Graphical Argumentation and Design Cognition

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ABSTRACT

Many efforts have been made to exploit the properties of graphical notations, supported by hypertext tools, to try and improve the quality of argument construction and the clarity of its communication. Structured argumentation over the World Wide Web is the most recent development in this direction. We are interested in graphical argumentation structures as cognitive tools to support individual and collaborative design in real time. This faces the particular challenge of integrating a new representational structure into the cognitive and discursive flow. This paper investigates the extent to which graphical argumentation provides supportive or intrusive structure, and presents a use-oriented analysis of a particular notation (QOC) used in the context of design rationale capture.

Through a series of empirical studies into QOC's use, we show that QOC provides most support when elaborating poorly understood design spaces, but is a distraction when evaluating well constrained design spaces. This is explained in terms of the cognitive compatibility between argumentative reasoning and the demands of these different modes of designing. We then clarify the different roles which argumentation can play in groupwork, and the potentially conflicting demands of requiring the same representation to support both short term and long term group memory. We conclude by highlighting key dimensions which describe the space within which this work is located. These dimensions also define an agenda for future work into Computer-Supported Collaborative Argumentation.

1. INTRODUCTION

1.1 Graphical argumentation schemes and tools

Since the early 1980s, many efforts have been made to exploit the properties of graphical notations, supported by hypertext tools, to try and improve the quality of argument construction and the clarity of its communication. The strategy of graphically representing arguments emphasises that asking the right questions and negotiating trade-offs are fundamental processes underpinning the solving of ill-structured, real world problems. Not surprisingly, most interest in the potential of such tools has been in their contribution to complex, intellectual work where the quality of argumentation plays a central role, such as writing (Hashim, 1991; Schuler & Smith, 1990; Streitz, Hanneman & Thüring, 1989), theoretical reasoning (Smolensky, Bell, Fox, King & Lewis, 1987; VanLehn, 1985), legal analysis (Newman & Marshall, 1991) and policy formulation (Conklin & Begeman, 1988; Rittel & Webber, 1973).

As described by Buckingham Shum & Hammond (1994), the driving force behind this work derives from roots in the work of Toulmin (1958), Englebart (1963) and Brown (1986). The common thread running through their work is the conviction that the intellectual demands of visualising the structure of an argument can provide insight into its strengths and weaknesses, thus facilitating its more rigorous construction. Furthermore, they argued that exposing an argument's structure in this way facilitates its subsequent communication since important relationships can be more easily perceived and analysed by others.

As will be explained shortly, there is now ample evidence that valuable contributions could be made by such techniques to support the software design process, particularly with respect to requirements engineering and the design of human-computer interaction. Our goal is to provoke more reflective designing at appropriate points, through the introduction of argumentation structure into design. We are construing the problem, therefore, in terms of understanding argumentation structures as cognitive tools which need to be integrated with the different processes they are intended to support. Thus, we have been investigating how argumentation structure interacts with the individual and group cognitive dynamics of design.

To clarify what is meant by graphical argumentation, let us consider a simple example which uses a notation loosely based on Toulmin's (op cit.) analysis of argument structure. Suppose one morning, I conclude that *I can't get to work today* because *I got up late* (Figure 1A). Someone might query why getting up late should necessitate missing work (Figure 1B). My response might be that: *There is only one early bus each day* (Figure 1C). My protagonist might then helpfully point out that *there is a bus at 11am*, and *a train at 10.30am* (Figure 1D). I might then respond that in fact, *I am also feeling ill* (Figure 1E).The debate could obviously unfold further, as this reason was probed. The expressiveness of the notation, and its visual layout rules (which vary with different approaches), determine how large and elaborate an argument can be expressed. Figure 1 serves to illustrate the kind of cumulative argument construction and critiquing which can take place around a shared, graphical argumentation structure (we are not proposing that design teams adopt this particular argumentation scheme).

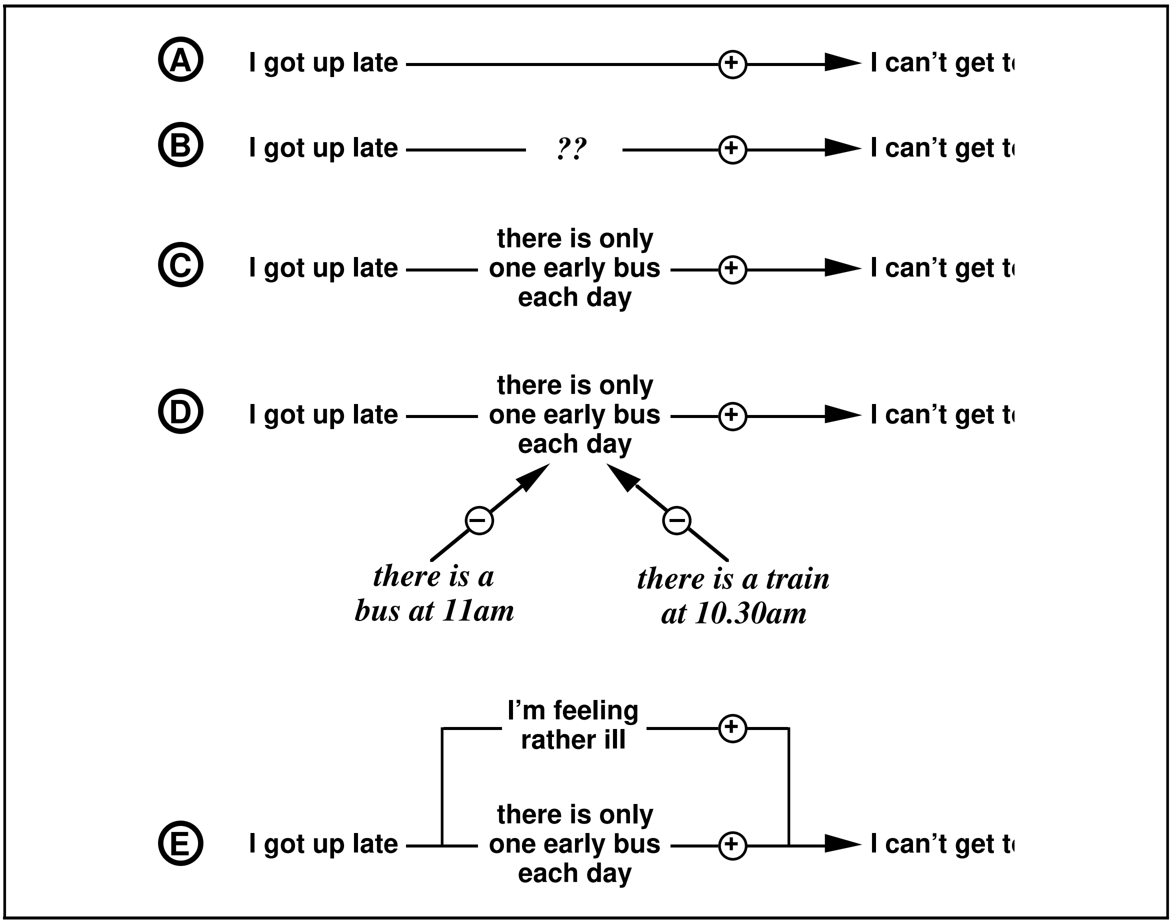

Figure 1: A graphical argument unfolds (A-E)

