarly expresses the specialised subtypes of **Figure 1**. It also refines ‘party to’ into ‘source’ and ‘destination’, and thereby shows the route by which the economic resource changes possession. For both the conceptual graph diagrams, certain aspects in the entity-relationship model are not reproduced to focus on the salient nub of events accounting.

Duality

The conceptual graphs of **Figure 2** and **Figure 3** do not yet fully capture events accounting. To achieve this the *duality* principle of economic scarcity needs to be considered.

Duality is defined by the statement "for every benefit there has to be a sacrifice made". The events accounting model indicates duality in the 'dotted part' of the earlier **Figure 1**. This 'cash receipt pays for the sale' is really a shorthand to make that top diagram concise. For instance 'party to' should also connect to 'cash receipt' because it is also part of the exchange. **Figure 4** reveals this duality in full at the supertype level.

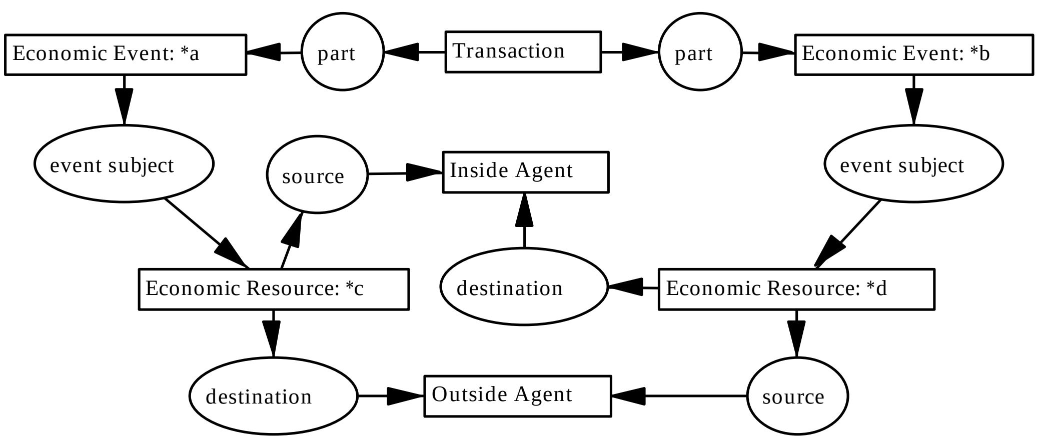


Figure 4: Completing the events accounting model by including duality.

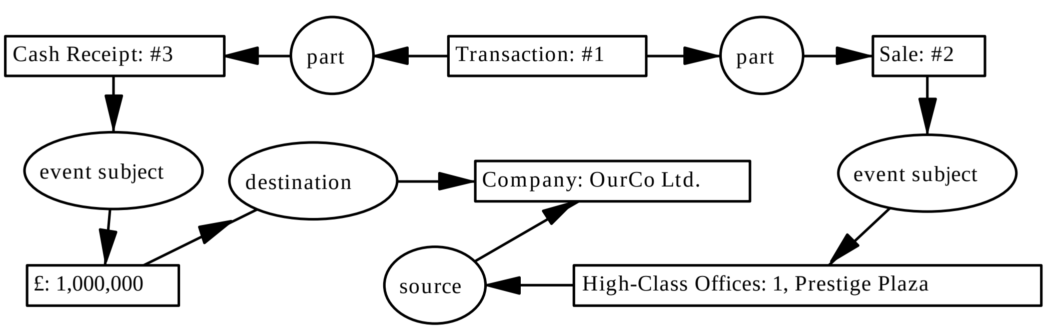


Figure 5: Apparent duality of selling offices.

In **Figure 4**, linking the economic events to the same transaction highlights the duality. Differing ‘*<letter>’ generic referents for a given concept, illustrated in **Figure 4** by the ‘Economic event’ concepts, explicitly denote that these referents cannot be coreferent. As already indicated, the ‘Economic Resource’ concepts may be specialised to any quantitative or qualitative concept describing an item of value. As one value describes the benefit in the transaction, the other value depicts what had to be sacrificed for that benefit. An example scenario is portrayed in **Figure 5**.

