From Sketch to Form on a Large Interactive Display Surface

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ABSTRACT

Recently large interactive display surfaces (LIDS) have become commercially available and affordable for normal commercial and classroom use. These units provide a new interface to computers. They allow direct manipulation of objects on a surface that typically has a display area of 1 metre by 2 metres. This is achieved by use of a whiteboard digitiser, a transmitting stylus and a back projected screen. The large screen provides an effective workspace for group activities. At the moment there is little software available to exploit this type of human computer interaction.

LIDS provide exciting opportunities during the early stages of interface design by providing a shared space that supports informal sketching. It is proposed that the unit can be used for sketching designs which can then be programmatically transformed to operational interfaces in a programming IDE. This paper describes the functional requirements for software to support sketching and sketch recognition and work in progress in the development of this software.

KEYWORDS

Informal Interfaces, sketching, prototyping, early design

1. INTRODUCTION

Whiteboards can provide an informal space where people can work together to sketch prototype designs. A digitised whiteboard can provide the informality of a whiteboard with the intelligent support of a computer. This paper gives a brief background to previous work with large interactive displays and informal interfaces and presents arguments for the use of informal interfaces particularly in a learning environment. Following this, the goals of this project are described with the requirements for a sketch interface to Visual Basic (VB) form design. Finally, planned evaluation and the current status of the project are discussed.

2. BACKGROUND

In the early 1990's Xerox developed a digitised whiteboard "Liveboard" and Trivoli, meeting support software (Pedersen, McCall *et al.* 1993). Others have seen digital whiteboards as an ideal environment for early design sketching in disciplines such as CASE based systems design (Damm, Hansen *et al.* 2000), architecture (Gross 1998), screen design (Landay and Myers 2001), and web page design (Lin, Newman et al. 2000).

There is an underlying philosophy across this diverse range of applications that informal sketching is the preferred starting point for designers (Gross 1998; Damm, Hansen et al. 2000). It allows them to explore ideas without the constraints of a formal computer environment. In contrast most computer design tools require the selection of specific widgets that are placed on the design surface. At the early stages of design the designer is often not ready to commit to a specific widget and may wish to leave some aspects under-defined while developing the overall look and feel of the design. The goals of informal interfaces are twofold: firstly to provide a natural sketch environment for designers that has the benefits of a computer interface with support for editing and saving, and secondly that the artefact of the design process can be used as an input into the creation of the formal computer interface.

This project aims to provide a sketch interface to VB's form designer for student use. It has always been difficult to get students to design before they program. The need and benefit of early design is more critical in current event driven environments such as VB. VB makes it very easy for students to jump into creating a form without planning, but there is a significant cost to alter the design. The result is often a poorly designed interface, which uses the wrong controls and has a poor flow of interaction.

Before describing the details of the project, the hardware, and software-hardware interaction will be explained. A standard data projector projects the screen image onto the back of an opaque surface. A Mimio (Virtual Ink 1999) whiteboard digitiser consists of a digitiser bar that fits to the side of the display area and transmitting pens or styluses. In mouse simulation mode, when the stylus tip is pressed onto the display area the bar picks up *mouse down*, *mouse move* and *mouse up* events and passes the xy position of the mouse to the event handler. Software can use the mouse events to create a pen-stroke and project virtual ink onto the whiteboard. This creates a large interactive surface conducive to group work (figure 1).

The virtual ink can be left unaltered or interpreted. For this project there are three major classes of pen strokes; gestures, glyphs and handwriting. Gestures are instructions to the computer to alter the sketch in some way, for example a stylised x will be interpreted as erase. Glyphs are symbols that have a specific meaning, for instance a small square will represent a checkbox, a small circle a radio button. Handwriting refers to pen strokes intended to be interpreted as letters and words.

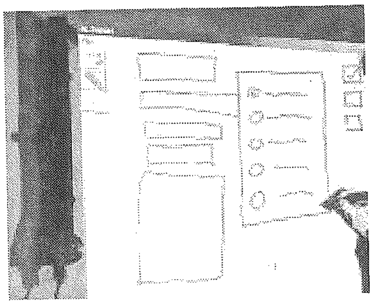

Figure 1

3. REQUIREMENTS OF A SKETCH INTERFACE

There are three parts to providing an integrated sketch environment for a product such as VB: firstly, a sketch space where the users can freehand draw, secondly the recognition engine that interprets the virtual ink, and thirdly the transformation from sketch to VB form.

3.1 Sketch Space

It is important that the sketch space is unadorned, as a simple environment will focus the users on the design task without distracting them with unnecessary detail. Recognition will happen immediately following stroke completion. Editing gestures will be acted on straight away. There is some debate (Hearst 1998) about how an interface should give the user feedback on recognition of a glyph. It is generally agreed (Gross 1998; Landay and Myers 2001) that the computer should delay transposition of the sketch glyph to a formal control until the user directs conversion. However it is likely that users would like some indication that a glyph has been correctly identified. Options in order of descending intrusiveness are; changing the colour of the virtual ink, placing a shadow control behind the virtual ink, or indicating the control in a status bar. The author prefers to the least intrusive option, a status bar, but clearly this can be trialled or left as a user configurable option.

Recognition is most effective when the set of gestures is small and each gesture has distinguishing features. To allow for effective recognition the sketch space will operate in three modes, drawing, editing and writing. Drawing mode will be used for drawing sketch elements that the recogniser will expect to be either VB controls (eg textbox, command button) or place holders (eg a horizontal squiggly will indicate text). Editing mode will provide the normal range of editing; cut, copy, paste, resize. An intuitive gesture set will be provided to support editing with pen gestures. Writing mode will implement character recognition from the virtual ink.

The current hardware provides very limited support. The available inputs are mouse down, move and up, there is no right mouse. Given this restriction some intelligent mode changes are possible; for example if a user starts to draw on top of a text place holder, handwriting mode will be assumed, or if a user holds the pen down inside a completed glyph then edit mode will be assumed. It will be impossible to accurately guess the user's intentions all the time; a set of buttons will provide user controlled mode changes.

3.2 Recognition Engine

Gestures and glyphs are recognised by Rubine's pattern matching algorithm (Rubine 1991). Classes of sample pen strokes are created, about 15 examples of each class. From these a range of features is extracted. A relative weighting for each feature for each class is calculated. The same features are extracted from pen strokes in the sketch spaces. The features are weighted against all the features of all the classes. The lowest weighted average represents the closest match. One of the strengths of this algorithm is that it is easy to retrain the recogniser by adding more examples to a class and to add additional classes. It is, however, a single-stroke algorithm, multi-stoke glyphs need to be assembled independently.

3.3 Integration into VB

The sketch environment is implemented as a VB addin. Accessing the addin takes the user directly to the sketch space where they can immediately

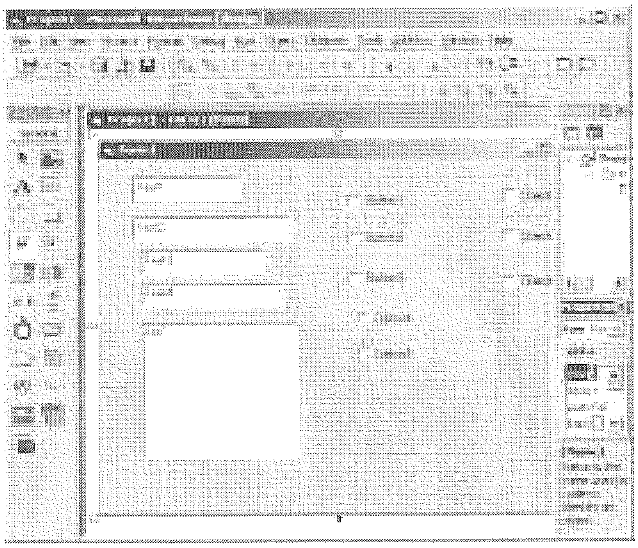

Figure 2

start to design. From the sketch space the user can move to the sample sets where they can add and delete samples or add new VB controls by providing samples and describing the relationship between the control properties and the sketch features. On return to the sketch space the weighting table is automatically recalculated and saved. When the sketch is completed the program will create the appropriate VB form controls from the sketch (figure 2). Glyphs that have not been recognised can either be ignored or the user can specify the appropriate component. From the sketch, appropriate control properties can be set such as position and size. The form can then be beautified by aligning controls.

4. EVALUATION

The usability of the sketch space is critical to the success of the project. It should provide an intuitive whiteboard type environment with the added features that are expected in a computer-drawing tool. It is planed to undertake formal usability testing in Waikato University's usability lab (http://usability.cs.waikato.ac.nz/).

This tool is intended for classroom use, so students will be observed using each prototype. The observations along with their comments will be used to refine the program.

5. PROGRESS TO DATE

A basic sketch space is operational with drawing and erase modes. Rubine's algorithm has been implemented along with an interface to create and edit gesture sets. Integration into VB6 has been implemented.

The next steps are: to fully develop the sketch environment for usability testing, enhance the recognition to enable multi-stroke glyphs and allow users to define the mapping to VB controls. Improving the integration to VB so that the relationship between controls is intelligently applied is also planned as is finding an appropriate handwriting recognition module and integrate it into the project. Ongoing usability testing and student observations will be carried out.

6. SUMMARY

A digital sketch space for form design is likely to be useful in that it will support the preferred freehand first prototype sketching of forms and allow the sketches to be used to electronically create program forms. The sketch environment needs to support drawing, editing and handwriting. Each of these will be a separate mode of operation and intelligent mode transition will enhance the usability of the interface. Recognition of the sketch can be successfully accomplished using established algorithms that can then be transformed into a working program form. This should be a useful tool for students, providing them with a 'fun' environment where they can work as groups to design user interfaces where their attention will be focus on design rather than creation of the form.

REFERENCES

Damm, C. H., K. M. Hansen, *et al.* (2000). Tools support for cooperative object-oriented design: Gesture based modelling on and electronic whiteboard. CHI 2000.

Gross, M. (1998). The proverbial back of an envelope. IEEE Intelligent Systems: 10-13.

Hearst, M. A. (1998). "Sketching intelligent systems." IEEE Intelligent Systems May/June: 10.

Landay, J. and B. Myers (2001). "Sketching Interfaces: Toward mor human interface design." Computer 34(3): 56-64.

Lin, J., M. W. Newman, *et al.* (2000). Denim: Finding a tighter fit between tools and practice for web design. CHI 2000.

Pedersen, E. R., K. McCall, *et al.* (1993). Tivoli: An electronic whiteboard of informal workgroup meetings. INTERCHI'93.

Rubine, D. (1991). Specifying gestures by example. Proceedings of SIGGRAPH'91.

Virtual Ink Corporation (1999). Mimio. http://www.virtualink.com

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Assessment: Central to Learning

Abstract

Staffroom walls often hear "I have to set another x tests by the end of the week. It all seems such a waste of time; I know who will pass anyway." Yes, most of us find setting assessments a chore and a bit of a drag. Yet they are central to academic study. It is assessment that positions the goalpost and the height of the hoop. It is assessment that controls who can continue at the next level. It is assessment that governs who receives those valued pieces of paper we call certificates, diplomas and degrees. This paper will examine the theoretical and practical role of assessment in our courses and consider some of the imponderables.

- *Does it matter what we assess?*
- *If assessment is so important, is more better?*
- *Are projects and assignments better/fairer than exams?*
- *Which is better: competence, mastery or grades?*
- *Can we use assessment to gauge our teaching skills?*

Introduction

Assessment in an educational setting is some judgement about a student's learning or knowledge (Knight, 1995). There are three major reasons to assess: to improve learning, for institutional management and for accountability (Renwick and Renwick, 1992; Angelo, 1994). The first, student learning is close to teachers' hearts. The second institutional management is our use of assessment for such things as streaming and imposing prerequisites. In our environment the major reason for this is to ensure that students are in courses that they can reasonably be expected to be able to pass. Accountability of education is an international reality. It is imposed on us, and therefore in the 'must do' category. We are accountable to a list of stakeholders: the government, employers, professional bodies, taxpayers, students and their parents. It is perhaps for this reason that teachers and students often resent assessment rather than see it as a part of learning. There is an alternative view that an integrated approach to assessment can be at the heart of student learning (Knight, 1995; Popham, 1995).