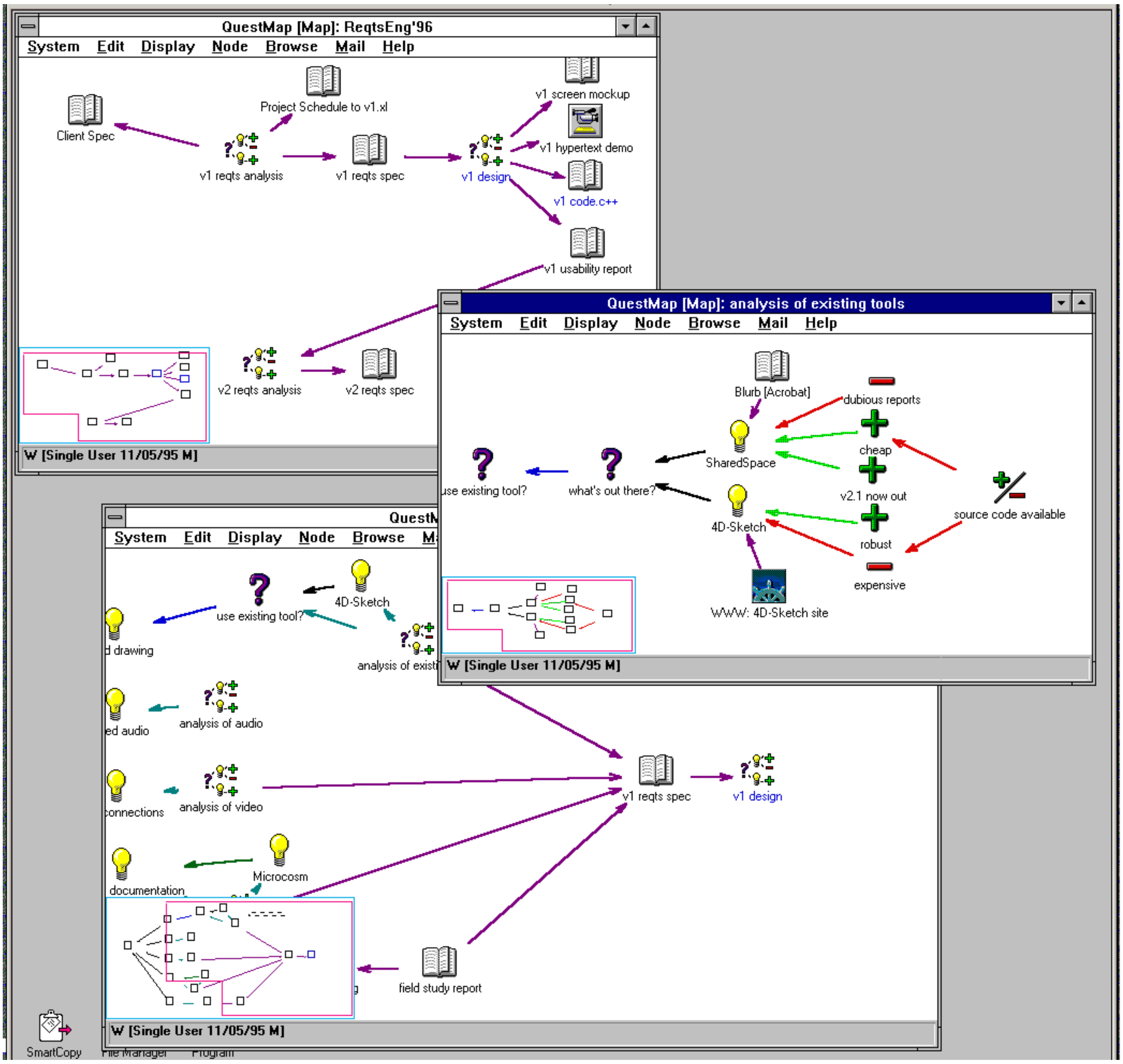

Figure 2: A screen from the *QuestMap* system (CMSI, 1993). Based on the IBIS argumentative model, this is a collaborative system providing teams with a way to conduct extended, public discussion about *Ideas* in response to *Questions*, and capturing the *Pros* and *Cons*. In the example shown, a high level structure (top map) has been defined to track a system development process from requirements analysis through successive prototypes and evaluations. Embedded in this are maps showing how key project deliverables (e.g. *specifications*, *code* and *screen mockups*) have been derived. Argumentation from embedded maps is shown in the lower window and right windows.

At present, perhaps the most fully developed tool based around a graphical argumentation scheme is the *QuestMap* collaborative hypermedia system, illustrated in Figure 2 (CMSI, 1993), which grew from research into the *gIBIS* hypertext system (Conklin & Begeman, 1988; Conklin & Burgess Yakemovic, 1991). This was in turn based on Rittel's formative work on the *IBIS* (Issue-Based Information Systems) notation for tackling 'wicked problems' (Rittel, 1972). Rittel identified a number of characteristics of such problems, including the difficulty of reaching a common problem statement between stakeholders due to conflicting perspectives, the absence of clear criteria as to when a solution has been reached, and hence the need to identify appropriate criteria and from there, generate alternative solutions (see section 4 for more detail).

Rittel concluded that wicked problems can only be tackled through an *argumentative* method, which took seriously (rather than finessing as most design models did) the inevitable debate, negotiation and conflict which take place in work of this sort. The IBIS conversational model encourages participants to contribute *Issues*, *Positions* in response to those Issues, and *Arguments* to *support* or *object-to* Positions. When visualised graphically (a key step which the *gIBIS* system made) a map of the discussion grows as new Issues are spawned from old ones (e.g. via an *expands-on* link).

Figure 3: Web-based argumentation using the *Open Meeting* system (Hurwitz & Mallery, 1995).

With the explosion in size of the Internet, the need for tools to support asynchronous discussions between geographically dispersed participants is at a premium. We are now witnessing the emergence of partly graphical interfaces to support argumentation of the sort illustrated above. One example (Figure 3) shows *Open Meeting* (Hurwitz & Mallery, 1995), a World-Wide Web-based system which supports discussions as textual threads through a combination of hierarchical indentation, augmented by icons which indicate whether a contribution is for example, an agreement, disagreement, or new idea. *Open Meeting* also provides several knowledge-based techniques for retrieving and filtering the content of the nodes constituting the discussion.

Another Web-based system called *HyperNews* uses a very similar presentation, shown in Figure 4 (LaLiberte, 1995). These approaches are very similar to IBIS and its antecedents. For example, a large design rationale field study using “indented-text-IBIS” employed a

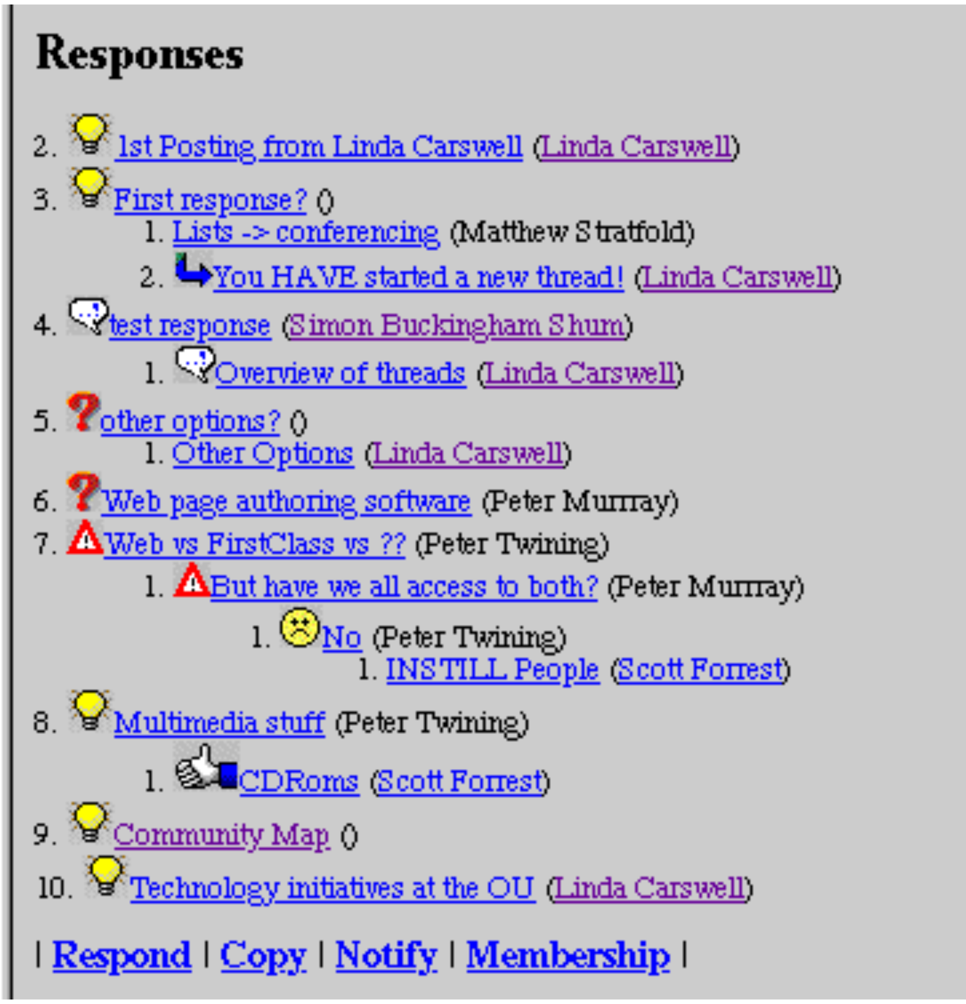

Figure 4: Web-based argumentation using the *HyperNews* system (LaLiberte, 1995).

hierarchical outline view of Issues, Positions and Arguments (Burgess Yakemovic & Conklin, 1990).

As Web-aware applications approach the quality of interactivity which we now expect from conventional applications (e.g. QuestMap), graphical argumentation over the net could become more widespread (e.g. Gaines & Shaw, 1995). Looking a little further into the future, the emergence of digital libraries and journals are early signs of the shift from paper-based to digital culture in the way in which scholarly work is published, peer reviewed, and archived. The fundamental *goal* of structured argumentation schemes—to improve the rigour and clarity of ideas—and its *technical feasibility*—structured, global hypertext—make such approaches an obvious tool to consider as scholarly work evolves with the new media (O'Donnell, 1993).

To summarise, the structure of the argumentation in a debate can be represented in a variety of textual/graphical forms. Structured argumentation, particular in graphical form, has been proposed as a way to support work requiring complex intellectual reasoning. More recently, with the spread of the Internet, argumentation tools are finding application as a means of organising and visualising asynchronous, multi-threaded online discussions.

We now consider the specific domain of software design, in which graphical argumentation for *design rationale* has been proposed as a solution to a number of pressing problems facing system developers.

