Towards a Metaphor-Driven Information Systems Design Process

Neil McBride
School of Computing
De Montfort University
Leicester
United Kingdom
LE1 9BH
Email: nkm@dmu.ac.uk

Abstract

This paper describes a methodology for using metaphors derived from a natural science discipline to generate ideas for solving design problems within information systems development. The method involves the evaluation of the design problem to identify characteristics that might suit it for a metaphor-driven approach, the selection of a source domain from which concepts will be derived, the searching of that source domain for ideas that resonate with the target domain, the generation of the new ideas or constructs for the information system design problem and the evaluation of those new constructs. The method is tested using a design problem involving the search for new ways of representing data in data models as alternatives to relational and object-oriented data models. Quantum theory is used as a source domain. A wide sweep of concepts within quantum theory is conducted, and a series of ideas concerning data modelling is generated. Four design themes are identified: the importance of identity and relationship, the importance of networks, information entanglement and observer effect. From this exercise, the philosophy, structure, interface and processes of a alternative data model are briefly describe. The paper supports the concept of software creativity and danger of traditional engineering approaches to designing information systems missing out of innovative ideas is highlighted.

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1. Introduction

Metaphors play an important role in the design of any artefact. In order to design we take ideas, artefacts and concepts from our experience and apply them to new problems. Metaphors act as lenses to enable the problem solver to develop different interpretations of a problem. They act as catalysts for generating solutions and filters for evaluating solutions. They also have a role in information system design in making the unfamiliar familiar. Hence metaphors such as desktop, house, shop are used in developing information system to reduce the unfamiliarity of the technology.

The use of metaphors is a key element of information system design and hence should be a subject of design science research in information systems. Metaphors are critically important in the design of interfaces. The selection of the metaphor drives the design and development of the system. Under the interface, the construction of the data structures and processes may be driven by metaphors. For example, in extreme programming, the design of the information system processes is driven by the overall metaphor for the project which is selected at the start of the project.

Metaphors may determine the underlying architecture of a system and the mode of interaction. The turtle metaphor characterises Logo and Starlogo and defines the nature of interaction with the system. In other systems a dashboard gives rise to the nature of the system and its interaction with users. These metaphors create familiarity with the computer system by linking the interface and interaction with the computer with familiar or everyday concepts.

Metaphors will not only influence artefacts and instantiations of artefacts, but also the three others output of design science research, constructs, methods and models (Hevner et al, 2004). Genes and genetic processes provided metaphors for the basis of genetic algorithms and genetic programming. The autonomic nervous system has provided metaphors for the development of self repairing IT infrastructures and the immune system is providing metaphors for more adaptable IT security.

Metaphors also provide the driving force for the methods of information systems development. The building construction metaphor still dominates system development (Avison 2001), although other metaphors such a filmmaking or jazz improvisation may be more suitable (McBride, 2003). Metaphors are key to organisational life and through influencing business processes also influence systems development process and the link between developers and other organisational members (Kendall and Kendall, 1993).

1.1 'Metaphor' in Information Systems Research

The study of metaphor in information systems research has, to date, focussed on two strands. Firstly, there is the use of metaphors in human-computer interfaces. Metaphors are very important in usability engineering, where user interface metaphors must be defined and tested (Rosson and Carroll, 2002; Travis, 2003). Usability engineers's interests tend to focus around the use of common and familiar metaphors such as hypertext, index card, desk top and visual metaphors which imitate familiar ideas such as buildings, shop fronts and maps. This use of metaphors is important in e-commerce where familiarity and the instant recognition of how a website operates are important to obtain and retain customers. Studies have been done on how human computer interface metaphors affect computer system users (see Hamilton (2000)). These types of studies are interested in the effect of existing metaphors, represented in computer systems, on individuals and organisations, not on generating new metaphors for problem solving.