The tertiary classroom of the new millennium is more diverse than ever before. There is a wide range of engagement, abilities and cultures. It cannot be assumed that the student will engage in the learning process regardless of the delivery and assessment method. "Good teaching is getting most students to use the higher cognitive levels that the more academic students use spontaneously" (Biggs, 1998). The teaching focus must be clearly on what the student does and there must be a clear alignment between objectives, teaching and assessment (Biggs, 1998). In an environment where attendance at class and completion of exercises and homework is optional, the most powerful tool that a teacher has to encourage student participation is the part, which in the student's view, really counts – assessment (Popham, 1995).

What are we Trying to Achieve?

In all educational settings we are trying to achieve a multitude of things at one time. The students need to obtain knowledge and skills. Generally we should not be satisfied that they know how, but they should also know why. We want them to reach a leave of understanding where they can effectively communicate with people who are knowledgeable in the domain (Nickerson, 1985).

However there is often too much emphasis put on knowing why without knowing how. It is often important that basic skills can be applied automatically so that more sophisticated problems can be addressed without overloading short-term memory. A good example of this is program language syntax. If the learner is trying to remember the syntax for a copy statement at the same time as the algorithm for a binary search they will probably suffer from memory overload.

At the same time we are generally trying to develop their intellectual thinking. Studies by Belenky and Clinchy (1986) and others (Perry, 1970) have mapped the intellectual development of people through a series of stages: silence, received knowledge, subjective knowledge and procedural knowledge. Silence is normal only in very early childhood. Received knowledge is the typical level of operation for childhood and the early teenage years, during this time the explanations of others are ready accepted without question. This is followed by subjective knowledge when a search for self and internal voices replace external knowledge, the teenage years where typically people endeavour to explain the world in their own terms often without regard to others opinions. The final stage is procedural knowledge at which point people are consciously, deliberately, and systematically analysing new ideas and integrating them into their own knowledge base.

It can be assumed that the majority of our school leavers are operating at the subjective knowledge level. One of our goals is to develop them intellectually so that they are operating at a procedural knowledge level.

How can Assessment Help Achieve these Goals?

Assessment is the single most powerful tool we have as educators in the tertiary environment (Popham, 1995). It is the only part of the teaching and learning process where there is complete accountability on the part of the student. As teachers we need to make best use of this tool to achieve the learning goals of our programmes. Regardless of the purpose of assessment it must be seen as a fair and valid measure of the skills and abilities it is intended to measure (Herman, 1992). A review of the main categories of assessment tools will describe the advantages and disadvantages of each.

Types of Assessments

The continuum of possible assessment tasks is huge; clearly each will affect the learning experience in a different way (Hager and Butler, 1996). At one end of the continuum are three hour finals as the only assessment, at the other are workplace assessment and informal evaluation by student or teacher that is not reflected in an official result. In between there are other typical task such as essays, assignments, case studies, projects, tests, attendance and portfolios.

Tests and Examinations

Tests and examinations are perhaps the familiar form of assessment. They are generally conducted under controlled conditions and the student has a number of set questions to answer (Woolfolk 1993). There are a number of advantages of this form of assessment. The examiner can be more certain that the work is that of the individual. A test can be a motivator to encourage students to learn basic material. A test also concentrates that time spent on assessment, leaving the majority of course time available for learning. There are some disadvantages of limited time tests. Tests are effectively a snapshot of a selection of a student's knowledge. They are, of their very nature, a sampling procedure. The other major disadvantage is that it is difficult to assess higher order cognitive skills with small problems that can be solved in a limited time.

Controlled assessments present a dilemma when one evaluates their fairness and validity. Many would claim that they are more fair and valid than uncontrolled assessment as one can be sure that the work is that of the individual and all participants have equal time and resources. However it is also claimed they often have little affinity with real tasks that they purport to assess (Gardener, 1992).

Assignments and Case Studies

Typical assignments in our courses require students to solve a problem that has been defined by the teacher. Assignments have some advantages over tests in that they allow the students to undertake larger pieces of work over a longer time period (Woolfolk, 1993). Carefully designed assignments can cover the skill requirements of the course and engage students in higher level cognitive activities of problem solving and reflective thinking. It is also possible with assignments to challenge students to consider significant problems and then construct thoughtful models of the problem and problem solution; this gives the student practice at reasoned problem solving.

Academic essays, where students are not encouraged to voice their own opinions but to research and present the thoughts of knowledgeable others can contribute to the students' intellectual development. The student has to put aside his or her own views that are normally uppermost during the subjective knowledge stage and consider the principles being expounded by the experts. It is likely that this exercise will contribute to their intellectual development (Belenky and Clinchy, 1986; Perry, 1970).

However assignment work also has some drawbacks. It is often not possible to be certain that the work submitted is that of the student submitting it. The other major drawback is that if a class is all working on the same problem, generally one or two of the more able members of the class will solve the difficult aspects of the problem and share the solution with the group as a whole. This is an example of Vygotsky's (Carpenter, 1980) theory of learning from peers in practice, but in this case to the detriment of most students. Often the tasks set as assignments have little relationship to 'real' problems. Case studies are in many ways similar to assignments (Linn and Clancy, 1992). Generally case studies resemble a 'real' problem, although the problem had often been 'sanitised' by the teacher and therefore lacks the complexity and messiness of the real world.

Whenever the teacher specifies the problem it is difficult to engage the student in one of the most difficult aspects of problem solving, problem definition. A problem specification will of its very nature direct the solution space (Gonzalez and Dankel, 1993). This means that it is difficult with assignments and case studies to fully engage the student in one of the components of problem solving. Clearly assignments and case studies are more likely to allow the student to complete work in an environment that is close to the normal work environment, although, as will be described later, programmers are often required to work in conditions that more closely resemble an examination. However some students do not submit their own work. The origin of work is often difficult to prove and validity and fairness become a real issue if there is no controlled assessment.

Authentic Assessment

Recently there has been a shift to authentic assessment, assessment tasks that mirror the real world and are integrated with learning, assessment where the learners are active participants and the criteria are open and negotiable (McDowell, 1999; Aitken, 1993). The goal is to engage learners in the assessment as well as the learning. This engagement should assist the learner to develop better learning and self-evaluation skills that are so vital as we move to a society where life-long learning must be the norm. Portfolio assessment is perhaps the most common form of authentic assessment.

In the broadest terms, portfolio assessment is a purposeful collection of a person's work. With portfolio assessment the teacher does not specify what the student should do, but rather what skills he or she should demonstrate. Portfolio assessment has traditionally been used in creative fields such as fine art and music. More recently it has become common in a much wider range of educational settings (Gardener, 1992).

A well-designed portfolio will meet the teaching goals of engaging the students in the higher order cognitive activities of reflection and creativity (Arter and Spandel, 1992; Biggs, 1998; Gardener, 1992; Hauser, 1993). When the teacher leaves problem specification to the student the student is able to engage in the complete problem solving cycle from problem specification to implementation and review. Effective use of portfolios in a course requires careful planning and implementation. The requirements and method of evaluation must be specifically defined.

Portfolio assessment has some limitations. As with assignments and case studies the teacher cannot be sure that the work submitted is the student's. This is potentially more of a problem than with predefined tasks as the student can simply submit work copied from a book or the Internet and it could be difficult to prove that it is not the student's original work. The other major difficulty with portfolio assessment is assigning grades. When students undertake a wide variety of tasks it could be difficult for a teacher to grade in a fair and consistent manner.

A Comparison of Types of Assessment

To review the major types of assessment: tests and examinations provide a snapshot of student ability, are good tools for encouraging learning of basic skills and recall knowledge, can be relied on as the work of the individual. Assignments and case studies can be used to encourage students to engage in larger pieces of work, apply discipline to their research and writing, and integrate assessment into the learning process. They do not however require the whole of the problem solving life cycle. Portfolios have all the advantages of assignments and case studies with the added advantage of encouraging students to define their own problems and review their work. All uncontrolled assessments suffer from the problem of verifying authorship.

The choice of assessment tool clearly should be dependent on the goals of the course. A number of variables must be taken into consideration: the learning outcomes required, the length of the course, the maturity of the students, the portion of contact to non-contact learning time. If the goal is simply to be able to recall knowledge then simple tests are appropriate. However if demonstration of high order skills is required then assignments, case studies and portfolios are more appropriate. Portfolios lend themselves to courses of longer duration, as they are generally a collection of work. The more mature the student the less supervision they are likely to require.

Grading Systems

There are three major grading systems used in New Zealand polytechnics: graded passes with a 50% pass mark and A, B, C grades; mastery with 80% pass and in some cases 95% merit pass; competence with an 100% pass mark. Both mastery and competence generally include resits and resubmissions. Criterion based assessment is pervasive to all of these methods.

I have experience of all of these systems. My experience is that the higher the pass mark, the less that is taught and I believe the less the students learn. When we set an assessment we do so consciously or subconsciously with the expectation that most of the students in the class will be able to pass. This is regardless of the course criteria, they are generally open to interpretation. To use an analogy we set the height of the goal posts so that most students can score. When we lift the pass mark we lower the goal posts. When we mark assessments we make a professional judgement as to whether the work is satisfactory. If it is the student gets a passing grade regardless of whether this is 50%, 80% or 100%.

What we do when we lift the passing mark is not encourage the able students to learn and think independently. With the Bachelor of Information Systems degree at Manukau we returned to a 50% pass mark and graded passes. Doing only what is required will not get you an A+ in our system. Our best students have been motivated and rewarded fo independent work, in simple terms they have learnt more.

There are situations where competence assessment i appropriate: knowledge of the road rules, identification o the live wires in a circuit. Many would add such tasks a driving a car, landing a plane, however I would argue tha there are levels of competence with these tasks particularl when problems occur. Competence to drive a car in norma traffic conditions will not demonstrate competence i driving on a motorway at rush hour.

Which is Best for Learning?

There is no best assessment method! An assessment pla that matches the learning outcomes of the course is what important. If it is important for students to master basic skil early in the course, such as programming language synt or a methodology, a test on these skills at the beginni stages of the course is likely to have the desired effect. If is important that the students undertake a large piece work, then assignments and case studies are appropriate. students would benefit from doing a range of different tas then a portfolio approach may be best.

Which is the Best Measurement of Student Achievement?

Any of the above methods will provide a measurement student achievement. A very large study in the USA compared two ends of the spectrum, standardised tests portfolio, concluded that the method of assessment did alter the result. Students scored very similar scores with b tools. Minority groups did not improve their scores portfolios.

To summarise, the two primary goals of assessment are to learning and evaluate students. It seems likely that portfo are an effective method of assessment for the promotio learning. Many have assumed that course work assessme 'fairer' and a more accurate evaluation of a student's ab However, Supovitz and Brennan (1997) carried out a study comparing portfolio assessment to standardised and found that ethnic, gender, and socio-economic inequ persisted with portfolio assessment. While some gr scored better in one regime or the other there seemed little overall difference as a measure of achievement.

References

Aitken, J. E. (1993). *Empowering students and faculty through portfolio assessment.* Annual meeting of the Central States Communication Association, Lexington, KY.

Angelo, T. A. (1994). Classroom Assessment: Involving Faculty and Students Where It Matters Most. *Progress, Trends and Practices in Higher Education 6*(4) pp 1-2,5,10.

Arter, J. A. and Spandel, V. (1992). Using portfolios of student work in instruction and assessment. *Educational Measurement: Issues and Practice 11* pp 36-11.

Belenky, M. F. and Clinchy, B. M. (1986). *Women's ways of knowing: The development of self, voice and mind.* New York: Basic Books.

Biggs, J. (1998). *What the student does: Teaching for enhanced learning in the '90s.* Auckland: Higher Education Research and Development Society of Australasia.