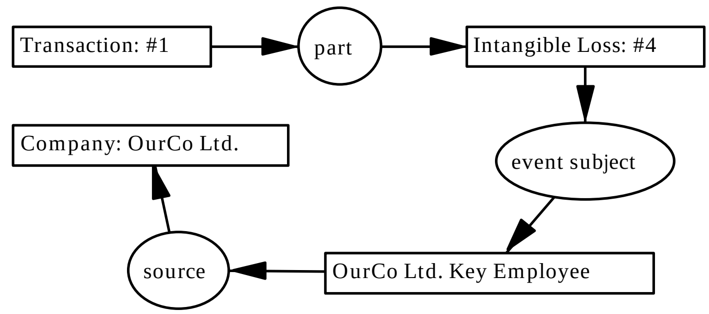


Figure 6: Further cost-side duality of selling offices.

Intangible Values

Figure 5 describes a business wishing to realise cash by selling its expensive offices, with a view perhaps to purchasing cheaper ones. The diagram shows a ‘£1,000,000’ cash benefit to ‘OurCo Ltd.’ for the loss of their high-class offices at ‘1, Prestige Plaza’. As such, the bookkeeping model may easily record it. The ‘#<number>’ referents are individual instances simply denoted by a serial number.

However **Figure 5** may still not give the full picture. In addition to the loss of the present offices, there may be an intangible loss due to disgruntled key employees leaving the corporation as a consequence. As discussed earlier, such intangible values remain outside the bookkeeping model. Nevertheless the business could require such factors to be included as they may determine the very survival of the business itself. The conceptual graph of **Figure 6** manages to add this qualitative cost. The graph of **Figure 6** can thus be *joined* onto **Figure 5** at their common ‘Transaction: #1’ concept.

Comments on the Events Accounting Model

The events accounting model, in summary, does not restrict the recording of transactions to only those that can be captured by numeric monetary measures. Thereby its wider scope enables qualitative value judgements to be modelled and hence be gauged along with the quantitative elements. In databases, such parameters are defined in data fields which can be then subjected to some selection criteria. Within any knowledge-base, in addition to this 'lookup' facility, there should exist the ability to infer new knowledge. If accounting transactions can be presented in a knowledge-based form they can be subjected to such inferences.

Introducing inference

Conceptual graphs, as they stand seem to be able to map relationships and events in a way that is similar to the events accounting model. What makes them stand apart from ER diagrams and promotes them into the domain of strategic decision making is their embodiment of procedures for making inferences. Inferences in conceptual graphs are based upon the existential graphs logic theory of Charles Sanders Peirce. Sowa (1984) argued that 'Peirce logic', cited by its founder as 'the logic of the future', significantly enhances traditional predicate logic. One aspect of this improvement is, like conceptual graphs, the visual nature of Peirce logic. The visual inference of Peirce logic eases the human's understanding about logical complexity. It reveals insights not otherwise evident in the usual procedurally based inference methods using, say, 'if-then' style rules (Kent 1997).

INTRODUCING THE COGNITIVE MAPPING DIMENSION

Cognitive mapping is a practical technique derived by Eden (1991) based on the personal constructs theory of Kelly (1955), and is used by strategic planners to structure the highly subjective problems that characterise strategic planning. Polovina (1997) extensively interrelate cognitive maps with conceptual graphs, from which the following discussion draws upon. The cognitive map element shown in **Figure 7** continues the office relocation example discussed so far.

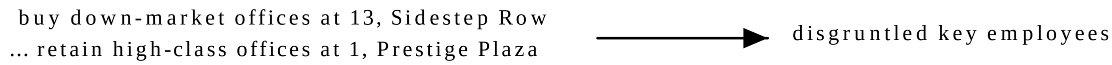


Figure 7: An example showing the essential elements of a cognitive map.

In **Figure 7** the left-hand concept contains the emergent pole 'buy down-market offices at 13, Sidestep Row'. The contrasting pole, separated from the emergent pole by '...', is 'retain high-class offices at 1, Prestige Plaza'. Where a contrasting pole is unspecified, as in the case of 'disgruntled key employees', then the contrasting pole is determined to be '*not* <emergent pole>'. Hence the contrasting pole for the latter concept becomes 'not disgruntled key employees'. The link leads from the 'buy cheaper offices at 13, Sidestep Row ... retain current offices at 1, Prestige Plaza' concept to the concept with the emergent pole 'disgruntled key employees' and default contrasting pole 'not disgruntled key employees'.