1.2 Argumentation-based design rationale

There has been a convergence of interest in recent years by several design research communities, on the representation of *design rationale* (DR) underlying software design decisions. DR is serving as a focal point for strands of Human-Computer Interaction (HCI) (Carroll & Moran, 1991; MacLean, Young & Moran, 1989; Moran & Carroll, 1996), Software Engineering (Conklin, 1989; Jarczyk, Loffler & Shipman, 1992; Lee, 1991; Potts & Bruns, 1988; Potts, Takahashi & Anton, 1994; Ramesh, 1993), Knowledge Engineering (Stutt & Motta, 1995; Vanwelkenhuysen, 1995), and Knowledge-based Design Environments (Fischer, Lemke, McCall & Morch, 1991; Garcia & Howard, 1992). Since DR seeks to provide *rationalisation* for *design*, DR formalisms are also being explored in response to the foundational problem of how to appropriately inform HCI design practice with relevant theory (Bellotti, 1993; Bellotti, Buckingham Shum, MacLean & Hammond, 1995; Carroll & Kellogg, 1989; Carroll, Kellogg & Rosson, 1991).

In the domain of HCI, the extent to which design knowledge and reasoning can be formalised (which for present purposes means made machine-interpretable) is more limited than in more established engineering design domains. This is due in part to the relatively recent emergence of interactive system design with its emphasis on the user interface and understanding human work processes, and due in part to the necessarily craft nature of designing artifacts for human interaction. A design team's understanding of the work context and of user requirements is invariably incomplete; this requires a design process in which requirements, constraints and design solutions must be regularly re-negotiated, and creates a difficult situation for subsequent designers since the rationale behind decisions may often be unclear, for instance, to someone maintaining the user interface in future versions of a system. Furthermore, keeping track of discussions, decisions and their rationale is made harder in organisations where teams form on a project-specific basis (perhaps 'out-sourcing' to external contractors), proceed to work interdependently but with substantial autonomy, and then disband. Each of these factors may mean that team members do not know each other, or share less common background and culture; such conditions do not facilitate communication, and can make the later recovery and appropriate re-use of that reasoning hard or impossible.

The recruitment of argumentation schemes continues the core interest in supporting reflective, collaborative problem solving of earlier argumentation research, but draws additional motivation from concerns to find solutions to these particularly pressing problems in system design. In this context, some of the problems which argumentation-based design rationale can address include:

- clarifying vague requirements, and tracking the rationale for their inevitable evolution (Potts *et al.*, 1994);
- representing multiple stakeholders' viewpoints, including that of end-users in participatory design (Sjöberg & Timpka, 1995);
- negotiating trade-offs between multidisciplinary analyses, such as system and user modelling (Bellotti *et al.*, 1995);
- maintaining consistency in decision-making, e.g. through propagating changes through networks (Lee, 1990));
- communicating design reasoning to others – (McKerlie & MacLean, 1994);
- supporting the building of cumulative design knowledge, through reusing DR (Carroll & Rosson, 1991).

Design rationale in the form of semiformal argumentation assumes from the start a 'dialectic, collaborative' model for design knowledge, that is, the knowledge invested in a particular project is the product of more than one individual, and often beyond any single individual's grasp. According to this view, the processes of articulating and reconciling different perspectives are central to design, and should be recognised and supported. The conceptual basis for this view of design is substantial and wide-ranging: Rittel & Webber's (1973) analysis of the requirements for an approach capable of tackling real world 'wicked problems' (see section 4); analyses showing the centrality of conflict and negotiation in design process (Goldkühl, 1991; Matthiassen, 1987), and analyses of the need to fairly represent the different stakeholders who are affected by a system (Timpka, Nyce, Sjöberg & Johansson, 1993).

1.3 Argumentation structures as cognitive tools

Most of the benefits listed above flow from the representational properties of semiformal argumentation networks, that is to say, they are available once such networks have been constructed. However, proponents of graphical argumentation must confront the challenge facing all knowledge representation enterprises, namely, the initial 'capture problem'—recording and appropriately structuring DR has associated overhead. Semiformal hypertext notations still introduce significant representational overheads, reflected in reports within the hypertext literature of such user problems as 'cognitive overhead' and 'premature commitment to structure' (Conklin, 1987; Conklin & Begeman, 1989; Fischer, 1988; Halasz, 1988; Marshall, 1987; Shum, 1991).

Using such schemes is undoubtedly easier in an asynchronous mode of working, in which one can classify and formulate a response to an argument at one's leisure. The evidence available from the success of systems like HyperNews and Open Meeting is that most people can learn to use a simple notational scheme such as *Issues*, *Alternatives*, *Pros* and *Cons* to structure asynchronous discussions. However, our particular interest in this paper is in the *concurrent use* of such notations in meetings (either face-to-face or via networks), when the time constraints which govern analysis, coordination and contributions to discussion are very different. Concurrent use of argumentation schemes during design has been proposed by most of the design argumentation researchers referenced above; however, there are some reports that the use of such schemes during design can obstruct rather than facilitate meetings (Fischer *et al.*, 1991; Rein & Ellis, 1991). Such reports cannot be ignored in the development of argumentation schemes which are meant to provide cognitive support for reasoning during meetings.

On reflection, however, reports of cognitive overhead should not be surprising. Closely related to argumentation schemes are graphical 'concept mapping' tools, which are used to visualise conceptual relationships in teaching (JRST, 1990; Kommers, Jonassen & Mayes, 1992) and knowledge engineering (Gaines & Shaw, 1995; Vanwelkenhuysen, 1995). The basis on which these work is that deeper understanding of a domain comes through the *discipline* of expressing knowledge within a structural framework, working to articulate important distinctions and relationships. Similarly, *argumentation* schemes aim to clarify reasoning by encouraging parties to make explicit important assumptions, distinctions, and relationships as they construct and rationalise ideas. In other words, it should not be surprising if expressing DR as semiformal argumentation takes some effort.

The goal as we see it is to provoke more reflective designing at appropriate points, through the introduction of argumentation structure into individual and group design. We are construing the problem, therefore, as one of understanding argumentation structures as cognitive tools which need to be integrated into the workflow they are intended to support. How does argumentation structure interact with the individual and group cognitive dynamics of design? This leads us to pose two related questions:

- *Firstly, how can we turn the representational effort required by an argumentation scheme to designers' advantage by supporting their ongoing problem solving?*
- *Secondly, does this help to highlight at what points it is most useful to capture design ideas and rationale as explicit argumentation?*

We now introduce the *QOC* argumentation scheme for *Design Space Analysis*, and summarise the results of three studies of QOC in use by different designers, working in different configurations, on a range of design problems. The implications of these studies are then discussed with respect to the cognitive and group processes which we believe to have been important in determining why QOC supported some forms of design work, but failed to support others.

2. QOC DESIGN SPACE ANALYSIS

MacLean *et al.* (1989) present an approach to representing DR which uses a graphical argumentation scheme called *QOC* (for *Questions*, *Options* and *Criteria*). QOC was designed to be used as a means of more systematically representing the 'design space' around an artifact, and as such forms part of the more general *Design Space Analysis (DSA)* perspective as proposed by (MacLean, Young, Bellotti & Moran, 1991).[1] In QOC, *Questions* are used to encapsulate key issues which shape the design, *Options* are alternative answers to Questions, and *Criteria* are appealed to in assessing one Option over another. In addition, *Assessments* are the relationships between Options and Criteria (at their simplest, *supports* or *objects-to*). These elements are summarised in Figure 5. Boxed Options indicate a decision, or at least a working commitment. The similarity between QOC and the argumentation schemes already described will be immediately apparent.

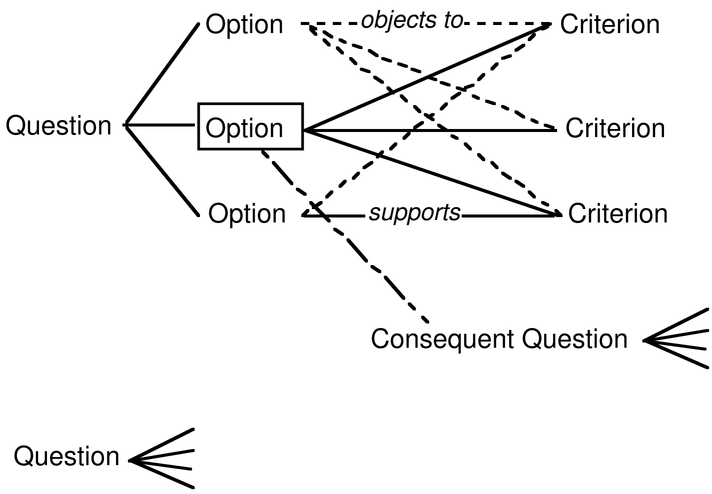

Figure 5: The vocabulary of the QOC notation, used to represent Design Space Analyses (MacLean *et al.*, 1991).

The *design space* is the web of alternative Options for solving the Questions, and the trade-offs which are negotiated by choosing one Option over another. The design space can never be represented in its entirety, since one can continue to ask Questions *ad infinitum*, and from numerous perspectives (e.g. software engineering vs. human factors). DSA is the *process* of discovering the important dimensions in a space (what are the key Questions?), of exploring the space of alternatives (Options) which define the local spaces around those

[1] Except where we are discussing specific aspects of Design Space Analysis (DSA), for simplicity, we shall use the term 'QOC' to mean 'QOC used within the DSA perspective'.