Carpenter, T. P. (1980). Research in cognitive development *Research in Mathematics Education* Reston, VA: National Council of Teachers of Mathematics.

Gardener, H. (1992). Assessment in context: The alternative to standardized testing. in B. R. Gifford and M. C. O'Connor. (ed.) *Changing Assessment: Alternative views of aptitude, achievement and instruction.* Boston: Klower, pp 77-119.

Gonzalez, A. J. and Dankel, D. D. (1993). *The engineering of knowledge based systems.* New Jersey: Prentice Hall.

Hager, P. and Butler, J. (1996). Two models of educational assessment. *Assessment and Evaluation in Higher Education 21*(4) pp 367-378.

Hauser, J. (1993). *College student portfolios: A representational format for "best profile" dimensions.* International Reading Association's Panel of Speakers, San Antonio, TX.

Herman, J. L. (1992). What research tells us about good assessment. *Educational Leadership 49* pp 74-78.

Knight, P. (1995). *Assessment of learning.* London: Kogan Page

Linn, M. C. and Clancy, M. J. (1992). Case for case studies of programming problems. *Communications of the ACM 35*(3) pp 121-132.

McDowell, E. (1999). Editorial. *Assessment and Evaluation in Higher Education 23*(4): 335-338.

Nickerson, R. S. (1985). Understanding understanding. *American Journal of Education 93*(2) pp 201-239.

Perry, W. J. (1970). *Forms of intellectual and ethical development in the college years: A scheme.* New York: Holt, Rinehart and Winston.

Popham, W. J. (1995). Farewell, curriculum: Confessions of an assessment convert. *Phi Delta Kappan 79* pp 380-384.

Renwick, L. B. and Renwick, D. P. (1992). Assessing the thinking curriculum: New tools for educational reform in B. R. Gifford and M.C. O'Connor (eds) *Changing assessments: Alternative views of aptitude, achievement and instruction* Boston: Klower pp 37-75.

Supovitz, J. A. and Brennan, R. T. (1997). Mirror, mirror on the wall, which is the fairest test of all? An examination of the equitability of portfolio assessment relative to standardized test. *Harvard Educational Review 67*(3) pp 472-502.

Woolfolk, A. E. (1993). *Educational psychology* (5th Ed) Boston: Allyn and Bacon.

Intelligent Sketch Editing

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ABSTRACT
Advancements in technology now enable us to sketch on digital canvases on computers. One substantial advantage digital sketching environments have over their non-digital counterparts is editing features such as beautification and recognition. However, little attention has been paid to using those features and extending them to solve the fundamental differences between physical and digital environments such as the limited physical display space for digital sketching. We propose to extend advanced sketching features to ameliorate the problem of limited display space.

Author Keywords
Sketching, Pen-based Computers, Fish-eye techniques.

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies

INTRODUCTION
Sketching is an intuitive process to express and explore ideas in a pictographic manner, traditionally done using pen and paper. Nowadays pen-based devices provide the opportunity to transfer the sketching experience to the digital environment. Furthermore, advancements in hardware are pushing down costs making pen-based devices available and affordable to a broad audience. Wider availability of these devices provides more of an opportunity for users to integrate pen-based interfaces into their daily lives. But despite its potential, pen-based interfaces have not been widely adopted and remains in the realms of research and specialists.

There are fundamental limitations of digital sketching that are hindering basic usability. Those limitations arise from hardware as well as software issues. In order for sketching to gain wider popularity these issues need to be fully identified and solved.

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Limited display size is one problem already identified [1, 2] but little research has been done into ways to support larger canvases in a small display. While it is possible to, for example, take another piece of paper to extend one's paper drawing canvas the same is not so easy with a digital canvas. Size limitations become very apparent when one writes on a smaller digital display such as a mobile phone.

Current sketch environments offer a variety of techniques to address this problem such as the use of a grid or small radar window where only a fraction of the overall canvas is visible at a time [3, 4]. Another approach is to zoom in and out of the canvas possibly resulting in scaling ambiguities [5]. Yet another method is to use a two window approach where each window has an associated thumbnail window. While the sketch window is used for drawing, the thumbnail exists independently in a portfolio of thumbnails - relationships between thumbnails can also be defined. This approach enables multiple stakeholders to work on individual parts of a sketch using multiple displays and then merge their work independently [5, 6]. Each of these techniques has its advantages and disadvantages yet an overall satisfactory solution has not been found.

To solve the problem we propose two different advanced editing approaches. The first method explores techniques to manipulate ink while sketching whereas the second method concentrates on optimizing the canvas space in an iterative manner. Regardless of the techniques applied, the intuitiveness of sketching has to be preserved. Thus sketching has to be kept simple so that people are able to concentrate on the idea exploration rather than on operating the sketch tool.

There are a variety of techniques to manipulate the digital ink while sketching such as pressure induced manipulation [7-9] and fish-eye [10, 11]. The latter is used to visualize a certain part of a canvas by zooming into this area while also showing the surroundings of the zoomed area. The transition between the zoomed and normal view is done gradually by showing different intermediate zoom levels in between (Figure 1).

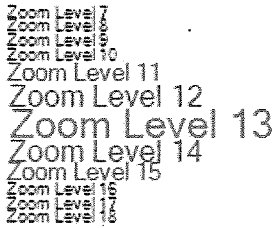

Figure 1: Fish eye view of a menu showing the different zoom level

For our second approach we examine layout algorithms to iteratively optimize the drawing canvas space. When space is running out one could trigger the sketch optimization and elements could be rearranged more efficiently. However, to apply layout algorithms the sketch must have a semantic structure (such as a graph) denoting the relationships between the elements. These relationships can be applied by using a known grammar [5, 12, 13]. A more general and fully automatic approach is to determine the spatial relationships between the elements such as inclusion or intersection [5, 14].

The next section provides the motivation for this research before the related work is outlined and finally our proposal is discussed.

MOTIVATION

Sketching is used to explore and visualize ideas in order to support the problem understanding or to communicate ideas in a very fast and informal way. Traditionally pen and paper provide the means to engage in sketching. More recently digital pen and canvas have been introduced.

While sketching on pen and paper is limited to drawing ideas without any means of manipulation, a digital canvas is not restricted to purely drawing. Zooming, rotating, scaling, relocating and erasing are only a fraction of possible basic editing features a digital environment has to offer. There are further more advanced editing techniques such as beautification[15], recognition [13, 16, 17] or various transformations to other representations [5, 13].

With all these editing features generating an enormous potential it is surprising that digital sketching has not been widely adopted by a broader audience. To bridge that discrepancy and make sketching more accepted the basic differences digital sketching still faces in comparison with its non-digital counterpart have to be identified and then overcome.

Solving this problem would greatly benefit the acceptance and therefore usage of digital sketching. It would further stimulate research in this area and allow end users to better integrate sketching in their daily routine; e.g. for writing a shopping list on their computing devices using a digital pen.

RELATED WORK

Studies have been conducted to examine the benefits of computer-based sketch tools [18, 19]. Although sketch tools are still not as intuitive and accepted as traditional sketching using real pen and paper, input based on a digital stylus was recognized to be more genuine and friendly than other input devices [20, 21]. Likewise various studies have shown that sketching is better for early design than widget-based design tools [21, 22].

Limitations of a digital input display have been identified as one problem of digital sketching over real paper. Warr [1] examined existing sketching tools from a creativity perspective. The central idea was to first investigate and define what creativity expressed in design is and second to what extent current sketch tools support creativity. Based on a series of experiments Warr defined requirements a creativity support tool has to comply with in order to support creativity in design. One of Warr's experiments showed that small screens (PDA sized) are a usability problem as the smaller the screen, the less detailed users are able to sketch. Since Warr's focus was on supporting initial and "rough" sketching he did not follow up on the identified problem.

Some sketch tools have addressed the problem of limited canvas space by offering a huge drawing space from which only a part is visible at a time and different means to transition between the parts.

Damm et al. [3] introduced a floating radar window showing the entire sketching space and a rectangle outlining the currently visible drawing space. To navigate around the sketching area the rectangle is dragged around. This approached proved to be problematic when people tried to move parts of a sketch from the currently visible area to another one as multiple actions have be done simultaneously; i.e. dragging the rectangle a bit at a time and then moving the selected ink in a repetitive manner until the final location is reached.

Another approach is to use a grid rather than a small radar to transition between the sketching areas [4]. By tapping on a button the grid view replaces the current window and shows the entire sketching space from a bird's eye perspective and allows the user to select a specific grid cell. This enabled multiple people to work in the same sketch space whereby every individual had his/her own grid cell(s). However, as only part of the canvas is visible it is cumbersome to sketch the transition areas between the single cells.

Denim [23], a system designed to support the creation of web sites, uses 5 predefined zooming levels to access different fidelity stages of a project which are shown on the canvas; i.e. overview, site map, storyboard, page and detail. Depending on the zoom level, a single website can be edited (e.g. page level) or relationships can be defined between multiple web pages using connectors (e.g. storyboard and site map). To check and explore the interactions defined between the pages in a site, the run mode can be used. In this mode a browser like window displays the pages and allows users to transition between them using the links defined in the project by connectors.

A technique which has not been applied to sketching is fish eye. It allows enlarging a fraction of a canvas while still showing the entire canvas (Figure 1). The transition zone between the enlarged and the "normal" area shows its context in different levels of enlargement which gradually decreases the closer it is to the normal zone. It was first implemented in a digital environment in the mid 1980s [10, 11]. Fish eye functions have been used in various areas such as menu navigation [24], high precision zooming [25] and to better control pressure [7]. The latter can be also use to trigger the fish eye and select the desired zoom level. For example, the user pushes the digital pen onto the screen where the pressure applied corresponds to the zoom level; i.e. the more pressure the higher the zoom. Once the zoom level is set the user can sketch in the enlarged area which follows the pen while sketching.

Fish eye functions may be used while the user is sketching to maximize space usage, alternatively layout algorithms can be used to optimize space. For example, if users are running out of space, they trigger a layout algorithm which then automatically rearranges the sketched information in a space optimizing manner.

Layout optimization can only be applied if the sketch has a known semantic structure such as a graph. This structure can be either predefined or derived automatically. Alvarado et al. [12] use a predefined language to describe the structural characteristics of shapes. The language denotes the shapes' characteristics as well as domain patterns. The latter describes relationships between the shapes. However, since each sketch is unique at the point of creation one cannot foresee and therefore already define a sketch specific language. Thus this definition has to be done by the user resulting in extra workload on a non-expert.

It is also possible to automatically derive a graph structure (if present) in a sketch using recognition. Most graphs consist of nodes and some form of connectors. Nodes can be represented by various forms such as ellipses (e.g. mind map), rectangles (UML class diagram) and circles ((un)directed graphs). Once the sketched elements' roles are classified (i.e. node or connector) those elements can be rearranged while preserving the elements relationships. To further maintain the graphs characteristics, spatial relationships such as containment and overlapping of elements are to be preserved.

Functions to create and edit graphs including optimization algorithms are already present in a selection of tools such as Tom Sawyer Software [26] and yEd [27]. However these tools rely on mouse and keyboard input.

There are numerous sketch tools [3, 5, 12, 13, 28-32] but only a few facilitate layout algorithms [15]. Plimmer et al. [15, 33] created SketchNode, a tool which is used for researching how people construct and edit graphs. SketchNode employs a spring force-directed algorithm to rearrange graphs [34]. When observing participants during their evaluation study, Plimmer et al. [15] found that participants preferred ordering their graph in a grid and hierarchical layout fashion. However, different graphs in sketches need different layout algorithms; e.g. hierarchical layout is not suitable for mind maps.

Plimmer et al. [33] also identified 3 requirements for a successful sketch reflow algorithm namely the *preservation of the hand drawn appearance*, *the intelligent edge reflow* and *user-centered design and validation.* Preserving the *hand-drawn appearance* of the graph is crucial because the level of a graph's fidelity has a direct impact on creativity [35, 36]. The special feature about *intelligent edge reflow* is that the sketch context and the interplay between sketch elements are considered when rearranging elements. For example, rearranged connectors should not intersect with other elements of the sketch. The idea behind a *user-centered design* is that a reflow algorithm should be based on a sketcher's drawing practices and validated empirically rather than on the preferences of its designer.