From the above the down-market offices lead to disgruntled key employees whereas the current offices lead to these employees not being disgruntled. After refining this statement from the elementary form illustrated by **Figure 7** into conceptual graphs, the choice of offices and its consequence may be remodelled as given by the graphs of **Figure 8** and **Figure 9**.

In **Figure 8** the pair of specified poles denoting the choice of offices are restated as a conceptual graph by placing each pole into a separate conceptual graph concept and together surrounding them within a Peirce negative context. The single specified disgruntled employee pole and its unspecified 'not' contrast is also restated in **Figure 8** although this graph, on careful examination, merely turns out to be a tautology.

Figure 9 demonstrates, in conceptual graphs, the cognitive map links as two implications based on the Pierce logic operations of deiteration and double negation Polovina and Heaton (1992). The conceptual graphs show both implications to be generalised, assuming this step is valid, to show that for any down-market offices the key employees located there are disgruntled whilst in any high-class offices they are not (modus ponens). Similarly if such employees are not disgruntled then they are not located in down-market offices (modus tollens).

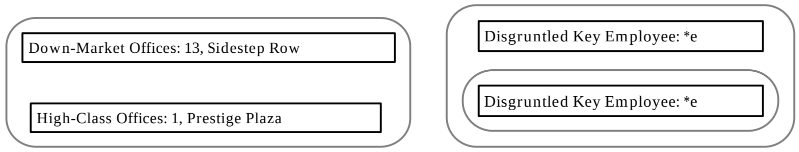


Figure 8: Conceptual graphs for the concepts of the example cognitive map.

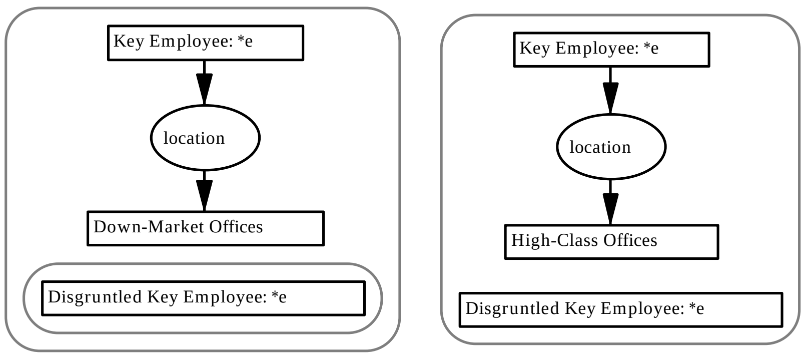


Figure 9: Conceptual graphs for the links of the example cognitive map.

Conceptual graphs provide the contrast in cognitive map concepts by stating that one pole must be false if the other is true. However when both poles are specified the converse, that if one is false the other is true, cannot be determined. This distinction, which is not clear from the elementary cognitive mapping model, is intended. The business (referred to earlier as ‘OurCo Ltd.’) may, in the event, dispose of 1, Prestige Plaza and obtain offices other than at 13, Sidestep Row or even not any other down-market offices for that matter. Hence it may be quite wrong to assert that they *will* be at either 13, Sidestep Row or 1, Prestige Plaza.

Furthermore conceptual graphs allow each pole to be generalised or specialised to differing degrees so enabling a potential continuum of contrast. This contrast happens to accord more precisely with Kelly’s original personal construct theory than Eden’s cognitive maps. There may be, for example, a more general contrasting pole to a more specific emergent one. Ultimately the most general contrasting pole is the ‘not <emergent pole>’. As for the cognitive mapping links, the modus tollens inference is arguably not evident in the elementary form given by **Figure 7**, and thus underpins the visual advantage that Peirce logic possesses.

As well as the ability to a) generalise and specialise problem scenarios to the appropriate degree and b) vividly express modus tollens, conceptual graphs further reveal that c) there is no real distinction between the concepts and links of cognitive mapping anyway. As should be evident from a careful examination of both **Figure 8** and **Figure 9**, these links turn out to be like emergent and contrasting poles. Hence conceptual graphs remove the arbitrary choice as to what is a link or a pole. Moreover strategic planning problem situations can now be captured alongside the accountancy domain through the single medium of conceptual graphs. This opens the way towards suggesting a bridge between the two techniques.