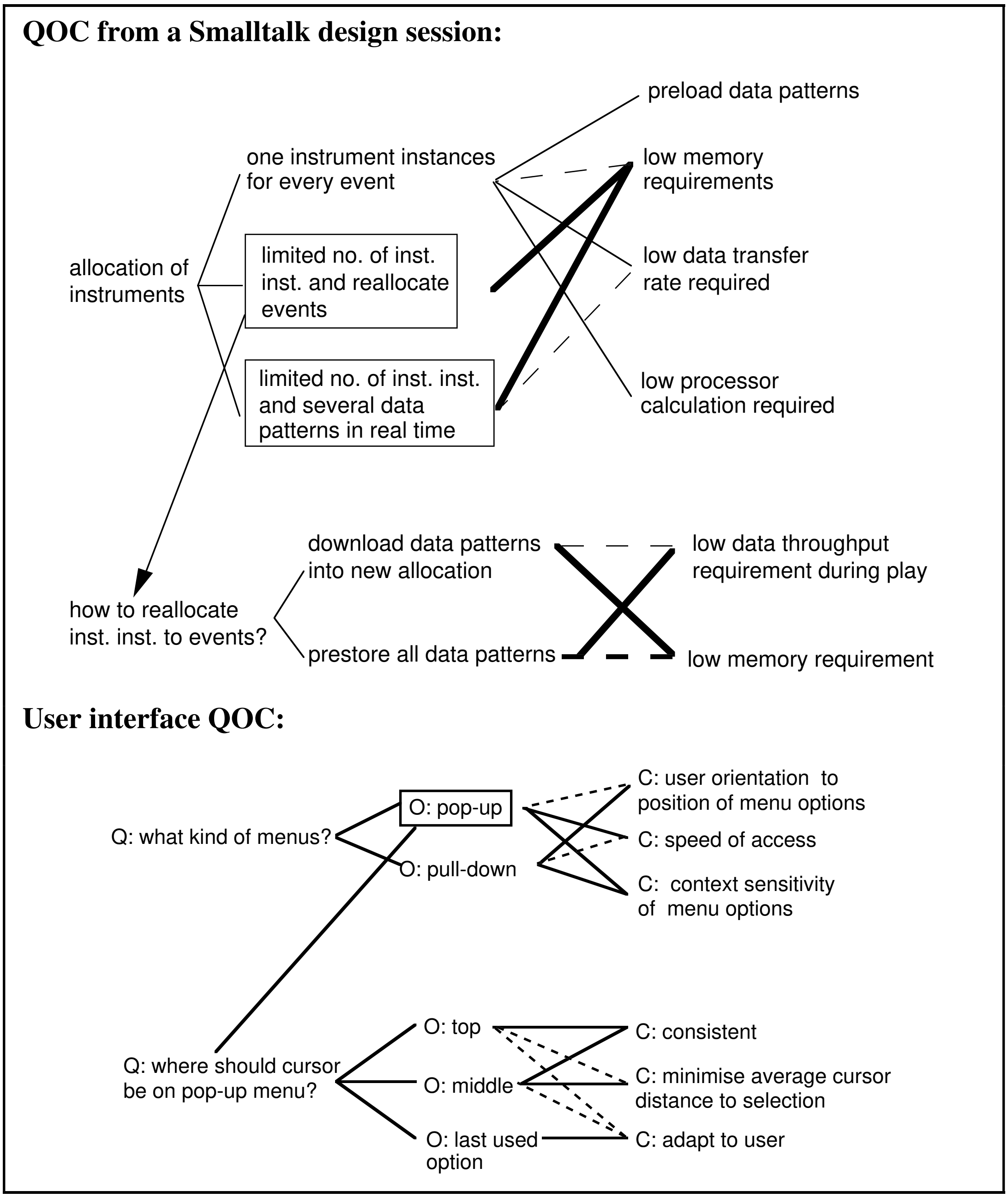

FIGURE 6: Two examples of QOC representing DR for very different kinds of design (note the use in the top example of informally weighted Assessment links; important Criteria can also be emphasised if desired).

dimensions, and of justifying why one point in a local space is better than another (through Criteria and their Assessments of Options). Extracts from two QOC argumentation structures are shown in Figure 6 to convey the kind of representation with which one works.

3. QOC IN USE: EVIDENCE FROM EMPIRICAL STUDIES

This section summarises the key findings of a series of detailed empirical studies of QOC in use by designers. Two of the studies (A and B) have been reported in more detail elsewhere (Buckingham Shum, 1996), to which the interested reader is referred. Study C has not been reported before, and consequently this is presented in more detail.

3.1 Data collected

All of the data reported in this paper are drawn from video-based observational analyses of designers using QOC whilst solving design problems. Extracts from the design transcripts are used extensively throughout this paper to illustrate points. (Source transcripts may be obtained from the author.) In all of the studies, designers used pens and large sheets of paper as opposed to a software tool. Under these conditions, the authoring process could be studied with minimal interference from extraneous factors, whilst preserving or even enhancing properties of the representational medium such as display space, resolution, and ease of local editing. Whilst computational tools are undoubtedly necessary for long term maintenance of large DRs, the core tasks of deciding how to express reasoning as structured argumentation remain essentially unchanged. Finally, in each study, the designers were debriefed, and given the opportunity to provide any feedback they wished on QOC's value in the session, and more broadly in relation to their work.

3.2 Study A: Cognitive tasks in using QOC

Study A was the first in a series of investigations into QOC as a cognitive tool. Although we hoped that designers would find QOC useful, they were not using it for real design tasks taken from their own work; rather, the primary focus was on early use in learning. The requirement to present them with problems which were suitable for QOC analysis, and tractable enough to tackle in an hour, worked against the likelihood that using QOC would provide deep insights (a persistent problem in the evaluation of novel design formalisms—cf. Blandford, Buckingham Shum & Young, 1995). Study A was judged successful, therefore, in that it provided a detailed account of the "nuts and bolts" of using QOC. Analysis was based on video analysis of twelve pairs of designers tackling a user interface design task.

In order to express ideas as QOC a designer is faced with four interleaving cognitive tasks (these are illustrated in Buckingham Shum, 1996):

- **Unbundling:** identifying and separating constituent elements of ideas which have been 'bundled together' when they were initially expressed, but which from an argumentation perspective need to be teased apart. A typical example would be someone who raises a problem and proposes a solution plus a supporting argument. The first step to avoiding fruitless argument is to recognise that there are several new elements being introduced, each of which can be responded to in different ways. Much time is wasted in meetings because a disagreement with one element in an argument is taken to be a dismissal of the whole argument. Teasing out discussion elements and structure pre-empts this kind of confusion.

- **Classification:** deciding whether a contribution is a Question, Option or Criterion. This is not always as simple as it sounds, since Options and Criteria may initially be expressed as Questions, or Criteria as solutions. Questions can be asked about single Options, rather than raising issues to which the Options are candidate solutions, and so forth. The task here is to cut through the surface form and recognise the 'deeper content.'

- **Naming:** how to label the new contribution succinctly but meaningfully. It can often be difficult to articulate ideas succinctly. The skill of doing so is nurtured over time, and the discipline involved can be helpful, although it can also be intrusive in a brainstorming mode of working. The overhead which naming creates is also dependent on the anticipated future use of the QOC, for instance, is it for colleagues present in the meeting, for a formal project review with a manager in three month's time, or for another team to whom you are handing over the design?

- **Structuring:** how a new element relates to other ideas. Many meta-level representational and rhetorical decisions may arise at this point. For instance, what

Question(s) does a new Option address? How does an Option trade-off against existing Criteria? Is this Question sufficiently similar to another in a different context, or should a new Question be spawned? Has this Criterion already been used elsewhere under a different name?

An important conclusion from this study was that the above tasks can work against the facile capture of early ideas whose status or relationships were not yet clear. This motivated the concept of "rough QOC" as an important representational stage prior to the ability to formulate more rigorous argumentation (see Shum, 1991, for an analysis of 'cognitive dimensions' which need to be taken into account). Buckingham Shum & Hammond (1994) discuss how argumentation tools could provide for rough DR such as this, and support its incremental formalization into more coherent argumentation, as understanding of the problem grows.

In summary, Study A provided a more precise understanding of the 'cognitive demands' of using an argumentation scheme. These four cognitive tasks in fact apply to a wide range of graphical entity-relationship notations. Studies B and C clarify when it is most useful to engage in this kind of cognitive work.

3.3 Study B: QOC's scope of application (single designer)

Study B was a longitudinal case study, tracking a Smalltalk designer's use of QOC as he developed a digital music composition system. Three sessions were spent with the designer at approximately monthly intervals.

In Session 1, it became clear that a lot of thinking had already been invested in the problem, with some ideas quite well developed, but others relatively vague. The main task to which QOC was put was to systematically lay out the space of alternatives (Options) being faced, in order to understand the high level trade-offs. The designer was very positive about QOC's role in this context—QOC assisted in drawing out existing but vague ideas, and clarified relationships between Options and Criteria which had up to this point remained obscured. Details and examples from Session 1 have been reported elsewhere (Buckingham Shum, 1996; Buckingham Shum & Hammond, 1994).