In summary, the problem of limited viewing space when sketching is already known and solutions have been proposed [1, 3, 4]. However, those solutions still face disadvantages which require further research. There are other known techniques such as fish eye views [10, 11] and layout optimizations which potentially can overcome those disadvantages. Furthermore, there are no studies which directly compare the various techniques.

DISCUSSION

As a first step the *problem has to be confirmed.* Therefore we are conducting an observational study where participants are asked to draw big mind maps requiring more space than visible at a time. They are 3 ways offered to users for navigating around the canvas: scrolling, a little radar window (as done by [3]) and a grid view (as done by [4]). Afterwards the participants are asked which method they prefer (and why) and what general criticisms they have with each method. Additionally, we will observe the participants to identify behavioral patterns when having to navigate the canvas.

The next step is a detailed literature review to identify techniques which can be used to overcome the problem before the identified techniques are implemented. There are two mandatory criteria each technique has to satisfy. First, the most important criterion is to preserve the ease and intuitiveness with which people sketch. The big advantage of sketching in general is that it supports creativity and provides an easy and fast way to communicate ideas. Second, the sketched ink has to appear instantly on the canvas regardless of the sketching speed; when moving the pen over the canvas there has to be no offset between the pen position and digital ink shown on the canvas. The implemented techniques have to be iteratively evaluated to further tune them for the sketch environment.

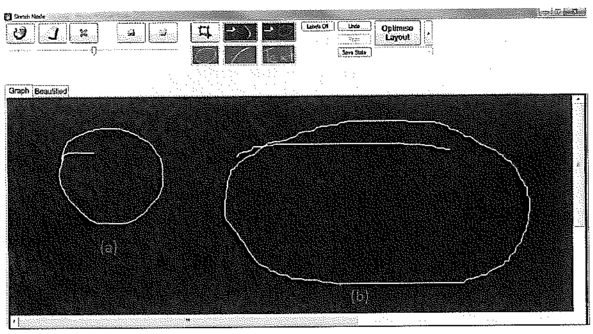

Figure 2. SketchNode showing two nodes drawn under different zooming levels with no scaling applied. Node (a) has been sketched with no zoom and node (b) when zoomed out.

One decision which has to be made when zooming is whether or not scaling is to be applied. When automatic scaling is used, the current zoom level is taken into consideration when sketching a shape and an automatic resizing occurs when the zooming level changes. If no scaling is applied then shapes sketched when zoomed out grow bigger when zooming back in. While shape (a) in Figure 2 has been sketched with no zoom, shape (b) has been drawn when the canvas was zoomed out. As a result shape (b) now is considerably bigger than shape (a). As there is no general correct and incorrect choice of whether to scale or not, people's behavior while sketching has to be studied to find the most suitable compromise for the sketching environment.

Another challenge when layout algorithms are to be used is the derivation of a sketch's underlying graph structure. In the most simplistic form a graph consists of a set of nodes with edges indicating the relationships between these nodes. Whether to derive the graph structure automatically by using recognition techniques and exploiting the graph elements' spatial relationships or to use a form of grammar or language describing a sketch's possible elements and their relationships mainly depends on the level of required detail. Using a predefined grammar offers higher detail than doing it automatically as every desired aspect can be precisely modeled. However, this method requires the grammar to be defined as well as labeling the sketch's elements; i.e. to link a sketched shape to its type defined in the grammar. The latter can be done using recognition functionality.

The efficiency of the implemented techniques (e.g. layout algorithms and fish eye techniques) has to be determined using a series of evaluation studies. The studies' results have to show whether one technique, a combination or none of them is a satisfying solution. An optimal solution regarding the limited displayed space would allow for easy and intuitive enlargement of the visible space while not hampering the ease and intuitiveness of sketching. If no optimal solution can be found it has to be concluded to what degree the used techniques satisfy the problem.

CONCLUSION

Limited display size is a problem. There have been various attempts to solve it but a perfect solution is yet to be found. Several promising techniques have been introduced which have the potential to resolve these challenges. This work would stimulate more research in the sketch domain and thus encourages a broader acceptance among a wider end user community.

REFERENCES

1. Warr, A., *Understanding and Supporting Creativity in Design*. 2007, University of Bath.
2. Gatward, K., *Effects of canvas size on sketching: Implications for Creativity Support Tools*. 2008.
3. Damm, C.H., K.M. Hansen, and M. Thomsen. *Tool Support for Cooperative Object-Oriented Design: Gesture Based Modelling on an Electronic Whiteboard*. in *Chi 2000*. 2000: ACM.
4. Mangano, N., et al. *Software Design Sketching with Calico*. in *ASE*. 2010. Antwerp, Belgium: ACM.
5. Plimmer, B. and I. Freeman. *A Toolkit Approach to Sketched Diagram Recognition*. in *HCI*. 2007. Lancaster, UK: eWiC.
6. Landay, J. and B. Myers. *Sketching Storyboards to Illustrate Interface Behaviors*. in *CHI '96*. 1996. Vancouver, BC Canada: ACM.
7. Shi, K., et al. *PressureFish: a method to improve control of discrete pressure-based input*. 2008: ACM.
8. Mizobuchi, S., et al. *Making an impression: Force-controlled pen input for handheld devices*. 2005: ACM.
9. Ramos, G. and R. Balakrishnan. *Fluid interaction techniques for the control and annotation of digital video*. in *Proceedings of the 16th annual ACM symposium on User interface*

software and technology. 2003. Vancouver, Canada: ACM Press.
10. Furnas, G., *Generalized fisheye views*. ACM SIGCHI Bulletin, 1986. **17**(4): p. 16-23.
11. Spence, R. and M. Apperley, *Data base navigation: an office environment for the professional.* Behaviour & Information Technology, 1982. **1**(1): p. 43-54.
12. Alvarado, C. and R. Davis. *SketchREAD: A Multi-Domain Sketch Recognition Engine*. in *Proceedings of the 17th annual ACM Symposium on User interface Software and Technology*. 2004. Santa Fe, NM, USA: ACM Press.
13. Hammond, T. and R. Davis. *LADDER: A Language to Describe Drawing, Display, and Editing in Sketch Recognition*. in *IJCAI*. 2003.
14. Calhoun, C., et al. *Recognising Multi-Stroke Symbols*. in *AAAI Spring Symposium on Sketch Understanding*. 2002.
15. Plimmer, B., H.C. Purchase, and H.Y. Yang. *SketchNode: Intelligent sketching support and formal diagramming*. in *OZCHI* 2010. Brisbane, Australia.
16. Paulson, B. and T. Hammond, *PaleoSketch: accurate primitive sketch recognition and beautification*, in *Proceedings of the 13th international conference on Intelligent user interfaces*. 2008, ACM: Gran Canaria, Spain.
17. Wobbrock, J.O., A.D. Wilson, and Y. Li, *Gestures Without Libraries, Toolkits or Training: A $1 Recognizer for User Interface Prototypes*, in *Proceedings of the 20th annual ACM symposium on User interface software and technology*. 2007, ACM: Newport, Rhode Island, USA.
18. Plimmer, B.E. and M. Apperley. *INTERACTING With Sketched Interface Designs: An Evaluation Study*. in *SigChi 2004*. 2004. Vienna: ACM.
19. Goel, V., *Sketches of Thought*. 1995, Cambridge, Massachusetts: The MIT Press.
20. Yeung, L.W.S., *Exploring Beautification and the Effects of Designs' Level of Formality on the Design Performance During the Early Stages of the Design Process* in *Department of Psychology*. 2007, University of Auckland: Auckland.
21. Bailey, B.P. and J.A. Konstan. *Are Informal Tools Better? Comparing DEMAIS, Pencil and Paper, and Authorware for Early Multimedia Design*. in *CHI 2003*. 2003. Ft Lauderdale: ACM.
22. Plimmer, B.E. and M. Apperley. *Software for Students to Sketch Interface Designs*. in *Interact*. 2003. Zurich.
23. Lin, J., et al. *Denim: Finding a Tighter Fit Between Tools and Practice for Web Site Design*. in *Chi 2000*. 2000: ACM.
24. Cechanowicz, J., P. Irani, and S. Subramanian. *Augmenting the mouse with pressure sensitive input*. 2007: ACM.
25. Ramos, G. and R. Balakrishnan. *Zliding: Fluid Zooming and Sliding for High Precision Parameter Manipulation*. 2005: ACM.
26. *Tom Sawyer Software*. 10.11.2010]; Available from: http://www.tomsawyer.com/home/index.php.
27. yWorks. *yEd Graph Editor*. [cited 10.11.2010; Available from: www.yworks.com/products/yed/.
28. Bailey, B.P., J.A. Konstan, and J.V. Carlis. *DEMAIS: Designing Multimedia Applications with Interactive Storyboards*. in *ACM Multimedia*. 2001.
29. Hammond, T. and R. Davis. *Tahuti: A Geometrical Sketch Recognition System for UML Class Diagrams*. in *2002 AAAI Spring Symposium on Sketch Understanding*. 2002.
30. Landay, J. *Interactive Sketching for User Interface Design*. in *Chi '95 Mosaic of Creativity, Doctoral Consortium*. 1995. ACM.
31. Caetano, A., et al. *Javasketchit: Issues in sketching the look of user interfaces*. 2002: AAAI Press, Menlo Park.
32. Chen, Q., J.C. Grundy, and J.G. Hosking, *SUMLOW: Early Design-Stage Sketching of UML Diagrams on an E-whiteboard.* Software Practice and Experience accepted November 2006., in press.
33. Plimmer, B., et al. *Preserving the Hand-drawn Appearance of Graphs*. in *Visual Languages*. 2009.
34. Fruchterman, T. and E. Reingold, *Graph drawing by force-directed placement.* Software: Practice and Experience, 1991. **21**(11): p. 1129-1164.
35. Goldschmidt, G., *The backtalk of self-generated sketches*, in *Visual and spatial reasoning in design*, J.S. Gero and B. Tversky, Editors. 1999, Key Centre, University of Sydney: Sydney. p. 163-184.
36. Tversky, B. *What does drawing reveal about thinking*. in *Visual and Spatial Reasoning in Design*. 1999. Cambridge, Mass.

Towards A General Taxonomy of Communication Settings

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Abstract

Communication setting is an important aspect of current theories on the use of computer-mediated interaction. This paper investigates the key properties of communication setting. First Cherry's (1978) sender-channel-receiver model of communication is extended to account for multi-media signals, network transmissions and intelligent communication systems. Analysing the properties of the transmission interface (not the sender, receiver or message) gives rise to four properties - multiplexity, synchrony, linkage and transmission cost. A taxonomy of communication settings is developed using these properties, and its implications for media richness and contingency theory are explored. The taxonomy also has implications for research design and the development of computer-mediated group support systems (CMGSS). It suggests that successful computer-mediated applications, such as E-mail and bulletin boards, are asynchronous, and the computer's contribution is to make communication easier rather than creating new types of communication. The taxonomy also suggests that the key feature of small face-to-face meetings may be that they offer many-to-many interaction. If so, effort to develop electronic meetings may perhaps better focus on developing the asynchronous, many-to-many interaction, rather than trying to emulate the sort of multi-media, synchronous, many-to-many interaction that occurs in face-to-face meetings. Voting can be considered to be one example of the highly condensed form of communication, called many-to-many communication, and asynchronous voting may provide the communication power necessary for electronic meetings.

Introduction

Contingency theory states that behaviour is contingent upon combinations of task and the technology that mediates communication (Kraut et al, 1992), or as observed by Siegel et al (1986) "*The same people will respond differently in different communication settings*". To use contingency theory effectively requires a valid categorisation of the key attributes of "technology" or communication setting (Gutek, 1990). Therefore communication setting plays an important role in the development of theory regarding both computer-mediated communication (CMC) and computer-mediated groups (CMG).