A BRIDGE BETWEEN EVENTS ACCOUNTING & COGNITIVE MAPPING

An accounting methodology that incorporates the events model, rather than merely the bookkeeping model, enables the more qualitative elements of transactions based on economic scarcity to be captured along with the more quantitative elements.

Conceptual graphs enhance the entity-relationship model and include a visual method of inference in the form of Peirce logic. It thereby widens an organisation's numeric-based financial record systems into a *corporate knowledge base* that can now include the parameters of strategic planning.

For example, given:

```
Disgruntled Director < Disgruntled Key Employee.
```

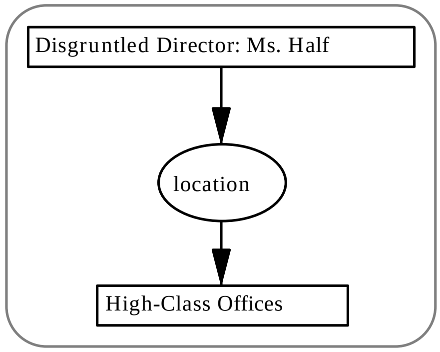
And should the graph:

Disgruntled Director: Ms. Half

Be a consequence of a strategic decision then, given the graphs so far for the office location example, the transaction disposing the offices at 1, Prestige Plaza would be *blocked*.

This occurs because the ‘Disgruntled Key Employee: *e’ concept in the right-hand graph of **Figure 9** would *project* into the above graph, and thus deiterated.

The result is the unwanted state of affairs given by:



"Ms. Half is not located in high-class offices (and why she is disgruntled)"

Note that in the new graph, that '*e' has taken up Ms. Half as its individual referent because, before any graph is deiterated, it specialises to *match precisely* the graph that dominates it. As a consequence '*e' specialises to Ms. Half. The other '*e' in **Figure 9** therefore becomes specialised, being coreferent, before deiteration takes place. Similarly the attached 'Key Employee' becomes specialised to 'Disgruntled Director'. Hence the resulting new graph.

From building the bridge in conceptual graphs it emerges that accounting is essentially *descriptive* in nature and can thereby be captured by knowledge representation alone whereas strategic planning is *prescriptive* and requires the dynamics of inference. However the benefit is not one way: Accounting can offer strategic planning a firmer conceptual basis from which its dynamic models can be built. Hence a way forward exists whereby a business might develop and maintain a corporate knowledge base that permeates more of its diverse activities.

HUMAN REVIEW

There is, however, a caveat: Computer modelling this knowledge base alone achieves little if this demonstrative representation cannot be timely, and accurately, reviewed and updated by 'those best in the know'; that is by the domain experts directly without the burden of an over-simplifying intermediate notation. We are nowadays commonly aware that much business activity is not only qualitative but also constantly changing. The corporate knowledge-base will thus be unable to keep up sufficiently with the rapidly changing tacit and implicit parts of business knowledge without this timely analysis and review by the domain expert users. We have discussed the technical merits of conceptual graphs but only hinted at their human usability; we thereby need to address this fundamental issue.

Sangster (1991), and King and McAulay (1992) had already identified the need for human domain expert review in management accounting. This subject area also happens to embody the actual techniques by which finance professionals analyse and present accounting data informatively to facilitate managers or other decision-makers in achieving their economically constrained strategic goals. This *strategic management accounting*, identified by Bromwich and Bhimani (1989) and detailed by Wilson (1995), therefore offers us a practical means to assess the ultimate value of conceptual graphs as the appropriate model for integrated strategic planning accounting information systems. We therefore take the ambitious step and suggest the hypothesis that "conceptual graphs are a suitable knowledge-based decision support tool for use by management accountants in strategic planning".

THE CONCEPTUAL ANALYSIS AND REVIEW ENVIRONMENT, CARE

To test this hypothesis one of us (Simon Polovina) devised the *C*onceptual *A*nalysis and *R*eview *E*nvironment, or *CARE*. Through the conceptual graphs-based CARE software, we would determine if the management accountant could interact with a corporate knowledge base based on a conceptual graphs-based human-computer interface, so determining the null or the alternative hypothesis.