In Sessions 2 and 3, however, serious difficulties were encountered in using QOC, and no explicit DR was constructed. The designer was focused on developing two Smalltalk data structures (sketching message passing hierarchies), describing his activity essentially as "gradual refinement" of the structures. It proved difficult to articulate useful Questions, Options and Criteria which offered any analytical leverage on the problem; Questions were either too general or specific to a particular design iteration; discrete Options were impossible to identify because the design was regarded as the gradual evolution of one Option over time; finally, Criteria remained useful only when expressed very generally at a global level of application, rather than differentiating alternatives to subproblems within the design space.

In summary, Study B found evidence that the argumentative mode of working required by and promoted through the use of QOC did support the design work brought by the designer to Session 1, but was incompatible with the work which dominated Sessions 2 and 3. An explanation for this is proposed following Study C, which provided corroborating evidence with a different set of designers and problems.

3.4 Study C: QOC's scope of application (group design)

Study C involved two established teams of designers from a software company, and three new design problems. In addition, the DR training was extended to pre-empt some of the representational difficulties which had been observed in Studies A and B, by encapsulating

QOC 'craft skill'. Further details can be found in (Buckingham Shum, MacLean, Bellotti & Hammond, 1993).

After a morning's training, the design teams each tackled two one-hour design problems. The first problem was provided by ourselves, the QOC tutors, and described an actual prototype system which allowed users to share multimedia documents of different kinds. The design task focused on evaluating and improving two alternative user interfaces for finding out who on the system was using which documents (this was called the People & Objects problem, or P&O). The designers were asked to use QOC to evaluate the designs, improve them if possible, and summarise their conclusions. This problem was chosen because it was sufficiently constrained for the one hour available, and provided numerous alternatives and criteria to consider. This was a relatively well-understood problem for the tutors, since QOC analyses had already been conducted (MacLean, Bellotti & Shum, 1993).

The second problem was one of the team's own choosing, taken from an ongoing project. One team (*NetGroup*) selected a user interface design problem, the problem being to display the global structure of a graphical network, and provide mechanisms for zooming in for more detailed views. The second team (*FileGroup*) were concerned with designing the optimal file format for storing data files in an application they were building. The designers had specified two clear issues to resolve in the exercise, which were to decide on a file format, and to design the file header which carried the information needed to interpret the file.

All data was collected on-site at the software company. Sketches, notes, and QOC were recorded on paper, and each session video recorded. All discussion and QOC was transcribed, recording the interweaving of sketches, notes, and QOC during discussion.

Analysis of the way in which the design teams used QOC for each problem was conducted by comparing their design activities against a process model for developing QOC design spaces which had been presented in the training. Essentially, this outlined five main phases of activity through which one typically goes in using QOC, with the provision for opportunistic jumping between the phases (Figure 7). Using this as a yardstick helped to highlight some key differences in the way in which QOC was used. The day finished with a video-recorded debriefing in which the designers provided feedback on how they had found using QOC for the first time.

Phase 1:	**Organise available material**
	Get relevant information down; get a feel for the main issues; classify ideas as QOC if their type is obvious
Phase 2:	**Structure material into rough QOC**
	Structure and make sense of the information available; find good Questions
Phase 3:	**Flesh out design space**
	Use current understanding of design to help generate new ideas; generate new Options and Criteria
Phase 4:	**Reformulate design space to tidy it up**
	Refine Questions (possibly leading to restructuring)
Phase 5:	**Make design decisions/commitments**
	Evaluate and select Options

Figure 7: QOC process model presented during training, drawing attention to five phases of activity involved in using QOC.

Summary of QOC-use in Study C

In the *People&Objects* (P&O) design problem, the designers were able to construct appropriate QOC structures, and followed the process model quite closely. The exception was Phase 4, in which there was very little explicit restructuring of the first-pass QOC representation, and apart from modifications to names, there was very little reformulation before final decision making. Comparison of the QOCs from the two groups showed that they addressed a similar number of issues (Netgroup eight, FileGroup nine), at a similar level of detail, and topic. This is perhaps not surprising, given that this problem was chosen as a vehicle for studying QOC use, and both the designers' and the hypothetical users' tasks were well-defined. However, the fact that they were able to use QOC to conduct an analysis of the problem does attest to a certain level of proficiency with the notation.

As described above, the two design groups tackled very different kinds of problems in the second design exercise, and it was here that distinctive differences emerged in the use of QOC. *NetGroup* followed the process model closely. Corresponding to Phases 1-3, they spent longer than before on recording key issues as unclassified notes, and classified and elaborated several as *rough QOC* (described in Study A). They elaborated the design spaces around three Questions, the second and third of which analyzed in detail an initial decision to display graphical representations (see Appendix). This refinement process corresponds to Phase 4 development of the QOC. They reviewed the QOC record at the end, and made their final decisions, as the model suggests (Phase 5).

In contrast, *FileGroup's* pattern of working was characterised by a disconnection between representing QOC, and discussing and resolving the problem; the QOC was almost superfluous. In terms of the process model's activity phases, FileGroup's mode of working exemplified a process of lengthy periods of discussion interspersed with bursts of minimal QOC activity. Exploring alternative Options and reformulating Questions (Phases 3 and 4) occurred to a very limited, relatively minor extent (e.g. adding a Criterion to an earlier Question; changing an Option name when its meaning became clearer). All of the Questions asked were predominantly to document decisions they had already made, with the cursory addition of an alternative Option which was then 'rejected' (Appendix). The designers' feedback on their experience of using QOC will be reported in the following sections as we discuss commonalities between Studies B and C and their implications.

To summarise, the empirical studies provided evidence of QOC both facilitating and obstructing design deliberation. The following sections seek to make sense of this by examining the interaction between the cognitive and collaborative affordances of QOC (i.e. QOC as a tool for individual and group deliberation), and the nature of the problem solving process in which the designers are engaged.

4. WHEN IS QOC ARGUMENTATION USEFUL?

When is graphical argumentation useful, and when does it distract from the task in hand? This is the key question which the developers of argumentative methods and tools must be able to answer.

Studies B and C provide a consistent response to this question concerning QOC's use. Let us start by considering the designers' own descriptions of how they were working on each problem, and how QOC fitted in. The Study B designer contrasted two different kinds of designing, drawing a distinction between Session 1, when QOC was useful, and Sessions 2+3, when it was not:

[Study B: Session 1]

> ...the activity I was doing here was different from what I was doing yesterday *[i.e. in work prior to session 1]* – the actual low level structures. This *[session 1]* is more about big decisions—policies—whereas this *[refers to own notes]* is about implementation. So this *[QOC]* is certainly very useful for strategies.
>
> ... It was quite tricky to think in that way then *[i.e. tricky to use QOC in session 1]* but it was useful... but I think I'd find it almost impossible to wrench myself into thinking in that way *[for sessions 2 and 3]*; it would be unnatural almost, 'cos it's not that kind of path that you take when you're doing this sort of thing.

On two occasions he used analogies to describe how he had been working in the latter sessions:

> Have you ever watched someone design a circuit board?
>
> It's more... like painting a picture of something, and you ask why did you put the trees there and not there? There are so many Criteria and they all interrelate.

Consider now the Study C designers in *FileGroup*, describing the P&O user interface problem (provided by us, as QOC tutors) in contrast to their own file-format problem:

[Study C: Final debriefing]

D1: In our last problem *[i.e. file-format problem],* it was actually a problem about how you store things which has real physical constraints and measurable results from doing something in a very real sense. So we could sit there and say, well, we could do it in compressed binary or whatever, and then say, we won't do that because it gives you this factor of something, whereas in the P&O *[problem]* we were saying, well this would be nicer to look at, more accessible, in some more, some less quantifiable way...

D2: (Our) final problem ... was much more hard and fast and much better defined in some sense...

D1: It wasn't so much selecting options or even selecting criteria, as measuring the criteria; we spent a lot of time deciding that... deciding the real critical trade-offs was actually the whole point.

The Study B designer describes Session 1 as "strategic", in contrast to being "low level" in Sessions 2+3. Similarly, the Study C designers talk of having a "better defined" problem to work on whose focus was "deciding the critical trade-offs." In both of these studies, we propose that the designers were engaged in a form of problem solving which may be broadly characterised as *multiple constraint satisfaction*—the evolution and testing of part of a design to gradually satisfy its requirements. The process is one of testing the design against scenarios of use, overcoming one small flaw after another.[2] This also describes the Study B designer's descriptions of mentally testing and revising the data structure, once he had made the higher level decision to pursue that particular Option. This, we also believe, is what the Study C designer meant by "measuring the criteria" in the above extract. FileGroup was tackling a problem with more focused goals at the start of the session, and well established, quantitative metrics for evaluating alternatives.

Within our QOC Design Space Analysis approach, we understand this process to be *design space evaluation.* The space of relevant Questions, Options and Criteria is relatively well understood, but what remains is the iterative adjustment of the Options and Criteria to obtain the optimal balance of assessments.