The purpose of this paper is to investigate the key properties of communication setting, or what is sometimes also called the medium of communication. The term "medium" will be avoided because it can result in confusion with the term "media", which generally refers to the physical media of vision, audition, and so on, as in the term "multi-media". The result will be a taxonomy of communication settings where E-mail, bulletin boards, telephone and face-to-face will all be considered to offer different communication settings. The taxonomy proposed aims to position computer-mediated interactions relative to other more traditional forms of communication, clarifying not only how they are different, but also how they are the same.

Previous Taxonomies

The advent of computer support for groups has made possible group interaction environments not before feasible, and a number of criteria have been used to define the variety of types of communication setting. Previous taxonomies will now be reviewed.

Cook et al. (1987) propose four types of *meeting classes*:

1. **Constrained by space and time.** Face-to-face meetings,
2. **Constrained by time but not space.** Distributed synchronous meetings,
3. **Constrained by space but not time.** Not a common form of meeting, and
4. **Not constrained by space or time.** Asynchronous meetings.

This taxonomy is still commonly used (e.g. Watson et al., 1994).

Dennis et al. (1988) provide a taxonomy of *EMS environments* based on:

1. **Group proximity.** Multiple individual sites, one group site, multiple group sites;
2. **Time dispersion.** Synchronous, asynchronous; and
3. **Group size.** Small, large.

Lim and Benbasat (1991) offer a more generalised framework for *group interactions* based on:

1. **Concurrency,**
    a) **Time dispersion.** Synchronous, asynchronous,
    b) **Spatial.** Collocated, dispersed.
2. **Message content.** Task orientated, social-emotional,
3. **Path.** Who the communicator is connected to,
4. **Channel:**
    a) **Technological support.** Computer-mediated, non-computer-mediated,
    b) **Mode,**
        i) **High social presence.** Auditory, visual,
        ii) **Low social presence.** Textual, graphical.

Burke and Chidambaram (1995) classify *meeting mode* in terms of:

1. **Technology support.** The GSS.
2. **Dispersion.** Collocated or distributed.
3. **Synchronicity.** Degree of interactivity.
4. **Channel capacity.** Capacity to transmit amounts and types of cues.

As can be seen there is some variation in what are considered relevant factors and in the interpretation of those factors. It is not clear whether the categorisation of *meeting classes, EMS environments, group interactions* and *meeting modes* are the same or different things, as the basis upon which the categorisations are made are not explicit. This paper will attempt to provide an explicit foundation for the taxonomy proposed by:

1. Stating a model of the communication situation,
2. Defining what is meant by communication setting in terms of that model, and
3. Analysing that definition to produce the taxonomy.

Communication Model

This section will develop a model of the electronic communication situation (see Figure 1). According to Cherry (1978), the essential elements of any communication system are a source, a channel and a receiver. To receive the intended information the receiver must decode the signal using the same protocol used by the transmitter to encode it, i.e. the sender and receiver must have a shared understanding.

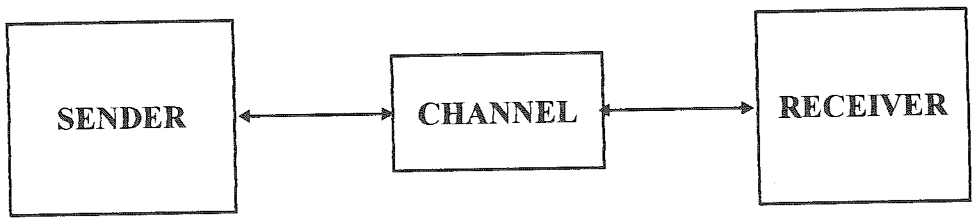

Figure 1. Simple communication model

This model will now be developed in three ways to deal with communications today.

Firstly, a single complex transmission may involve multiple channels, each channel carrying its own stream of information representing aspects of a single signal. For example a single video signal may involve both sound and vision channels. Even within a single physical medium there can be more than one channel. For example a stereo system transmitting a person speaking involves two channels, even though there is only one signal (the voice of the speaker). The original communication model must therefore be enhanced to include multiple channels (see Briggs and Nunamaker, 1994 for an example of an enhanced communication model of this type).

Secondly the term channel implies a passive transmission medium, such as a copper wire, where overload of channel capacity means transmission failure. However in modern packet-switched networks , like the Internet, overload is more likely to result in the transmission being stored and sent later, or re-routed, rather than a transmission failure. In this case the transmission "medium" has both *memory* and *processing power* at its disposal, and fulfils in an increasingly intelligent way its role as the intermediary between sender and receiver. The term medium or channel no longer adequately describes this situation. It is better to talk about the *transmission interface*, defined as hardware and software operating at the boundary between sender and receiver. Information passing through a transmission interface can be *stored* or *processed* before being passed to the receiver. The term *transmission interface* can also be used in the general sense, as something which connects, or operates at the boundary between, communicating entities (Lim and Benbasat, 1991). Therefore it is proposed that Cherry's original model be enhanced to refer to the channel as a transmission interface, which may contain channels.

Finally network transmissions can be point-to-point or multi-point (broadcast). A point-to-point transmission goes to a single receiver while a multi-point transmission goes to many receivers at once. The sending of a signal to many receivers on a point-to-point network (eg a star network) can be represented by the original model, because it is achieved by duplicating the sender-receiver transmission for each receiver. However multi-point or broadcast transmission sends from one sender to many receivers in a single operation. It is a fundamentally different form of transmission. Therefore it is proposed that Cherry's original model be enhanced, to include broadcast transmission to many receivers.

The revised model is shown in Figure 2. The model also allows for many senders, which will be explained shortly, as the concept of many-to-many communication is developed.

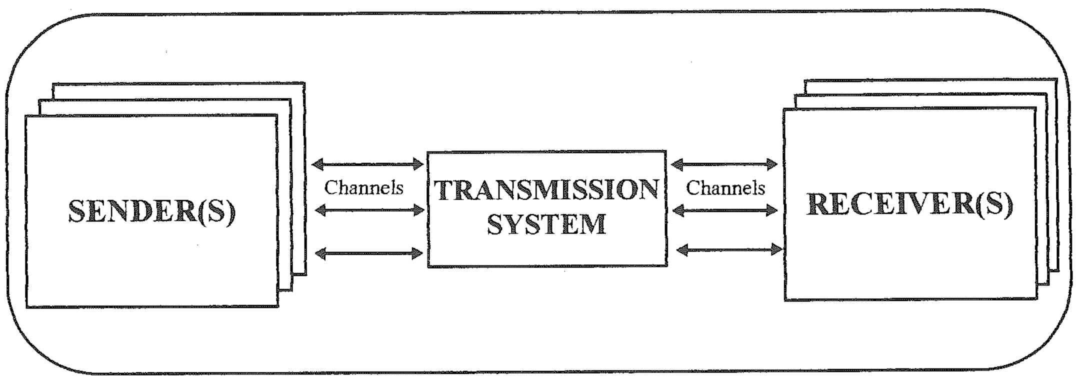

Figure 2 Enhanced model of the communication situation

Since this model will now be used to categorise communication settings it is worthwhile to briefly recap its concepts. The *communication setting* is defined by the *transmission interface,* which mediates the transmission of a *single signal* between sender(s) and receiver(s). A signal involves the transmission of information from a sender(s) to receiver(s). A complex signal may involve many *channels*, each carrying different aspects of the signal. Each channel carries a separate stream of information. Each channel involves one, and only one, *physical medium* (although the reverse is not true - a single physical medium may involve several channels). The transmission interface may apply *storage* and *processing* capabilities to the transmission. The transfer of information requires shared understanding, or *social constructs* (Lee, 1994), between sender and receiver, and is not simply a property of the message or the transmission interface. A single transmission from a sender may go only to one receiver, or may go to many, depending on how the sender and receiver are *linked.* A *communication environment* may provide many alternative communication settings, as for example where a subject may interact by phone or by memo, but subjects wishing to communicate tend to use settings alternately, rather than in combination (Jarvenpaa et al, 1988).

Definition

The communication setting is what exists before the sender and receiver begin to transmit, and provides *that through which communication occurs*. It includes any communication tools available, whether a chalkboard, computer hardware, group support system (GSS) or a facilitator. It is not merely the physical setting, but includes any rules or protocols that govern the handling of what is transmitted, and any processes that are applied to messages in the course of transmission. In computer-mediated communication (CMC) or computer-mediated groups (CMG), the communications setting is provided entirely by a computer network. The focus of this paper is on such "pure" electronic interactions (Finholt and Sproull, 1990) which do not involve face-to-face aspects. It may be possible however to apply the principles proposed generally to any communication environment, whether CMC, GSS or face-to-face.

Analysis of Communication Setting

This section will analyse the characteristics of the transmission interface in order to develop a taxonomy of communication settings. The development will be consistent with three principles:

1. **Defined solely by the transmission interface.** A taxonomy of communication settings should be based on a categorisation of variables of the transmission interface alone. *This excludes variables relating to task, group and individual,* such as group size and message content,

2. **Reflect model entities.** A taxonomy of communication settings should be consistent with the communication model shown in Figure 2, and

3. **Generally applicable.** A taxonomy of communication settings should wherever possible apply the same theoretical principles to all communication interactions, not just computer-mediated ones.

Some terms typically used in such taxonomies are not present. For example:

1. *Colocated* is not a communication setting in the sense used here, since it is expressed in terms of sender and receiver position. Colocated communication, according to the communication model used, equates to communication using the very high bandwidth face-to-face environment;

2. *Distributed* is also not an aspect of the transmission interface - communication settings like the telephone provide all that is necessary for distributed interaction, but could equally operate within the same room. The treatment *colocated vs distributed* is better called what it is, say *face-to-face vs audio*, which terminology current experiments tend to adopt (e.g. Suh, 1996).

3. *Task, group and individual variables*, such as group size and message content, are excluded as they are not properties of the transmission interface.

Properties of the Communication Setting

From the communication model, the following properties of the communication setting will be developed:

1. **Multiplexity.** The number, type and capacity of channels provided by the transmission interface, eg auditory only, auditory plus visual, visual only, etc.

2. **Synchrony.** Whether the sender(s)/receiver(s) must be synchronised with the transmission operation, or whether the transmission interface stores the message and allows sender(s)/receiver(s) to be asynchronous to the transmission operation.

3. **Linkage**. Whether a single transmission operation operates from one sender to one receiver, one sender to many receivers, or many senders to many receivers.

4. **Transmission Cost**. Effort required of communicating users of the transmission interface.

These will now be considered in detail and used to define the taxonomy.

Multiplexity

For a single transmission, the sort of signal a transmission interface can carry depends on the number of channels, and the capacity and media type of each channel. The concept of transmission interface multiplexity involves more than simple media bandwidth or information capacity, because complex transmissions present multiple channels of information. For example a film show offers both sound and vision channels in a single transmission. Signals in the physical world offer a channel for each sense, such as vision, audition, olfaction, touch, and taste.

Multiplexity will be defined as the total sum of channels provided by the transmission interface for a single signal, and considered to be what defines signal complexity.

Symbology, such as occurs in language, can be considered to offer a secondary channel of communication which operates in the same way as the primary channels provided by the physical senses but on a higher level. For interacting groups, this means there are at least three channels of communication which can be applied to a single complex signal:

1. **Vision.** Communication through form,

2. **Audition**. Communication through sound, and

3. **Symbolism.** Communication through symbol.

For example a picture can convey meaning not only through its form (realism), but also through its symbolism. Speech can be seen as a combination of a symbolic channel (language) and a sound channel (tonality), and video as a combination of visual, sound and symbolic channels. Since plain text conveys relatively little information through its visual form (compared to say the face of a person speaking), it will be considered to be primarily a symbolic channel.

In summary, the multiplexity of the communication setting can be classified as in Table 1.