The second strand of study draws on the study of metaphors in organisational science where the use of metaphors in organisations and their effect on organisational dynamics and the story of the organisation is examined. The study of metaphors in organisational studies has been extended in information systems to an investigation of the perceived view of systems developers and the IT department in the organisation. Hirschheim and Newman (1991) explored the metaphor of the system developer as high priest of unknown technologies. Kaarst-Brown and Robey (1999) divided up IT cultures into the dragon on a pile of gold, the caged dragon, the pet dragon, and the team dragon. Here the researchers are developing metaphors to classify IT culture much in the same way as Handy (1978) classified management cultures using the metaphor of Greek gods. Kendall and Kendall (1993) looked at the metaphors applied to systems development by user groups. Nine metaphors, including game, journey, war, and organism are identified from user focus groups and applied to systems development methodologies.

Hence the work on metaphors in information systems concentrates on identifying metaphors which are already present in the organisation and may be affecting the design or acceptance of an information system, or using metaphors as a tool for highlighting the role of information systems and information systems development in organisations and developing some kind of classification. The work described in this paper is not part of that strand of information systems. Rather it is a contribution to the development of creativity in information systems design and software development.

1.2 Software Creativity

Traditionally, information systems design has been seen as an engineering discipline. Requirements engineering involved structured, repeatable and systematic techniques (Dallman et al, 2005). Approaches such as UML and SSADM provide a set of analytical techniques for understanding business processes and expressing them in terms of classes and methods or data and processes which can be represented in a computer system. The analysis of the business processes becomes a reductionist design process in which an optimal solution is derived logically by breaking down the processes sufficiently that individual steps which involve interaction with a computer can be recognised. Such a process virtually excludes the need for innovative thinking. The solution can be expressed as a model answer without room for originality or variation.

One problem with this approach is that the traditional requirements engineering approach does not permit many alterative, competing and equally valid solutions. The software engineer is inclined to think that there is one right solution to be discovered through the application of analysis tools. Neither does the engineering approach encourage the challenging of the business processes or the consideration of alterative ways of processing. There is a need even in the traditional design of computer systems for business processes to encourage divergent thinking, the challenging of the status quo and the seeking of alternative pathways. This requires the application of creativity.

Wong and Paynter (2001) point out that the need to build adaptive and flexible software, which may itself give competitive advantage, requires the application of creative thinking. I would add that the nature of the design problems faced in companies are of such an increasing complexity and variety that creative thinking is mandatory. Creativity, which involves the generation of a wide variety of ideas, thinking in divergent ways and challenging current ideas, needs to be promoted in the application of design science.

This paper adds to the literature on software creativity. It expands on the work of Wong and Paynter (2001) by taking a creativity technique and refining and formalising its use within a design science context. Wong and Paynter (2001) reviewed the creativity techniques of brainstorming, action words, mindmapping, analogy and excursion. Before the work of Couger (1989, 1996) little attention had been given to the importance of creativity in information system design. Obtaining creativity within an organisation involves promoting the right managerial environment in which there is motivation to be creative by addressing person, process, product and press (Couger, 1997) and training developers in the use of creativity tools of which the technique use in this study is an example.

1.3 Identifying Metaphors

The selection of the metaphor is a creative process whose consequences will be significant for the subsequent development of the system and the system's outcome in the organisation. The system analysis effort has gone into recognising existing metaphors within organisations and organisational processes and using those metaphors as a basis for designing information system artefacts.

There are a number of problems with this approach which give rise to important issues for design research in information systems. Although metaphors such as game, machine, journey, jungle might be identified within organisations and their system development processes, research questions need to be asked about where these ,metaphors originated. In terms of interfaces, the origin of metaphors needs to be understood. For example, Markus et al (2002) use a Ferris wheel as a metaphor for the interface of a system to support emergent knowledge processes, but give no indication of how it originated. While the Ferris wheel metaphor is subsequently shown through evaluation to be an effective metaphor in this system, it could have turned out otherwise. Selection of the metaphor might have sent the system down a wrong route. Metaphors may be limiting in design terms since the selection of a metaphor, primarily on the basis of its familiarity to the information system's audience may fix the design strategy for the system and exclude any alternatives. Once, for example, the metaphor of a desktop is selected, this will drive the design to the exclusion of any other scenarios.