Why is such a mode of working apparently incompatible with an argumentative design approach like QOC? We look to Rittel's analysis of problem solving at this point. Problems

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2 Gruber & Russell (1996) describe experimental design rationale tools which are able to provide simulation environments for well understood domains. Certain classes of rationale can be generated in response to queries by interrogating models of the domain and design.

which are amenable to the multiple constraint satisfaction mode of working are essentially what Rittel (1972; Rittel & Webber, 1973) termed 'tame' problems, in contrast to 'wicked' problems which cannot be solved algorithmically due to their open-ended nature. Wicked problems possess a number of distinctive properties that elude design methods which assume that the problem is already understood sufficiently for it to be analysed using automatic tools, or top-down methods. Specifically, wicked problems:

- cannot be easily defined so that all stakeholders agree on the problem to solve;
- have no clear stopping rules;
- have better or worse solutions, not right and wrong ones;
- have no objective measure of success;
- require iteration—every trial counts;
- have no given alternative solutions—they must be discovered;
- require complex judgements about the level of abstraction at which to define the problem;
- often have strong moral, political or professional dimensions which cannot be easily formalized.

As a mode of working, multiple constraint satisfaction assumes by definition that the constraints are well defined, and that one can tell when they are satisfied. As the above list indicates, these are characteristics which Rittel identified as being conspicuously absent in wicked problems, where one must struggle to gain a clear view of what the problem is by identifying key constraints.

In contrast to FileGroup, the NetGroup designers in Study C found themselves working with the craft principles of user interface design, with vague criteria for evaluating the quality of their interface design. As a result, they found themselves faced with a problem bearing many of the hallmarks of wicked problem solving. Consequently, laying out the issues using QOC caused far less disruption than experienced by the other team (FileGroup), because QOC supported the cognitive task at hand. Thus, in contrast to design space *evaluation*, there was far greater emphasis on *design space elaboration.*

In summary, just as Rittel showed that design methods for tame problems are futile for tackling ill-structured, wicked problems, the results of Studies B and C demonstrate the problems which are encountered in the opposite situation, in which designers tried to apply a technique intended for wicked problems to tame problems. Whilst this might have been predictable in theory (being the converse of Rittel's principle), to our knowledge, this is not a problem which has been recognised in the argumentation literature to date. The (unforeseen) selection of what turned out to be tame problems by the designers in our studies has provided empirical evidence to alert us to this boundary condition on QOC's applicability. This in turn highlights the need to sensitise designers to the fact that they may find themselves attempting to do the same thing. No design problem is wholly tame or wicked, but changes in 'degree of wickedness' depending on the designers' expertise and what stage they are at in the design process. If designers can develop the 'meta-skill' of being aware of the kind of design in which they are engaged, they are more likely to use QOC or a similar argumentation scheme at those points when it can offer greatest analytical leverage.

5. QOC AS A SHARED WORKSPACE ACTIVITY

The QOC analyses presented thus far have focused on the cognitive interaction between a single designer and the QOC notation. However, software design is frequently a group activity; meetings punctuate, indeed often regulate, the development process in almost all design organisations. A notation assumes new properties in a group context, since it may now serve as a *shared* language and focus of attention. In order to better understand QOC's effect on group dynamics, it is necessary to adopt a different perspective to that taken in analysing individual use. The vocabulary of discussion shifts now to concerns such as role distribution, group activity while QOC is recorded, and the importance of QOC structures as representations collaboratively developed and owned by the group.

In the following analysis, we begin by summarizing Study C designers' complaints that QOC acted as a 'brake' in meetings, disrupting a normally dynamic process. We then introduce a framework which describes the "shared workspace activity" of small groups engaging in conceptual design. This clarifies QOC's affordances in group settings, which in turn makes more explicit the roles and commitment which are needed in a group to facilitate QOC's collaborative use. This is then used to analyse the disruptive effect which QOC had in one of the FileGroup design team, and to consider broader implications for the roles which QOC can play in group design.

5.1 Designers' complaints about QOC

In Study C, there was evidence from both design teams that they found QOC to be something of a burden to use in the concurrent 'on the fly' manner in which they had been trained, since it introduced extra overheads to manage in the course of their discussions. The nature of some of these overheads is now well understood (Study A), but they have implications in a group setting which add a new dimension to the issues discussed so far. In the Study C debriefing, we received the following feedback:

- FileGroup designers felt that QOC had held back their normally fast-flowing design meetings;
- The FileGroup QOC scribe was 'left out' as discussion moved on whilst he was recording the last decision and rationale;
- Both groups reported that they felt they were meant to step through each decision in turn, by enumerating possibilities at each stage; this was felt to labour things;
- Both groups reported that there were points when the way forward seemed to be clear, or when a good decision had been made, but the group had moved forward so quickly that they then had to wait for the QOC to be updated, which was frustrating.

One factor to bear in mind is that since this was the designers' first exposure to structured argumentation, it would have been a bit cumbersome and intrusive, like any new method or language. Indeed, there is other evidence that reactions such as these are common on initial exposure to structured argumentation schemes (Rein & Ellis, 1991). However, it is not reasonable to attribute all of the above feedback merely to beginners' problems. On the contrary, we believe that an important issue surfaced in the group design exercise (Study C) which had not previously been recognised.

5.2 Shared representations: mediation, storage and expression

Tang (1991), has proposed a framework (Figure 8) for describing the shared workspace activity of small groups engaged in conceptual design. Based on studies of design teams using whiteboards and paper, he developed an analysis of their activities in terms of *actions* (textual listing, drawing, and gesturing), and the *functions* which these serve (storing information, expressing ideas, or mediating interaction). This characterisation of group design has since served as the conceptual basis for several prototype shared drawing tools (e.g. Greenberg & Bohnet, 1991; Ishii, 1990; Lu & Mantei, 1991; Tang & Minneman, 1990; Tang & Minneman, 1991).

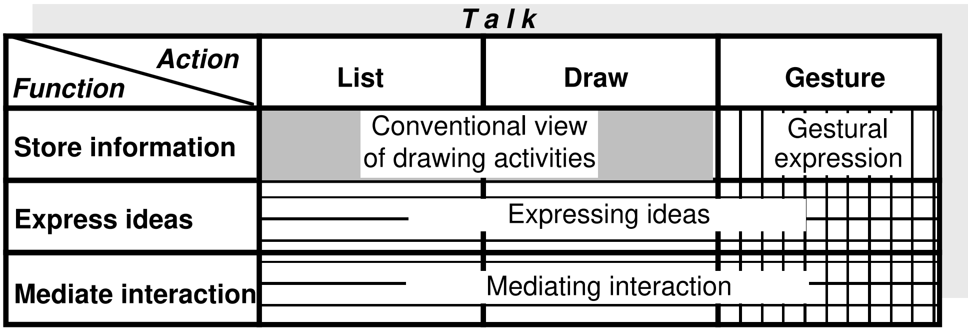

Figure 8: A framework for describing the workspace activity of design teams (Tang, 1989)

The framework distinguishes between recording notes and sketches for *information storage*, typically after explicit agreement, as opposed to the *development and expression of ideas*. The distinction is between documenting ‘complete’ ideas for later recall, and expressing ‘incomplete’ ideas to enable others to react to and build on them. Clearly, ideas recorded for later recall may at any point become a vehicle for developing further ideas (and Tang presents instances of interaction which bridge categories). The third function of workspace actions in the framework is to *mediate* interaction. Tang illustrates how all three action types are used by team members to coordinate discussion through the processes of turn-taking and directing the group’s attention to different issues. Finally, all of this representational activity is set against a background of discussion (*Talk* in Figure 8), which Tang does not analyse in any more detail.

The introduction of QOC argumentation into group design adds a new dimension to our conception of group design. Firstly, given its inherently conversational nature, an argumentation scheme is to some extent part of the *Talk* which exists as background to Tang’s three *Actions*. However, QOC argumentation is also an explicit, representational activity, and as such can be introduced as a new *Action* column, serving a number of possible *Functions* (Figure 9).

Function \ *Action*	**Collaborative Argumentation**
Store information	QOC serving as a long term, reusable project memory
Express ideas	QOC supporting the emergence and debate of new ideas
Mediate interaction	QOC structuring and focusing discussion

Figure 9: Using Tang’s framework to clarify QOC’s roles in group design

It is QOC’s role in each of these functions—*mediating interaction, expressing ideas and storing information*—that we now examine.

5.3 QOC’s mediation of group design

Argumentation schemes are designed specifically to mediate group interaction. An essential part of the Procrustean discipline of using a constrained vocabulary is to encourage a cognitive dialogue with the representation, so that it can ‘talk back’ to the designer and expose weaknesses in thinking. QOC has certain representational affordances that draw participants’ attention to particular issues. For instance, a Question with no Options, or Options with no assessing Criteria, demand attention at some point. More subtle patterns such as a Decision which has no objecting Criteria will suggest to more experienced users that they have not thought deeply enough about an issue, since there are rarely Options with no negative trade-offs.

Maintaining group momentum whilst recording QOC is another relevant issue. Faced with the task of documenting ideas, the aim is to record the information in the most efficient, timely manner possible. However, Tang observed that the delay this introduces creates a problem for a group striving to maintain momentum in a meeting, and suggested that a group can manage the delay in three possible ways:

- wait for the scribe to finish recording ideas;
- occupy the pause with individual work;
- move on to discuss another issue.