Communication Setting	Multiplexity
Plain text	Symbolic communication through language
Speech	Audio and symbolic channels
Video	Audio, visual and symbolic channels
Face-to-face	As for video, plus other channels

Table 1. Communication setting multiplexity

Combinations such as audio only (music) have been left out because they do not apply to relating groups. Some combinations have been left out because they are rarely used. For example the old silent movies offered a visual/symbolic transmission interface (not auditory). Other combinations have been left out because they are not yet common. For example video cameos may in the future be inserted in electronic text to enhance the variety and type of channels available (Lanham, 1993).

Synchrony

Synchrony is related to message *storage*, message *delay*, and in turn to the *interactivity* of the situation, all of which involve the same property of the transmission interface.

Synchrony can be defined as the sender and receiver being involved in the same interaction at the same time. However such a definition makes synchrony a property of the time relationship between sender and receiver, rather than a property of the transmission interface. Sender and receiver could thus be "synchronous" even for an transmission interface that involves storage and delays, such as E-mail or letter writing. For example sender and receiver could sit at their computers, simultaneously, waiting for delayed E-mail transmissions. A definition of synchrony in terms of sender and receiver would call this synchronous communication.

It is better to define synchrony solely in terms of the communication setting, as follows:

> *A synchronous transmission interface is one that requires a sender or receiver to synchronise their sending or receiving with the transmission operation.*

For example face-to-face conversation is synchronous because if you are not there when it occurs, you miss it. The reason for including sender in this definition will become clear when many-to-many communications, such as a show of hands in a meeting, are discussed shortly.

Asynchrony is usually achieved electronically by message storage, either in temporary form, such as E-mail, or in a more permanent form, such as in a book or stone tablet. Stored transmissions are, by contrast, usually not immediate, but involve transmission delays. These have been categorised as preparation time, transmission time, and response time (Bowers and Churcher, 1989; Lea, 1991). Together these delays affect *interactivity*, normally defined in terms of the time to send and receive messages, or speed of interaction (Kraut et al, 1992). In highly interactive communications, such as face-to-face conversation, messages are sent, received and responded to almost immediately, without any delays due to the transmission interface or receiver absence. However response delay depends upon whether the receiver is present and willing to respond immediately upon message receipt, and so is not solely a property of the transmission interface. It can be concluded that interactivity is a complex property of the whole sender-transmission interface-receiver communication, and so cannot be used as a defining feature of communication setting, because aspects of interactivity are defined in terms of sender, transmission interface and receiver.

For example in an experiment carried out by the first author (Whitworth, 1996), groups of five had to reach agreement on the answers to a test of 12 multi-choice questions, working solely through the computer. Communications were asynchronous, and each member could be working on different questions at the same time. After the first vote, subjects were able to see how the rest of the group responded. Slow users received immediate feedback of the responses from the rest of the group after their first vote, and for them the situation was very interactive, as it involved no feedback delays. However fast users found the same communication setting not so interactive, as they had to wait for the slow users before they could got feedback. For them, the situation was a delayed rather than interactive one. The communication setting, or transmission interface, however was the same for all users.

Does transmission time define asynchrony? E-mail is seen by users as being just as asynchronous as letter writing, even though transmission times for letters ("snail mail") are much longer than for E-mail (Lea, 1991). It appears that even if the transmission time for electronic communication were to reduce to almost zero, it would still be seen as an asynchronous transmission interface by users.

It is proposed that asynchrony be defined not in terms of delay, but *in terms of the ability of an transmission interface to receive and deliver messages for a given transmission operation over an extended time period*, thus freeing users from the need to be synchronously present at the moment of transmission in order to send or receive. In this definition speed of message transmission or user response delays are irrelevant. The key feature of an asynchronous transmission interface is that it allows individuals to decouple themselves from a particular communication operation, without fear of missing the contributions of others, or of being unable to contribute.

In conclusion, it is proposed that synchrony/asynchrony is a key property of the transmission interface from a user perspective. The definition of these terms are summarised in Table 2.

	Definition	**Similar Terms**
Synchronous	Requires the sender or receiver to synchronise themselves with the transmission operation	Immediate, interactive, transient, not stored
Asynchronous	Does not require the sender/receiver to synchronise themselves with the transmission operation	Delayed, stored

Table 2. Communication setting synchrony/asynchrony

Linkage

An important feature of a GSS is the pattern of information exchange it supports , usually categorised as one-to-one or one-to-many (DeSanctis et al, 1993). The nature of the link between sender and receiver(s) can be defined by what occurs *in a single signal transmission* as shown in Table 3.

Type of Linkage	**Label**	**Definition**
One-to-one (1:1)	Point-to-point	In a single transmission operation, data from one sender is transmitted to one receiver;
One-to-many (1:n)	Broadcast	In a single transmission operation, data from one sender is transmitted to many receivers; and
Many-to-many (m:n)	Vote	In a single transmission operation, data from many senders is transmitted to many receivers, often the same people as the senders.

Table 3. Communication setting linkage

The last category shown, many-to-many, is a form of communication that is not commonly recognised, but one which, it is proposed, is a natural extension of the other two. Many-to-many communication is not reducible to broadcast communication, just as broadcast communication is not reducible to point-to-point communication. The transmission interface offers fundamentally different forms of communication service in each case.

A distinction will be made between many-to-many *task situations* and many-to-many *linkage*. A many-to-many *task* situation is where many people wish to communicate with many others, as for example an informal discussion. A discussion task situation can be handled using a one-to-one, one-to-many or a many-to-many communication setting, with of course varying degrees of success depending on the situation demands. The various combinations of situation and linkage will now be described:

1. **Broadcast task situation**. A broadcast task situation can be dealt with by:

    a) **One-to-one linkage.** According to the definition, E-mail provides one-to-one linkage, even though one E-mail can be sent to many receivers, because each E-mail receiver requires a separate transmission operation, and each receiver gets their own copy of the E-mail message. A one-to-one transmission interface deals with a one-to-many requirement by duplication, e.g. list E-mail. This duplication means that using a one-to-one communication setting becomes increasingly expensive as the number of receivers increases, e.g. sending a mail message to all US citizens.

    b) **One-to-many linkage.** By contrast to list E-mail, a bulletin board provides true one-to-many communication, because the sender communicates with the many readers of the board by the single transmission act of posting a notice. Unlike list E-mail, all receivers are reading the exact same message. Clearly this is more efficient than the duplicating method used by one-to-one transmission interfaces, e.g. sending a message to all US citizens by TV broadcast.

2. **Discussion task situation.** A discussion task situation involves a many-to-many communication task requirement, and can be dealt with by:

    a) **One-to-one linkage.** One-to-one communications are particularly inefficient when dealing with discussion type situations, and information overload can be a problem in this case. For example, a manager requesting policy feedback using E-mail from a group of 20 staff could expect 20 messages in reply. The many-to-many task situation means everyone wishes to keep everyone else informed of what they are doing, so each staff member will send their reply to 20 people. The result, after a single question and response in a discussion situation is 400 one-to-one E-mail responses. Each of the 400 replies could in turn generate a response, which would also need to go to the entire group, so replies to replies could number over 8,000. It is not difficult to see how one-to-one communication settings, such as E-mail, can generate information overload when attempting to deal with discussion situations (Hiltz and Turoff, 1985). Consider for example 200 people discussing an issue by E-mail in order to reach consensus.

    b) **One-to-many linkage.** By contrast, a one-to-many communication setting, such as a bulletin board, offers a far more efficient communication operation for discussion situations. In the example given above, there will be at most 21 items, the original item plus 20 reactions, which is a considerable reduction in transmission operations for the same information transferred. A broadcast communication setting deals with discussion situations by duplicating the transmission operation for each sender, just as point to point communications, such as E-mail, deal with broadcast situations by duplicating the transmission operation for each receiver. In this case, each sender transmits one broadcast message to the group. In a face-to-face setting, each sender gets to "share the microphone", or take their turn at speaking, and in this way many people are able to communicate with many others. For most discussion situations this type of duplication is satisfactory. However for highly interactive discussion situations, where a group is dynamically acting as one, true many-to-many linkage may be necessary, where the group transmits and the group receives all in the one communication operation.

c) **Many-to-many linkage.** Many-to-many linkage follows the same principles as established for one-to-one and one-to-many communication. The communication of many senders to many receivers is a single communicative operation, as for example in a show of hands in a meeting. Each sender and each receiver is part of the same communication act. In the example given, of a manager raising a policy issue with 20 staff, many-to-many linkage would allow the entire question and reply to occur a single communication operation, which would be called a vote. In the framework presented here, what is called voting is only one example of a many-to-many communicative act. This is not a new idea. Hiltz and Turoff (1985) point out that voting can be a "highly condensed form of human communication". Voting illustrates the more general case of many-to-many communication.

The key requirement for many-to-many communication is that the information from the many signals coming into the transmission interface can be combined in some way, without significant loss of information, to form a single output signal, which can then be broadcast to the many receivers. For example if the sender messages are in numeric form, they can be combined, giving a result, such as the mean of the group choice distribution.

The same process in principle can occur in the natural face-to-face setting. For example, many sounds can naturally merge together to create a single larger sound. Audience clapping is a many-to-many communication situation that is the natural equivalent of voting. But while the merging of 200 clap sounds creates a single powerful group clap sound, the merging of 200 E-mails on the same subject does not create a single powerful E-mail (unless it be powerfully long, repetitive and boring). The medium of sound *has the ability to merge many signals into one signal* in a way that does not occur within a setting like text based E-mail.

However if the responses are numeric, the processing power of the computer communication system can provide many-to-many communication, and the combination of 200 votes agreeing with a position does create a group voice that is more powerful than that of any individual. What we call "voting" in a face-to-face setting is usually a slow formal process, that is costly to carry out, and often disrupts the flow of group interaction. Computer processing of course changes that.

In conclusion, group voting can be considered to be a communicative act, from all group members to all group members. It is an example of many-to-many communication, which differs from other more commonly recognised forms of communication only in linkage. It is a form of communication that can be well supported by a computer communication system.

Transmission Cost

It might be expected that CMC transmission cost will be high, since message preparation requires the user to type their message. However communicating involves a variety of factors in addition to message typing. The factors are, message:

1. Preparation,
2. Addressing,
3. Administration, and
4. Reception.

These will now be considered in more detail.

The cost of message preparation for CMC may be not that high, especially for short messages. Electronic templates allow the greeting, goodbye and sender address information to be pre-loaded, and if the communication is a reply, then the original sender's title is also carried forward, so that for a short message like "*OK. Do it.*" the typing cost is literally only the few words of the message itself. By contrast, for a similar short letter over half the work may involve writing the self address, salutation, and farewell. As well as requiring less layout effort, CMC is easier to amend than a hand written letter or memo because it is electronic, and provides services like copy, cut and paste. In other words, the cost of making an error in message preparation is less for CMC.

Automatic addressing and address lists however are where CMC offers great savings, compared to either addressing an envelope or dialling a telephone number. Kiesler et al (1984) reported that someone posted a new idea on the computer network which in one minute was sent to 300 colleagues in branches across the country and within two days enough replies were received to launch a new project. That the message was transmitted in one minute may be less relevant than that it is physically much easier to send an E-mail to 300 people than to post a letter or telephone 300 people. In this example CMC provided the user with the equivalent of a secretary to make, in letter terms, 300 copies of the message, place the messages in 300 envelopes, address 300 envelopes, and then stamp and post the 300 letters.

Once sent, the electronic mail system usually keeps a file copy, saving the sender this administrative trouble.

Finally, although the cost of message preparation may be higher for text than speech, the cost of message reception may be equivalently less. While typing is less than one third as fast as speaking, reading is faster than speaking or listening (Chafe, 1982). Research by Weeks and Chapanis (1976) suggests that an idea requiring 100 spoken words can be conveyed in about 25 words of typewritten text, so written text may be up to four times as dense as speech. In general it would appear that CMC typing speed losses may be offset by gains at the other end, especially for large groups, where each individual receives data from many others.

In conclusion, CMC communications, such as E-mail, although at first sight more expensive, may actually offer significant cost benefits to users, in the form of effort reduction for message addressing, administration, reception and even message preparation.