To assist this interaction, the conceptual graphs theory itself was kept as clear as possible. Ideally intricate parts of theory should be handled by the machine and be transparent to the domain expert, thus hiding the extraneous computational knowledge, yet without making the power of any CARE software too trivial. The CARE software would also prevent the domain expert from constructing graphs that have any incorrect syntax. CARE would also draw upon techniques that the management accountant is already familiar with. This was planned to be achieved by exploiting the similarity that conceptual graphs have with structured diagrams (i.e. flowcharts) and the negative context's resemblance to the '(…)' that denote negation in the bookkeeping model, these being commonly used techniques by accounting professionals.

Incidentally, if successful, CARE could allow integration to occur amongst many domain experts, especially given the growth of global networks currently epitomised

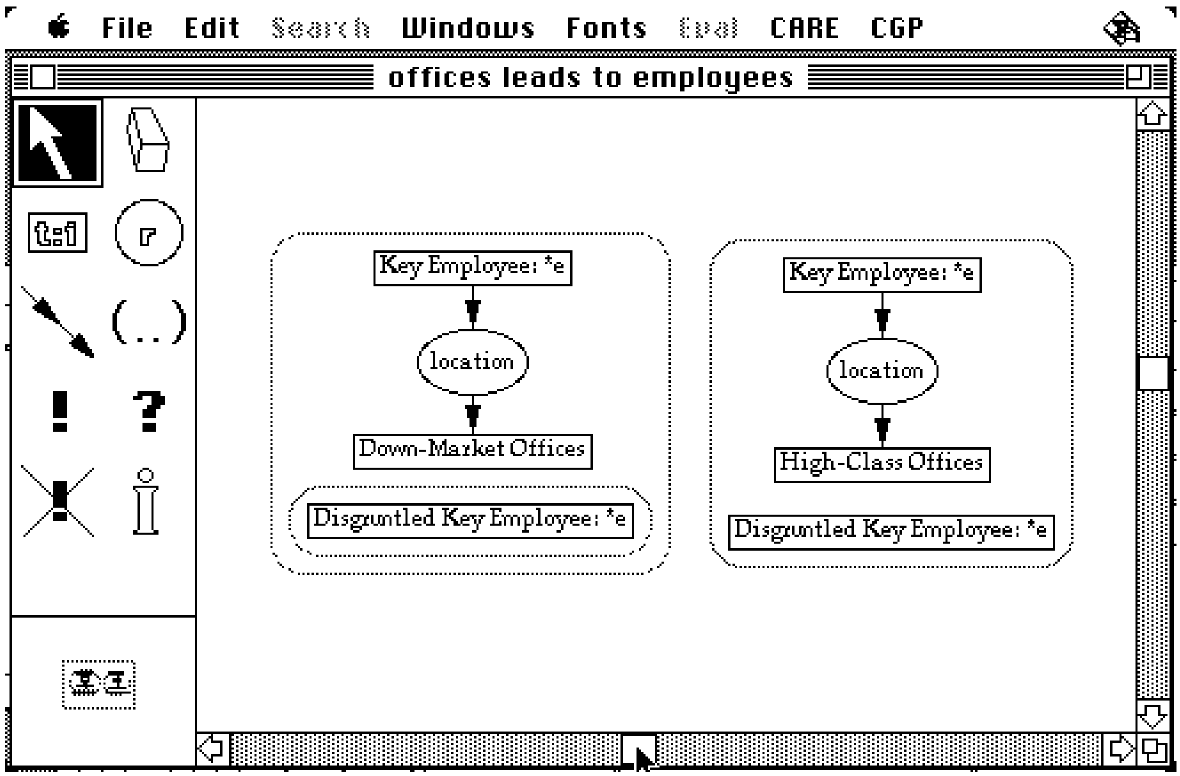


Figure 10: Example CARE screen.

by the Internet and the World Wide Web. A typical CARE modelling situation might begin with the initial graphs being drawn by one strategic management accountant. Subsequently, that expert's results could then be consolidated with graphs drawn by other such accountants or interested parties. CARE could be used to check for inconsistencies between the models. This would draw out differing opinions that could then be resolved to obtain a more comprehensive model. Such activity, especially as it expanded into capturing other problem domains of interest to the relevant organisation, would evolve into that organisation's *distributed* corporate knowledge base. Also, CARE need not ultimately be restricted to generalising over qualitative problems alone. Linking conceptual graphs to databases, spreadsheets, or other knowledge-based systems could be another avenue for CARE. Such computer-computer integration could significantly elucidate all manners of business problems.