If the metaphors applied to the information system and its development are drawn from the host organisation, then the origin of those metaphors needs to be explored. It may be that using a particular metaphor or metaphors in the development of a information system will increase the alignment of that system with the business needs and result in a more acceptable and usable system. However the metaphors used in the organisation may not necessarily be wholly beneficial to the organisation. Some metaphors may lock the organisation into a particular cultural view which is deleterious to the development of the organisation. The adoption of existing metaphors may only serve to fix existing flawed thinking or inflexible processes into the artefact such that the artefact serves to reduce the possibility of organisational development rather than enable organisational evolution and improvement.

Hence, in designing IT artefacts for organisations, any underlying metaphors which may be taken-for-grant or so woven into the fabric of organisational thinking, should be teased out and evaluated. But further than a reactive process of capturing and assessing existing metaphors, a proactive search for alternative metaphors should ensue.

The power of metaphors in design science to apply the familiar to the unfamiliar and hence create acceptance or ease of use is only one facet of the use of metaphors. Often the solution of a problem in the design of information systems requires that we break away from the familiar and take a new unfamiliar direction in order to create new design paradigms and alternative tracks of design thought. Here the point of applying metaphors is to apply the unfamiliar and unrelated to a problem to break through existing approaches and create new alternatives.

Within the process of design science, where a novel or intractable problem is being examined which requires a new understanding of users, of system requirements and of the processes or methods by which solutions can be specified and artefacts constructed (Markus, 2002), the construction of metaphors to enable novel solutions may be an important element of the design process. Such an exercise using metaphors to generate design for IT artefacts may require a structured design process in which metaphors are drawn from domains outside the problem area, applied to the problem area to generate design solutions which are then evaluated. Such a process would enable the origin of the metaphors to be traced and careful selection of metaphors from a variety of sources to be considered. Furthermore, a conscientious effort to generate solutions from metaphors can involve the generation of metaphor from areas of academic study and from areas of business, organisational or general life experience which are remote from the problem and may generate new ways of looking at the problem.

Computer scientists have begun to use such approaches to extend the domain of problems considered by the discipline and to pursue new avenues of research. As approaches based on classical computational mathematics and Von Neumann architecture reach their limits, computer scientists have begun to look outside the classical boundaries of the discipline for new approaches and for metaphors that might generate new solutions and drive the discipline into new avenues of research. A particular emphasis on drawing on biological metaphors to generate new computer and applications has emerged. An understanding or classification of the limits of computers and computer programs has been contrasted with the characteristics of biological systems and led to a consideration of alternative approaches to generate software artefacts which have new properties and to overcome the limitations of current computer architectures.

This exploratory paper considers whether a more formal approach could be used to generate novel designs for IT artefacts to provide solutions to novel problems. The next section describes an outline strategy for applying metaphors to a novel design problem. The approach is then applied to a problem area. The final section critically evaluates the approach and suggests ways forward for further research. The approach provides a structured approach to the search process in design in which a domain space of ideas and concepts which is remote from the problem space is searched for solutions. In other words, the search process in design science is envisaged as a search of one problem domain for solutions, structures, theories, and concepts that might jump across from the source domain to the target domain and provide alterative solutions in the source problem domain which do not necessarily follow the usual ways of thinking.

2. Development of a metaphor-driven design process for IT artefacts

In order to carry out a metaphor-driven design process we would need to understand the problem domain and then use an unrelated domain of knowledge to generate ideas which might apply within the problem domain. Some evaluation of the utility of the generated concepts or solutions would then be required.

A series of steps could be proposed which are described further below.