This may explain why CMC seems to generally result in more information transfer (Hiltz and Turoff, 1985) and over half of the CMC message information is "new information", which the respondents felt they would not have received or sent except through the electronic channel (Sproull and Kiesler, 1986, report 62%, while Finholt and Sproull, 1990, report "over half"). One group of users reported that the majority of organisational E-mail (58%) came from strangers, persons the recipient did not know, and a majority also came from outside the recipient's building (Finholt and Sproull, 1990). Although introducing CMC may replace other traditional media, it can also produce a net gain in all media communications (Lea, 1991) by increasing the "social connectivity" of individuals:

> *The most fundamental impact of CMCs is to increase the social connectivity of users (i.e. the number of people in regular communication) by about tenfold*
>
> (Hiltz and Turoff, 1985)

The total increase in communications suggests that CMC increases the number of interpersonal relationships that people enter into, which relationships in turn generate more of other forms of communication, such as FAX and memo.

In terms of user perceptions, computer-mediated communication such as E-mail is seen by users as a much more *spontaneous* medium than letter writing (Lea, 1991):

> *Since around a quarter of all user's constructs loaded on this component, spontaneity emerges as an important comparative dimension on which E-mailing is seen to be similar to telephoning and different from letter writing.*
>
> (Lea 1991, p169)

Both the increase in communication that follows CMC, and its perceived spontaneity, can be attributed to a reduced transmission cost of computer-mediated communication, which thus emerges as an important property of communication settings.

The transmission cost that is acceptable to a user for a particular message has been called the "messaging threshold", defined in terms of the psychological cost to the user of sending the message (Reid et al., 1996). If the cost imposed by the transmission interface is greater than the individual's messaging threshold for a given communication, then it will not be sent. Only messages whose urgency or relevance exceeds the message threshold are sent. If this view is correct, E-mail seems to reduce the cost of many messages compared to the message threshold, resulting in more communication.

Transmission cost may explain why systems which attempt to facilitate information exchange by increased message structuring, such as the Information Lens (Malone et al, 1987), gIBIS (Conklin and Begemann, 1988), and the Co-ordinator (Winograd and Flores, 1986), have not been particularly successful (Holtham, 1994). The rational structure such systems impose increases the psychological cost to the user of sending a message.

In summary cost of transmission seems to be a significant property of the communication setting. Written text seems to be a surprisingly cost effective medium for the exchange of factual information, overall, especially in large groups. Hence E-mail is seen as a more spontaneous transmission medium than letters. This reduced cost can also explain the increase in communication which occurs when E-mail is introduced, in terms of more communications falling under the messaging threshold. The increase in volume of communication observed due to E-mail may be due to the transmission of messages which were previously perceived as not worth the effort required to send (Finholt and Sproull, 1990).

A Taxonomy of Communication Settings

Table 4 shows a taxonomy of communication settings based on the transmission interface properties just discussed of multiplexity, synchrony and linkage. Transmission cost affects the likelihood that people will use a given setting. The settings within each cell are listed in order of increasing transmission cost to the user. The table is based on properties of the transmission interface alone, not of sender, receiver or message. Each of the cells in the table describes a *communication setting*, which can be used by senders and receivers as a context within which to send a variety of messages.

	One-to-one (1:1) (point-to-point)		One-to-many (1:N) (broadcast)		Many-to-many (M:N) (network)	
Multiplexity	**Synchrony**	**Asynch.**	**Synchrony**	**Asynch.**	**Synchrony**	**Asynch.**
Symbolic (e.g. text)	Sign- language	E-mail, Note, Letter, Braille	Semaphore	Bulletin-Board, Noticeboard Sign, Pamphlet*, Book*.	Show of hands, TV studio voting, Online chat*	Formal Vote
Audio-Symbolic (speech)	Telephone	Answer-phone	Radio,	Tape* , CD*	Radio net*, radio-talkback*.	
Audio-Visual-Symbolic (face-to-face)	Conversation Video- phone	Video-Answer-phone	Speech, TV	Video tape * = Duplicated	Discussion, Video-Conference* * = Duplicated	

Table 4. A taxonomy of communication settings

A few examples may help clarify the taxonomy described in the table. From the table it can be seen that a telephone generally provides a synchronous, one-to-one, audio-symbolic communication setting, while an answer phone allows the same type of communication to occur asynchronously. A letter also offers asynchronous, one-to-one communication, but without the audio channel. A book, although essentially a one-to-one communication (because each book goes only to one receiver), typically provides one-to-many communication by duplication (making copies of the book). Hence it is shown as one-to-many communication, but marked with a star (*), to indicate that it does so by duplicating one-to-one linkage. The message is asynchronous, which means the user can read the book at their leisure. Because considerable effort goes into preparing, printing and distributing a book, transmission costs are reasonably high, and so book is at the bottom of the list in its cell.

A speech given over the radio provides one-to-many communication. It not only provides the symbolic language channel, but also voice sound and tonality provide another channel to carry meaning. In this case, the receiver must be synchronous with the transmission operation, or they will not receive the message. A tape or CD of a speech, however, allows asynchronous voice communication to occur, in much the same way as for a book. Transmission to many listeners requires a tape to be reproduced and distributed, i.e. one-to-one duplicated communication. A particular tape message could however go to a particular individual, creating a one-to-one communication setting. By contrast radio, by its broadcast nature, must go out to all, and hence it is a true one-to-many form of communication. Television offers the same sort of communication setting as radio, except it adds a visual channel, and video tapes extend sound tapes in the same way.

It can be seen that this taxonomy provides a common way of looking at a wide variety of communication settings. The implications of the taxonomy will now be considered.

Implications for Research Design and Interpretation

Daft et al (1987) organised media in decreasing order of "richness", as follows: face-to-face, telephone, written addressed (letters) and written unaddressed (posters). From the point of view of the proposed taxonomy, this uni-dimensional categorisation of communication settings seems a considerable over simplification. Each of these media categories involves more than one channel, and the concept of "richness", in the sense of information capacity, can be applied to each of these channels separately. The categorisation of plain text as "lean" for example depends on which signal channel is considered to represent the transmission interface, the "lean", visual channel (typed text) or the "rich", symbolic channel (language). In addition comparison of face-to-face and E-mail communications settings changes not only the multiplexity, but also synchrony and linkage, leading to a confounding of variables. This has been pointed out by Kraut et al (1992), who suggest that interactivity, not expressivity, accounts for the results of media richness comparisons. Unfortunately their definition of interactivity (the quickness and appropriateness of feedback) can also confound variables, as interactivity is not solely a property of the transmission interface or medium.

It is suggested that if the research design seeks to vary the communication setting, only one property of the communication setting should be varied at once. Otherwise, as has been shown for media richness experiments, treatment effects can be confounded between different media properties such as capacity and synchrony. Comparisons of electronic vs face-to-face meetings likewise usually confound many variables, as do comparisons of compound communication environments, such as decision rooms vs face-to-face. These designs run counter to the standard research procedure of varying only one variable at a time.

A word of warning should be sounded in comparing what are fundamentally different types of communication settings. For example one could compare humans walking on land with humans walking underwater, but there would be little point since when underwater humans tend to swim not walk. It may be a mistake to consider the challenge of electronic groups to be the automation of the face-to-face group environment (Hiltz and Turoff, 1985) or see face-to-face interaction as the standard against which GSS should be measured (Lea, 1991). Electronic groups may be a group environment that exists in its own right, not merely as a pale shadow of face-to-face meetings (Hiltz and Turoff, 1985).

Contingency Theory

Contingency theory states that subjects choose the communication setting appropriate to the task. Without any statement guiding how this matching occurs, it is very broad and general theory, providing only relatively weak predictive power (Gutek, 1990). The principle behind contingency theory seems sound, but its application depends on correct definitions of technology and task. The taxonomy of communication settings proposed gives a more detailed, and it is believed more valid, definition of "technology" than that provided by the single dimension of media richness. Contingency theory also aids interpretation of the taxonomy by suggesting that one communication setting is neither intrinsically better nor worse than any other. For example although telephone offers an expressive medium with high interactivity, it usually has only one-to-one connectivity, and there are times when a simple, non-interactive, broadcast notice is a better context of communication. This is the essence of contingency theory - that choice of communication setting is contingent upon the situation (Lea, 1991). The concepts of contingency theory can be extended to the taxonomy shown in Table 4 as follows:

> *Good communicators, once the communication task and target are known, will select the appropriate communication setting according to multiplexity, linkage, synchrony and transmission cost.*

In other words contingency theory can be extended from the simplistic concepts of media richness, to the general properties of the transmission interface given in the taxonomy.

Implications for Electronic Meetings

The taxonomy suggests that computer communication is less creating new communication settings than expanding existing ones. Its contribution appears to be mainly to reduce the cost to the user of communicating in that setting. Computer mediation has made asynchronous forms of communication more effective and hence more attractive and useful. Hence the main factor Lea (1991) found from user's perceptions, after the main *spoken vs written* factor, was *spontaneity,* which can be seen as a user perception of lower transmission cost. E-mail was seen as much more spontaneous than letter writing.

The contribution of computer media to the taxonomy seems to be primarily in the area of asynchronous communication. For example we now have electronic mail, electronic books, and electronic notice boards, in addition to ordinary mail, books and noticeboards. Can the same transformation be applied to meetings, giving electronic meetings? It has long been an aim of CMGSS is to do just that, as the alternative name of electronic meeting system implies. Looking at the taxonomy, however, one difference from the previous cases is immediately apparent - mail, books and noticeboards provide asynchronous communication precedents, while face-to-face discussion provides a typically synchronous event upon which to base computerisation. This difference may explain why the electronic conversion has been relatively successful for mail, books and noticeboards, but the development of an electronic version of meetings has been relatively unsuccessful (Jessup et al., 1987; Jarvenpaa et al., 1988; Watson et al. 1988; Zigurs et al., 1988; Gallupe and McKeen, 1990; Dufner and Hiltz, 1990; Cass et al., 1991; George et al., 1992), particularly in the area of generation of agreement (Adrianson and Hjelmquist, 1991).

The problem may be that electronic media are inherently asynchronous. Asynchrony, as the first author found when developing CMGSS software, is not a virtue but a necessity on computer networks. This suggests that the natural position for electronic meetings is the shaded cell shown on the taxonomy table. This suggestion will now be considered in more detail.

The Communication Setting for Electronic Meetings

A meeting is considered to be a task situation where, to a greater or lesser degree, the entire group interacts dynamically. That means many people wish to communicate with many others. From the point of view of the communication setting, the primary problem is how to support many people who each want to communicate with many other people.

The reader may have noted that while *conversation* and *speech* appear on the taxonomy, *meeting* does not. This is because the term "meeting" is considered to refer to a communication *environment* rather than a communication setting. A meeting allows distinct one-to-one, one-to-many and many-to-many communication settings (not counting text interaction such as through the agenda or the minutes). Although meetings offer one-to-one communication, as when two individuals chat personally together, this form of communication is frowned upon. One-to-one interaction is considered inappropriate for a many-to-many task situation, and if everyone chats personally to the people around them, the meeting is usually considered to have "broken up", and ceases to be a meeting. More usually, as in a formal meeting or conference, each person takes a turn to speak to the rest of the group. In this case many-to-many information exchange occurs by duplicated one-to-many communication. However, in a very interactive face-to-face discussion in a small group, it is proposed that genuine many-to-many communication occurs.

How this occurs is not yet clear. One way has already been mentioned, where there is a show of hands to gauge group feeling on some issue. It can also be suggested that non-verbal channels of communication in a small face-to-face group may serve the same purpose. Using body language, facial expressions, various behaviours (such as drumming the fingers) and non-language sounds (eg groans or gasps), group members can provide the same communication effect as would be achieved by a show of hands or a vote. Another possibility is that in group discussions each communication has a valence, a single value such as agree or disagree, representing the behavioural position of the sender with regard to some task issue, and the combination of valences operates much like voting, as was found by a study by Hoffman and Maier (1961). Many-to-many communication may be what allows the group to stay in touch with the group in a dynamic discussion situation and what makes a group meeting more than just a series of speeches. Many-to-many interaction may be what gives groups the sense of group.