When we consider QOC use in Study C, we find that this problem did indeed arise. The designers used the third strategy, and reported that consequently the QOC scribe was left out of discussion and had to catch up. In general, the second strategy did not occur, since a single scribe was appointed for recording QOC, and hence controlled the representational workspace. It is also worth noting that whilst it was common for designers to watch whilst QOC was recorded (the first strategy), the process of deciding how to summarise what had just been talked about often provoked further contributions, such as suggesting a missing Criterion, or a better name for an Option.

This is the kind of shared 'ownership' of the QOC which can smooth the potential disruption caused by making rationale explicit in a meeting—the extra effort required to create the QOC is managed by making it the group's responsibility, not just that of a dedicated scribe. The frequency with which QOC is recorded will be one factor determining disruption of momentum. One group might prefer to record everything almost as it arises, whilst another might periodically reflect on what the most important ideas over the last hour, week or month have been. Naturally these two uses are not mutually exclusive, and will also depend on the kind of problem being tackled. The following sections examine in more detail the continuum between using QOC to proactively *express* ideas, in contrast to a more passive role in which it is used simply to *document* ideas retrospectively.

5.4 Idea expression and storage using QOC

Tang's framework contrasts the processes of *storing* ideas with that of *expressing* ideas, as follows:

> [T]he goal of storing information is an *artifact* that records information for later recall. The *process* of creating that artifact is often troublesome, due to the time delay involved. However, when expressing ideas, the goal is to enlist the interaction of the group to develop ideas. Having the group experience and participate in the *process* of creating workspace artifacts is an integral part of expressing and developing ideas. (Tang, 1989, p.86)

Goel & Pirolli (1989) have also documented how representations such as sketches support the process of developing and refining design ideas, as distinct from the subsequent encoding of the products of that process:

> Within a single symbol system, he *[the designer]* constructs multiple representations of the artifact. In both cases, we want to note that these external representations are not for communicating something after the fact. They serve an indispensable role in the generation, evaluation, and decision-making process. Once decisions are made, symbol systems serve to record and perpetuate them. (Goel & Pirolli, 1989, p. 32)

Given that one of the primary purposes of QOC is the preservation of rationale which may be forgotten, it is self-evidently intended to play an information storage role. However, the above quotes emphasize the importance of the *processes* involved in creating that record.

The distinction between *expression* and *storage* within Tang's framework describes very neatly the evolution from a representation for *unstable, provisional rationale*, to one for more *stable, consensus rationale*. This corresponds to shifts from implicit to explicit knowledge, from being a private to a public resource, and from being a one-off representation to facilitate a single meeting, to being a reusable resource of wider interest. These points are developed below.

Tang noted that artifacts used or created to aid the expression of ideas (such as single words, doodles, emphases on sketches or words) are often meaningless without knowing the context in which they were embedded, which would include gestures, preceding and ongoing discussion, and shared background knowledge. In other words, partially formed notational expressions of this sort will be unavoidable when a notational system plays an active role in synchronous group meetings.

Graphical argumentation is no exception. Quickly created, rough QOC is often unintelligible to outsiders, being dependent on those present at its creation for correct interpretation. When used for expressing and developing ideas, names are often impoverished, sufficient only for the group to understand; similarly, problem decomposition may be partial or simply wrong, again, useful only to the immediate design group as they explore the problem. There may be invisible links between elements which are 'seen' only by the group, or hidden significance in particular spatial relationships. Although these phenomena break the 'official' notational grammer of QOC, these are not 'wrong' uses of QOC which we should discourage designers from adopting. In training, we explicitly legitimize such exploratory representations in order to make designers aware that they should not expect to construct clean, coherent QOC argumentation first go.

There is a form of 'representational tension', however, deriving from two sources. Firstly, argumentation schemes provide most analytical leverage when the effort is made to engage in the four cognitive tasks identified in Study A—parsing, classifying, naming and linking. It is these which distinguish graphical argumentation from other less structured forms of notetaking or discussion. There is a balance to find, therefore, between recognising the importance of rough, ill-formed QOC, and the value of taking the extra effort to create cleaner, more rigorous QOC.

The second, related, source of tension is that as a rule, the lifecycle of a design rationale will not end at the stage of rough QOC. If it is to serve as a longer term project memory, and is to make sense to outsiders who cannot fill in the implicit information known only by the original group (who of course will themselves forget details as time passes), a QOC structure will need to be edited and integrated with other representations. How can we support the transition from expression to storage, that is, from expressions which rely on implicit background, and are informal, incomplete and private, to records which make necessary background explicit, and are more formal, complete and publicly intelligible? Typically, this is accomplished through two processes in combination, which we shall call enrichment and conversion.

Enrichment

In this process, the expressive QOC is retained as the basic structure for a more complete, longer term storage QOC. For example, important assumptions may need to be declared, acronyms and abbreviated names of nodes expanded, and implicit spatial organization of the QOC made more explicit.[3] As new Questions, Options and Criteria are added, they are often concretised in the form of sketches and other design renderings; however, rather than

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[3] Work on providing computational support for detecting and formalizing meaningful spatial arrangements of ideas is described by Marshall & Shipman (1995).

leave these locked in the memories of the designers or fragmented in various places and media, they can be linked into the QOC (as illustrated by MacLean & McKerlie, 1995). The design rationale itself may need to be linked to other relevant design documents to illustrate points or provide important background context (Shum, MacLean, Forder & Hammond, 1993). Through this process, rough QOC, a team's short term *working memory*, is enriched to the point where it can provide a *long term memory* resource.

There are strengths and weaknesses to this approach. Enriching the existing structure means that designers work within a single notational (probably hypermedia) environment, using the graphical browser as the central working representation. No conversion to, and associated editing of, other formats is required. The main requirement on any user is that they are familiar with the QOC notation. Our experience in training designers (MacLean, Buckingham Shum & Bellotti, 1992-94) is that it is not hard to grasp or read (assuming one knows what the subject matter is), but is more demanding to use, as described in this paper. Currently, there is documented evidence that project members not involved in the construction of enriched QOC, but familiar with the notation, can understand and build on it (McKerlie & MacLean, 1994). Elsewhere, we have proposed some of the functionality which might be expected in an environment to support the enrichment of argumentation (Buckingham Shum & Hammond, 1994).

Conversion

In this process, the key ideas and arguments currently in expressive, graphical QOC form are distilled into a different form for storage. The most obvious example is to write a conventional textual report; this might inherit its structure from the QOC network, and could include relevant fragments of QOC argumentation.

Conversion obviously introduces new effort to create the new format document. However, developments in hypertext writing tools suggest that the basic structure could be generated automatically from the QOC network. One danger of conversion is that the new document becomes 'frozen' (unable to respond to new developments), rather than 'living' as a resource which can continue to grow as new discussion is added (one of the strengths of network-based notations). However, conventional documents will always be needed in organisations, and digital document architectures are increasingly able to support modular updating—the goal is to preserve the links to the argumentation which gave rise to the document, just as we propose that the rationale for other designed artifacts is preserved and easily accessible.

5.5 Reflections on the argumentative approach

Although the concepts of enrichment and conversion are relevant to all representational schemes, graphical argumentation may possess a unique property in the context of the transition from expression to storage. The central claim made by Rittel & Webber (1973) is that argumentative modes of working are essentially the only way to tackle wicked problems. Rittel developed the IBIS notation on the basis that representational support was most needed in the *conversational, argumentative* process of articulating and reconciling conflicting views of the problem. Expressed in its strongest form, the philosophy behind IBIS is to provide a medium for recording *all* discussion during wicked problem solving. Conklin & Burgess Yakemovic (1991) build on this view, proposing that the knowledge capture problem can be overcome if all contributions to a discussion, not just parts of it or only what the whole group agrees on, are captured in the argumentation web, since in the early stages of wicked problem solving nobody knows what will subsequently prove to be valuable. When argumentation is given this central mediating role, the distinction between expression and storage blurs—everything expressed is automatically stored.

We believe that this approach is correct in essence, but should be qualified in two important respects. Firstly, to claim that short term (expressive) argumentation can double up as long term (storage) argumentation hides complexities which this paper elucidates. Thus, it is not clear that such an approach obviates the need for subsequent enrichment or conversion of the argumentation. The argumentation constructed in a meeting is unlikely to be rich enough to maintain intelligibility over a longer period, and to a wider community without subsequent enrichment/conversion. As described above, this is (a) because the gradual evolution of rough ideas is a central process in group problem solving, and (b) argumentation created by one group at a particular point in time may not be sufficiently intelligible for others to reuse it.

Secondly, greater emphasis needs to be placed on the interaction between argumentation and the other artifacts with which designers work (sketches; prototypes; requirements documents, etc.). Often, a lot of discussion and analysis is centred around these concrete artifacts, and it is not appropriate to try and capture it all as argumentation. The mode of working characterised as multiple constraint satisfaction in Studies B and C is one instance of the "artifact construction" mode of working (Fischer *et al.*, 1991) which plays such a central role in design. In summary, it is essential that argumentation does not exist in an abstract 'vaccum' disconnected from the concrete artifacts it is describing; it must be linked to these artifacts, to support both the *authoring* and the subsequent *reading* of the design rationale by others.