Figure 10 illustrates the interface to CARE software which, to permit rapid prototyping, was written in LPA MacProlog (http://www.lpa.co.uk/). With CARE, the user may draw, modify, select, drag or erase a conceptual graph. The user may also assert or query a conceptual graph into an integrated conceptual graphs processor (CGP) provided by Heaton (1994). CGP enabled inferencing to take place and a consistent knowledge base to be built up, or highlight the nature of contradictory knowledge. To maintain simplicity of use, all functionality is essentially accessed by the 'tool pane' shown at the left hand side of Figure 10. The menu bar essentially provided the usual file and edit set of functions; the **CARE** and **CGP** menus configured CARE and CGP respectively.

CARE EVALUATION SESSIONS WITH DOMAIN EXPERT USERS

After it had been successfully piloted at a workshop of conceptual graphs experts, CARE was subjected to a series of small-scale evaluations. CARE was taken into an academic domain expert environment and then to practicing accountants. These evaluations, including their experimental design and statistical analysis, are detailed in Polovina (1993). From the first point of contact between CARE and a domain expert, concerns began to be raised as to conceptual graphs' adequacy for the strategic management accountant. The intricacies of the strategic problem being modelled by the graphs, even at a trivial level, began to render the resultant graphs too difficult to interpret by the user. As the evaluations progressed, this situation became increasingly obvious. This was further underlined when CARE was presented to actually practising accountants.

For instance, one domain expert presented the following scenario:

"Until now, there have been no guidelines to help the Research Funds Committee prioritise bids for research monies that we allocate to universities, and for deciding how the research budget should be allocated. There is a need for such guidelines so that the decisions of the committee are consistent, and to provide guidance to university staff as to the eligibility and chances of success of any application for funds that they might be thinking of making. The Research Funds Committee has therefore agreed the following guideline:

Given no other factors, funds will be allocated in the following order (highest priority first): Probationers, Lecturers, Senior Lecturers, Readers and, lastly, Professors"

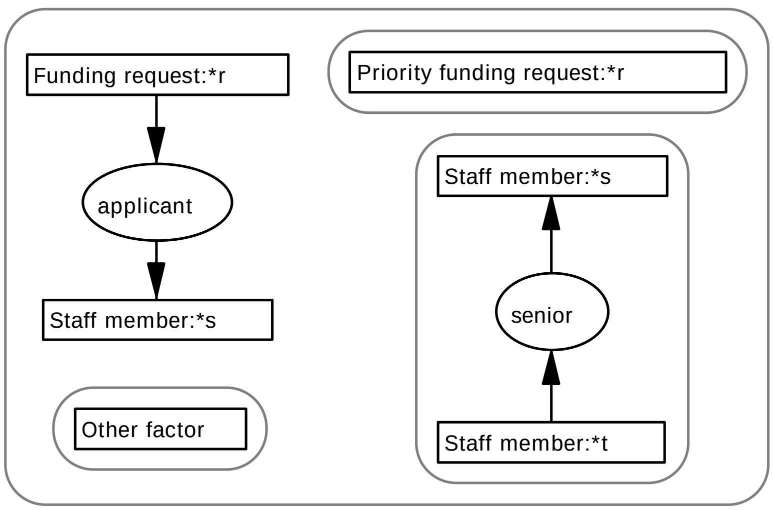


Figure 11: Highest funding priority for the least senior staff member.