The challenge of computer-mediated communication

If the above is correct, the challenge for computer-mediated groups may be to deal with many-to-many interaction, rather than provide increased richness of interaction. The provision of true many-to-many communication may be how computer-mediated group systems (CMGSS) will provide a step up in functionality from that provided by E-mail or bulletin boards. For example a brainstorming tool, where each group member adds ideas to a public screen, offers essentially the same functionality as provided by a bulletin board, namely duplicated, one-to-many linkage to support a many-to-many information exchange requirement. Such tools do not distinguish GSS from bulletin boards. A loose definition of GSS in terms of "group support", could define bulletin boards as examples of GSS. However the analysis so far suggests that CMGSS could be defined as *a computer system providing support for an interactive group,* i.e. a group requiring many-to-many information exchange. If CMGSS is to provide the electronic equivalent of a face-to-face meeting, it must provide for the sort of many-to-many interaction which is not offered by E-mail or bulletin boards.

However providing synchronous, multi-media, many-to-many interaction across a computer network is a tall order. For example a meeting of twenty people would generate twenty video streams. If the GSS simply showed them on the screen within 20 separate video mini-windows, that would generate information overload immediately. The computer would somehow have to combine all these streams into one common "space", and to do so in a synchronous manner would require the resolving of any contention, such as two people speaking at the same time. The problems that arise in setting up a synchronous many-to-many setting, to provide the electronic equivalent of a meeting, go well beyond any lack of media capacity or richness.

Suppose however the defining communication setting for electronic meetings were to be *asynchronous, many-to-many* interaction. A many-to-many transmission interface *combines many input signals into one signal* that are broadcast to group members as one signal. Looking at the taxonomy shows that while electronic groups might seem to be exploring a new communication setting, there is in fact a precedent. The other many-to-many, asynchronous, symbolic interaction is formal voting. It is slow, costly to do, and not usually very interactive, but nonetheless a formal vote is a many-to-many, asynchronous, symbolic interaction. During a vote the many communicate with the many.

This means that lean text electronic meetings, like electronic mail and electronic bulletin boards, do have a natural precedent. Voting is the slow, formal expression of an essential form of group interaction. The contribution of computer mediation to this communication setting may therefore be the same as its contribution to letter mail and physical noticeboards - to reduce the effort of the interaction, thereby making it easier to do and hence more spontaneous. In the case of formal voting this is not difficult. The power of the computer allows votes that would take 5-10 minutes to carry out formally to be completed in seconds. In an experiment carried out by the author (Whitworth, 1996) each group voted 84 times over about 40 minutes without apparent strain, or anyone complaining about having to "vote" so many times. Subjects were happy to vote because that is how they found out what the rest of the group was doing.

In conclusion, the high demands of many-to-many situations require more than just a "rich" medium of interaction. Comparison with face-to-face meetings suggests that the critical defining feature of electronic meetings, as distinct from E-mail and bulletin boards, may be *their ability to deal with many-to-many interaction across an asynchronous transmission interface*. This is a more stringent definition that usually applied, where any sharing of low level resources across a network is considered to be "groupware" (Holtham, 1994). This can be done either by duplicating one-to-many communication, or by providing true many-to-many interaction. Such a view implies that the "voting tool", rather than being just one of the ways that GSS differs from other forms of electronic communication, may be the defining difference. It also suggests that the development of dynamic computer voting may be the key to development of group dynamics in the electronic environment.

Summary

The general conclusions of this paper are:

1. Communication settings, defined in terms of the properties of the communication transmission interface, differ on more dimensions than just media richness,
2. The key dimensions are suggested to be multiplexity, synchrony, linkage and transmission cost,
3. Research into the differences between communication settings will be clearer if it varies only one property of communication setting, but even so comparisons should recognise that different environments may evoke naturally different responses to the same task (eg swimming and walking),
4. Computer-mediated interaction offers not so much a new way of communicating as a more effective implementation of existing communication settings, a way that allows easier and hence more spontaneous interaction
5. The natural communication environment for computer-mediated groups may be asynchronous,
6. A single CMGSS may include several distinct communication settings (eg E-mail, bulletin board, and voting),
7. The defining feature of meetings or small discussion groups may be a task requirement for many-to-many communication (which can theoretically be carried out by one-to-one, one-to-many or many-to-many communication),
8. Many-to-many linkage provides a highly condensed form of communication, and may be what allows group members to contribute to and keep in touch with the group position in a dynamic group situations, such as a discussion,
9. Voting can be regarded as an act of many-to-many communication, and can be considerably speeded up in computer-mediated interaction,

If the above are correct, an asynchronous, many-to-many, symbolic text communication setting may provide a natural base for computer-mediated groups, one where the computer could provide the processing power to manage a many-to-many interaction which simulates the informal vote type process it is proposed occurs in dynamic, face-to-face group discussions.

References

Adrianson, L and Hjelmquist, E. 1991, Group processes in face-to-face and computer mediated communication. *Behaviour and Information Technology*, 10, 281-296.

Bowers, J. and Churcher, J. 1989, Local and global structuring ofcomputer-mediated communication: developing linguistic perspectives on CSCW. In Cosmos. *Office: Technology and People*, 4, 197-227.

Briggs, R.O. and Nunamaker, J.F. 1994, Getting a grip on groupware. In Lloyd, P., *Groupware in the 21st Century*, Ch 7, 61-72.

Burke, K., and Chidambaram, L. 1995, Developmental differences between distributed and face-to-face groups in electronically supported meeting environments:. an exploratory investigation, *Group Decision and Negotiation*, 4, 213-233.

Cass, K., Heintz, T.J. and Kaiser, K.M. 1991, Using a voice synchronous gdss in dispersed locations: A preliminary analysis of participant satisfaction. *Proceedings of the 24th Hawaii International Conference on System Sciences*, Vol III, 554-563.

Chafe, W. L. 1982, integration and involvement in speaking, writing and oral literature. In D. Tannen (Ed) *Spoken and Written Language*, Norwood, NJ:Ablex.

Cherry, C. 1978, *On Human Communications: A Review, a Survey and a Criticism* (3rd Ed). The MIT Press, Cambridge, MA.

Conklin J. and Begeman, M.L. 1988, gIBIS: A hypertext tool for exploratory policy discussion. *ACM Transactions on Office Information Systems*, 6(4), October, 303-331.

Cook, P., Ellis, C., Graf, M., Rein, G. and Smith, T. 1987, Project Nick: Meetings augmentation and analysis. *ACM Transactions on Office Information Systems,* 5(2), April, 132-146.

Daft, R. L., Lengel, R.H. and Trevino, L.K. 1987, Message equivocality, media selection, and manager performance: implications for information systems. *MIS Quarterly*, September, 354-366.

DeSanctis, G., Poole,M.S., Dickson, G.W. and Jackson, B.M. 1993, Interpretive analysis of team use of group technologies. *Journal of Organizational Computing*, 3(1), 1-29.

Dennis, A.R., Joey, F.G., Jessup, L.M., Nunamaker, J.F. Jr et al. 1988, Information technology to support electronic meetings. *MIS Quarterly*, 12(4), 591-624.

Dufner, D.K. and Hiltz, S.R. 1990, Distributed group support systems:Experimental design and pilot study. *Proceedings of the 23rd Hawaii International Conference on System Sciences*, III, 386-393.

Finholt, T. and Sproull, L.S. 1990, Electronic groups at work. *Organization Science*, 1(1), 41-64.

Gallupe, R.B. and McKeen, J. 1990, Enhancing computer-mediated communication. *Information and Management*, 18(1), January, 1-13.

George, J.F., Nunamaker, J.F. and Valacich, J.S. 1992, Electronic meeting systems as innovation. *Information and Management*, 22, 187-195.

Gutek, B. A. 1990, Work group structure and information technology: a structural contingency approach, in Galegher, J. et al (Eds). *Intellectual Teamwork: Social and Technical Foundations of Cooperative Work*, 63-78.

Hiltz, S.R. and Turoff, M. 1985, Structuring computer-mediated communication systems to avoid information overload. *Communications of the ACM*, 28(7), July, 680-689.

Hoffman, L.R. and Maier, N.R.F. 1961, Quality and acceptance of problem solutions by members of homogenous and heterogenous. *Journal of Abnormal and Social Psychology*, 62, 401-407.

Holtham, C. 1994, Groupware: Its past and future. In Lloyd, P., *Groupware in the 21st Century*, Ch 1, 3-14.

Jarvenpaa, S. L., Rao, V.S. and Huber, G. P. 1988, computer support for meetings of groups working on unstructured problems: a field experiment. *MIS Quarterly*, 12(4), December, 645-665.

Jessup, L. M., Tansik, D. and Laase, T. D. 1987, Group problem solving in an automated environment. *Proceedings of the Academy of Management 1987 Annual Meeting*, Anaheim, CA, August.

Kiesler, S., Siegel, J. and McGuire, T. 1984, Social psychological aspects of computer-mediated communication. *American Psychologist*, 39(10), October, 1123-1134.

Kraut, R., Galegher, J., Fish, R. and Chalfonte, B. 1992, task requirements and media choice in collaborative writing. *Human Computer Interaction*, 7, 375-407.

Lanham, R. A. 1993, *The electronic word: Democracy, technology and the arts.* University of Chicago Press, December.

Lea, M. 1991, Rationalist Assumptions in Cross-Media Comparisons of Computer-mediated communication. *Behaviour and Information Technology*, 10(2), 153-172.

Lee, A. S. 1994, Electronic mail as a medium for rich communication: an empirical investigation using hermeneutic interpretation. *MIS Quarterly*, June, 143-157.

Lim, F. J. and Benbasat, I. 1991, A communication-based framework for group interfaces in computer-supported collaboration. *Proceedings of the 24th Hawaii International Conference on System Sciences*, Vol III, 610-620.

Malone, T.W., Grant, K.R. Turbak,F.A., Brobst, S.A. and Cohen, M.D. 1987, Intelligent information sharing systems. *Communications of the ACM*, 30(5), 390-402.

Reid, F. J. M., Malinek, V., Stott, C.J.T. and Evans J.St.B.T. 1996, The messaging threshold in computer-mediated communication. *Ergonomics*, 39(8), 1017-1037.

Siegel, J., Dubrovsky, V., Kiesler, S., and McGuire, T. W. 1986, Group processes in computer mediated communication. *Organisational Behaviour and Human Decision Processes*, 37, 157-187.

Sproull, L. and Kiesler, S. 1986, Reducing social context cues: electronic mail in organizational communication. *Management Science*, 32(11), 1492-1512.

Suh, K. S. 1996, Effects of communication media on intellective and negotiation task performance. *Proceedings of the 17th International Conference on Information Systems*, December, 99-111.

Watson, R. T., DeSanctis, G. and Poole, M. S. 1988, Using a GDSS to facilitate group consensus: some intended and unintended consequences. *MIS Quarterly*, 12(3), September, 463-478.

Watson, R. T., Bostrom, R. P. and Dennis, A. R. 1994, Fragmentation to integration. In Lloyd, P., *Groupware in the 21st Century*, Ch 4, 29-39.

Weeks, G. and Chapanis, A. 1976, Cooperative versus conflictive problem solving in three telecommunications modes. *Perceptual and Motor Skills*, 42, 897-917.

Whitworth, B. 1996, Using normative influence to generate agreement in computer-mediated groups operating across lean networks. *The 1996 Information Systems Conference of New Zealand, Doctoral Consortium*, Massey University.

Winograd, T. and Flores, F. 1986, *Understanding Computers and Cognition: A New Foundation for Design.* Norwood, N.J.: Ablex Pub. Corp..

Zigurs, I., Poole, M. S. and DeSanctis, G. L. 1988, a study of influence in computer-mediated group decision making. *MIS Quarterly*, December, 625-644.