6. CONCLUSIONS AND FUTURE WORK

For many years, researchers have been striving to understand how computers can augment our ability to solve problems. One of the most obvious ways is to seek to augment the *debates* about problems—both in one's own mind and with other minds—which underpin much intellectual work. The strategy of graphically representing the structure of, and links between, arguments is based on extensive evidence that asking the right questions and negotiating trade-offs are fundamental processes underpinning the solving of ill-structured, wicked problems. However, structuring reasoning and discussion comes at a cost, namely, it requires the integration of a new representational structure into the cognitive and discursive flow. The question which we have sought to address is whether this provides supportive or obstructive structure.

This paper has presented a use-oriented analysis of the QOC argumentation scheme in the context of design rationale capture. It describes the individual and group demands of using a semiformal argumentation scheme to support design reasoning, seeking to identify when, and clarify why, QOC supports particular kinds of design problem solving and obstructs others. We have argued that QOC provided most support when designers needed to elaborate poorly understood design spaces in order to clarify the key Questions, Options and Criteria. However, it was intrusive when they were trying to evaluate relatively well understood design spaces in which the main task was to satisfy multiple constraints through iterative testing and adjustment, until an optimal solution has been obtained. We have argued that this can be understood in terms of cognitive compatibility between the argumentative mode of working required and encouraged by QOC, and the cognitive work associated with these two very different kinds of design problem solving. In the final section, we have drawn on a framework for understanding how shared representations are used in meetings to clarify factors particular to group settings which shape QOC's use. Firstly, QOC can play a proactive or passive role in shaping deliberation, and secondly, this interacts with the role which it is expected to play in the future as a form of longer term project memory.

Although the studies reported here are grounded in the design domain, ill-structured, wicked problems in many domains involve elaborating and evaluating problem and solution spaces. Our analysis of QOC should therefore be relevant to argumentation in other domains in which problem elaboration and negotiation play a central role.

In this paper, we have been most interested in graphical argumentation structures as cognitive tools to support individual and collaborative design in real time. However, this is just one of a range of ways to use argumentation schemes. To return to one of our opening points, the emergence of large scale hypertext in the form of the World Wide Web has already spawned experimental uses of structured argumentation on a scale which has not been possible to date, by users working synchronously and asynchronously in new domains. This emphasises a number of key dimensions which will impact the success of new argumentative tools and methods. These include the *users* (e.g. their background; whether they are working alone or collaboratively), the *notation* used to express arguments (how elaborate should it be?), the *technology* used to represent the notation (e.g. outline views on the Web, vs. direct manipulation networks), the *domain* which will influence what argumentation constructs are required, the *time constraints* which determine how much time there is to reflect on and construct arguments, and *organizational practices and culture* which will influence the degree to which argumentation methods and tools will be accepted. Together, these describe a space of scenarios in which collaborative argumentation can take place. These dimensions also define an agenda for future work in the maturing field of Computer-Supported Collaborative Argumentation.

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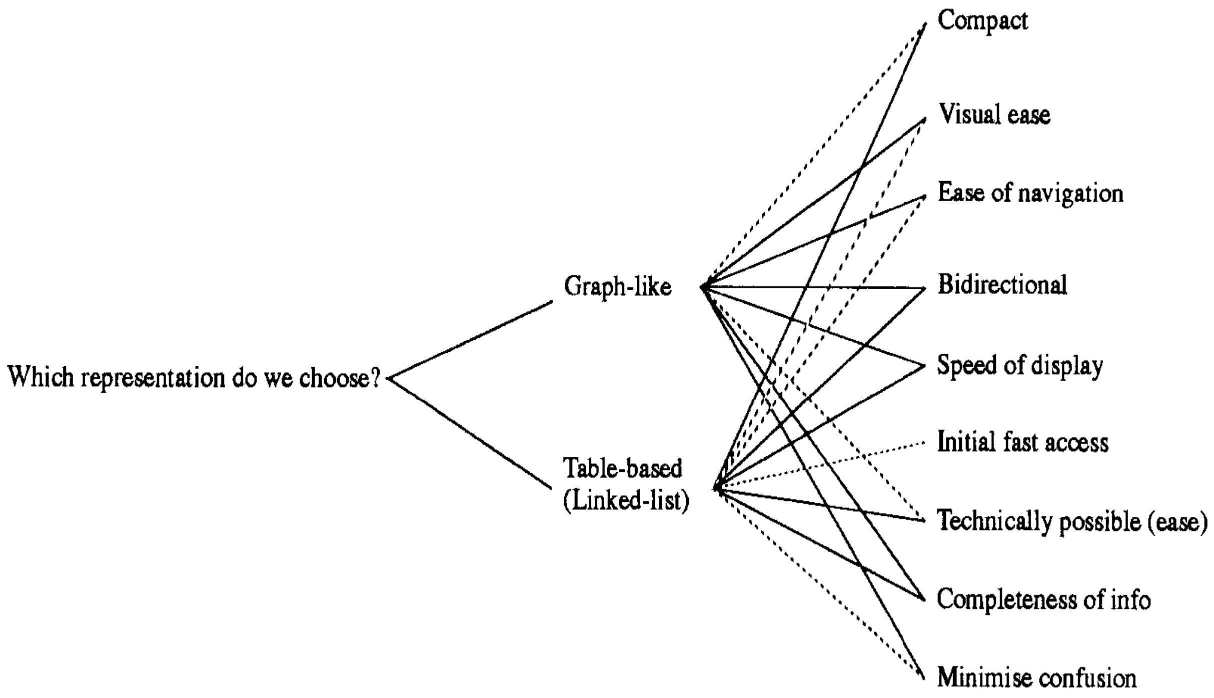
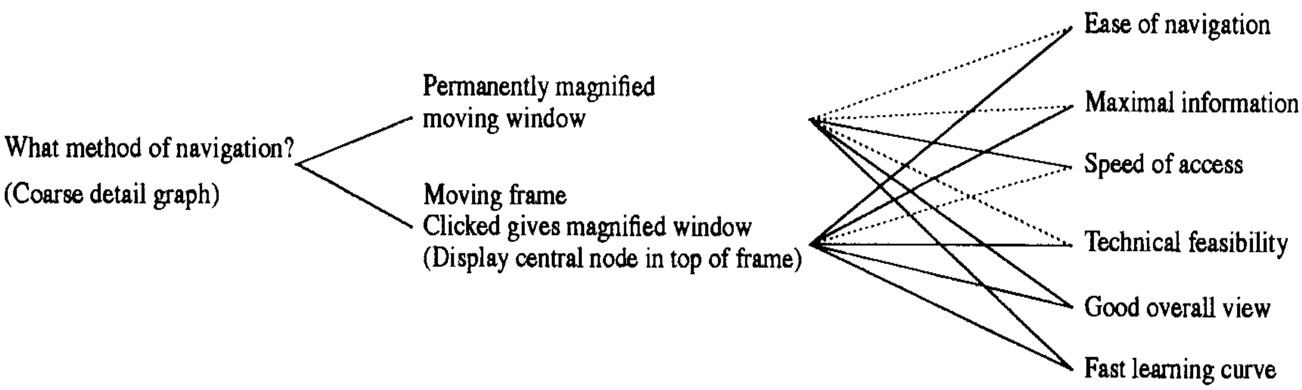
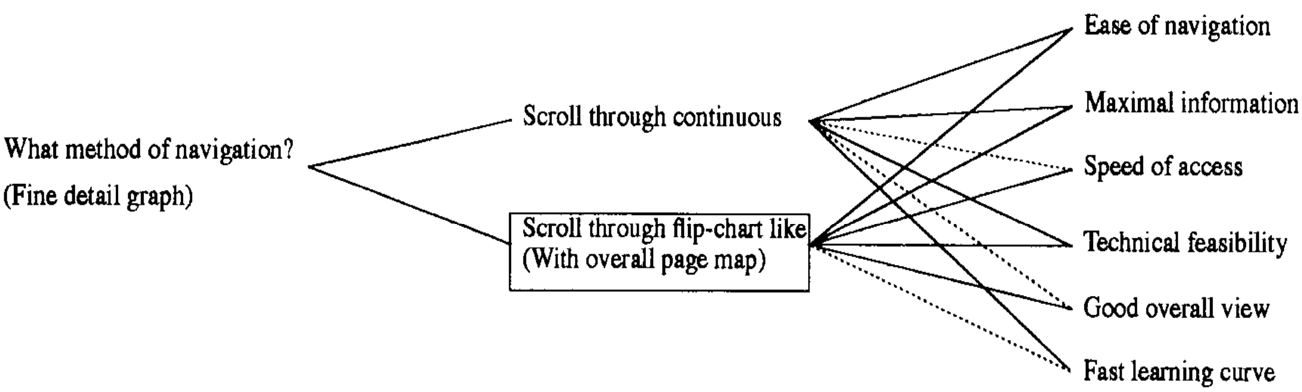
APPENDIX: QOC ARGUMENTATION FROM STUDY C DESIGNERS

NetGroup: QOC for own problem







FileGroup: QOC for own problem