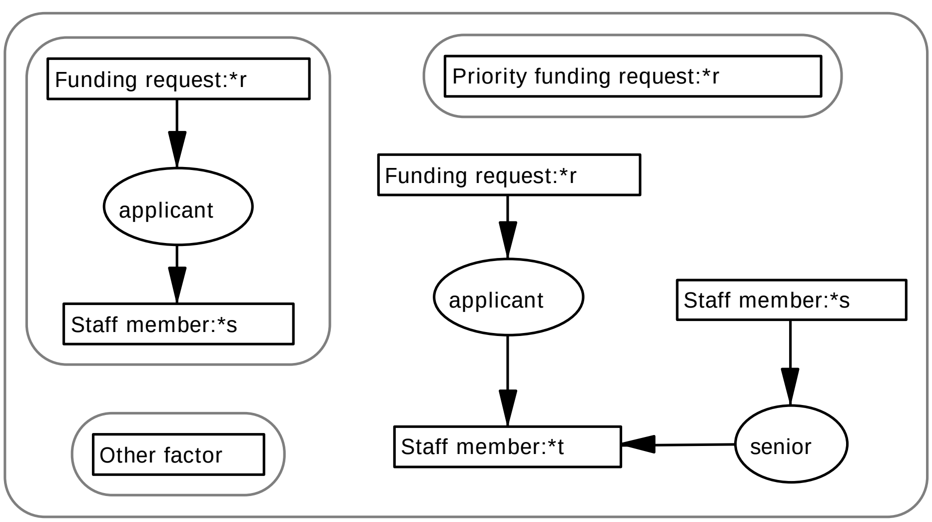


Figure 12: Funding priority for the more senior staff members.

The conceptual graphs that modelled the researching funding priorities are given in **Figure 11** and **Figure 12**. The domain expert could not model these graphs; this was left to one of us (Simon Polovina). Clearly these graphs are even too difficult for most humans to read, regardless of background. We are coldly reminded of Miller (1956)'s axiom "the magical number seven, plus or minus two … limits on our [human] capacity for processing information". We are also reminded of Simon (1964)'s bounded rationality (or satisficing), particularly evident in the imprecise 'Other factor' concept in both figures: what defaults are appropriate to determine if some factor is indeed significant or not?

Therefore despite their strong prima facie attractiveness and positive response from the conceptual graphs community session, the inherent complexity of conceptual graphs fundamentally undermined their usability, other than for very trivial problems well below the level needed to be viable for strategic management accountancy.

WHERE FROM HERE?

We can see that conceptual graphs, though expressive, are based upon precise or 'crisp' as opposed to 'vague' or fuzzy logic (Kosko 1994). Conceptual graph's visual nature 'gives up the ghost' by unmasking the limitations of crisp logic, thereby underpinning the inherent vagueness in real world strategic problem solving. Interestingly Kosko, a champion of fuzzy approaches to decision making, has developed "Fuzzy Cognitive Maps" (FCM) in an attempt to embody diagrammatic approached to decision making with fuzziness. These are fuzzy signed directed graphs that resemble those of Eden (1991) yet incorporate fuzziness in a quantifiable way. Kosko has used these maps successfully in supporting approximate reasoning, although not in the context of strategic decision making. There is a case for future work that will incorporate FCM into conceptual graph representations and evaluate the value added in terms of more accurate reasoning against increased complexity.

Peirce's diagrammatic Gamma logic is also designed to deal with vague concepts. Peirce added to his graphs a series of layers and colours in an attempt to deal with vague concepts (Peirce 1931-1958) but he never completed the program of development of these graphs. Subsequent work by Øhstrøm (1997) indicates that although possibly fruitful this formulation brings with it exponential degrees of complexity, nevertheless this is a possibility for further enhancing the applicability of Conceptual graphs in the problem solving domain and warrants further study.

IN CONCLUSION

This work has shown both the benefits and inadequacies in the conceptual graphs approach in supporting decision-making in strategic management accounting. Conceptual graphs embody logical and object-oriented principles, they are visual and adequate to model limited problems, however as these problems become complex and vague this tool becomes unmanageable and inadequate. That is not to say that conceptual graphs are inappropriate; their potential to deal with complex situations is blocked by their 'crispness' as logical tools. This obstacle may be addressed by incorporating fuzzy logic into the conceptual graphs formulation.

On the one hand it is necessary to develop tools that will support strategic decision-making and on the other hand such tools must be useable and not needlessly complex. Furthermore these tools must be embodied with the ability to process inference and deal with fuzzy concepts. Naturally we must ensure that fuzzy logic does not *add* complexity. The work detailed in this paper leads us to suggest the need for the further development of conceptual graphs to incorporate the fuzzy domain, and the need to provide an interface to these tools that is useful for the decision-maker. Its success would realise the practical accounting-to-strategic gateway that presently remains elusive.

REFERENCES

Bromwich, M. and A. Bhimani (1989). Management Accounting: Evolution not Revolution, Chartered Institute of Management Accountants.

Chen, P. P., Ed. (1981). Entity-Relationship Approach to Information Modelling and Analysis. Saugas, CA, USA, ER Institute.

Chen, P. P. (1985). Position Statement on Mapping Specifications to Formalisms (Panel Session). 4th International Conference on Entity-Relationship Approach, IEEE Computer Society Press.

Eden, C. (1991). Working on Problems Using Cognitive Mapping. Operations Research in Management. M. Shutler and S. Littlechild, Prentice-Hall.

Geerts, G. and W. E. McCarthy (1991). Database Accounting Systems. Information Technology Perspectives in Accounting: An Integrated Approach. B. Williams and B. J. Sproul, Chapman and Hall.

Heaton, J. E. (1994). Goal Driven Theorem Proving Using Conceptual Graphs and Peirce Logic (PhD Thesis). Department of Computer Studies, Loughborough University of Technology.

Kelly, G. (1955). The Psychology of Personal Constructs. New York, Norton.

Kent, T. B. (1997). The Interconnectedness of Peirce's Diagrammatic Thought. Studies in the Logic of Charles Sanders Peirce. N. Houser, D. D. Roberts and J. V. Evra. Bloomington and Indianapolis, Indiana University Press**:** 445-459.

King, M. and L. McAulay (1992). “Barriers to Adopting Management Expert Systems: Case Studies of Management Accounting Applications which Failed.” Expert Systems **8**(3): 139-147.

Kosko, B. (1994). Fuzzy Thinking. London, Harper Collins.

McCarthy, W. E. (1987). On the Future of Knowledge-Based Accounting Systems (The D. R. Scott Memorial Lecture Series, University of Missouri). Artificial Intelligence in Accounting and Auditing: The Use of Expert Systems. M. Vasarhelyi, Markus Wiener Publishing**:** 19-42.

Miller, G. A. (1956). “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information.” The Psychological Review **63**(2): 81-97.

Øhstrøm, P. (1997). C.S.Peirce and the Quest for Gamma Graphs. Conceptual Structures: Fulfilling Peirce's Dream. D. Lukose, H. Delugach, M. Keeler, L. Searle and J. F. Sowa. Berlin, Springer-Verlag. **1257:** 357-370.

Peirce, C. S. (1931-1958). Collected Papers of Charles Sanders Peirce. Cambridge MA, Harvard University Press.

Polovina, S. (1993). The Suitability of Conceptual Graphs in Strategic Management Accountancy (PhD Thesis). Department of Computer Studies, Loughborough University of Technology.

Polovina, S. (1997). Assessing Sowa's Conceptual Graphs for Effective Strategic Management Decisions, Based on a Comparative Study with Eden's Cognitive Mapping. Conceptual Structures: Fulfilling Peirce's Dream. D. Lukose, H. Delugach, M. Keeler, L. Searle and J. F. Sowa. Berlin, Springer-Verlag. **1257:** 566-580.

Polovina, S. and J. Heaton (1992). "An Introduction to Conceptual Graphs." AI Expert **7**(5): 36-43.

Sangster, A. (1991). "Expert Systems in Management Accounting: Barriers to Development." Expert Systems Information Management **4**(2): 115-131.

Simon, H. A. (1964). "On the Concept of Organisational Goal." Administrative Science Quarterly **9**(1): 1-22.

Sowa, J. F. (1984). Conceptual Structures: Information Processing in Mind and Machine, Addison-Wesley.

Sowa, J. F. (1985). Position Statement on Mapping Specifications to Formalisms (Panel Session). Proceedings of the 4th International Conference on Entity-Relationship Approach, IEEE Computer Society Press.

Sowa, J. F. (1990). "Knowledge Representation in Databases, Expert Systems, and Natural Language." Artificial Intelligence in Databases and Information Systems (DS-3).

Wilson, R. M. (1995). Strategic Management Accounting. Issues in Management Accounting. D. Ashton, T. Hopper and R. W. Scapens, Prentice-Hall: 159-190.