2.1 Evaluate the design problem

An understanding of the design problem must be established. Do the problem characteristics suggest that a metaphor-driven design process would be appropriate? If a number of candidate architectures already exist then there may be nothing to gain from searching for alternative architectures. For example, the design of an Internet site for a new retail business may be well-served by the use of a shopping metaphor. The shopping metaphor can then be rapidly adopted and used to design the new system. However for other problems existing metaphors and design architectures may be limiting. If there are clear limitations in current approaches to the design problem a metaphor-driven approach might be suggested. Current limits to commercial information systems in terms of inflexibility and inability to adapt may suggest that a search for alternative design approaches may be fruitful. Furthermore for some design problems, such as those met in emergent knowledge systems, existing approaches may not yield solutions.

2.2 Select a source domain

If the design problem lends itself to a metaphor-driven approach, a source domain from which ideas can be generated should be selected. The selection of the source domain is a critical decision since it will exert an influence over the type of solutions offered in the target (problem) domain. The aim in selecting the source domain is not to provide familiar ideas to create understanding of target domain concepts, but to provide unfamiliar ideas which will generate new ways of thinking about the design problem. Hence one characteristics of the source domain is that is should be unfamiliar and conceptually distant from the target domain. For example, using a computational domain to generate ideas for a computer system is unlikely to produce new solutions. However, the source domain should provide a rich set of concepts capable of generating a diversity of design alternatives. It should encompass philosophies or ways of thinking which are foreign to the source domain. This suggests that an entire academic discipline might be suitable. The rich set of concepts should be accompanied by an ability to accommodate a multiple and even conflicting interpretations of concepts or phenomena. In addition, while being unfamiliar the source domain should offer some parallels to the target discipline. In the case study described below both the source, quantum theory, and the target, database design, involve information structures. Their parallel concerns with structuring material offers a bridge for transferring ideas. In designing information systems that are adaptable to their environment, the properties of biological domains which have solved many of the problems of adapting to changing environments offers a good source of metaphors. In developing learning systems, design problems may find solutions in a source domain of cognitive psychology or child development. However, the temptation to select a source domain which is too obviously similar might be worth resisting.

If the metaphor aligns too well it may reinforce well-confirmed theories instead of challenging them. It is also important that the metaphor does not become a straightjacket in which we are trying to force every element of the home discipline to fit the metaphor. Therefore there needs to be some tension between the metaphor and the area of study it is to enlighten. The metaphor needs to be comprehensible to the user. It must be possible to naturally understand the concepts that the metaphor brings to the investigation, or to understand their basis by reference to standard textbooks. It should not be necessary to become an expert in the field which is providing the metaphors. It should be acceptable to turn to popular science literature and introductory television programs, for example, to gain a basic knowledge of the metaphorical area.

2.3 Search the source domain for ideas and design structures and transfer to the source domain

The third possible step in metaphor-driven design will involve a search of the source domain for ideas, concepts, processes, and design structures which might transfer to the target domain and a consideration of their form or influence on the target domain. This is an iterative process. It can involve both looking at concepts in the source domain and asking what would this look like in the target domain, and looking at aspects of the design problem and searching the source domain for possible ideas for solutions. This step is a creative process involving liberal interpretation of the source concepts and the target design problem. The target domain problem may be expressed in terms of limitations of current information systems, intractable requirements or currently available solutions for which competitive or substitute ideas are required.

This phase is primarily a search phase, in which the foreign domain space is searched for solutions.

There are several dangers in this step. Firstly the source of metaphors may not be sufficiently understood. This may not matter if the wrong understanding still generates useful metaphors. The purpose of the exercise is to generate solutions to the design problem, not to become experts in the source domain. However if the lack of understanding of the domain space reduces the search space because whole areas of understanding are absent, that is a more serious problem. The second problem arises if too literal interpretation of the source concepts is made in transferring to the target domain. A metaphor should be applicable without asserting a comparison. Exact blow-for-blow comparisons between the source and target domains are not required and may be limiting. Liberal interpretation of source concepts and wide application in the target domain should be sought. A final danger, which became apparent in the case study concerns the risk that preconceptions and current understanding by the designer will limit the use of source metaphors. Free thinking may be limited by the designer repertoire of solutions. In my exploration of alternative database models, my immersion in the relational model made it difficult to think outside extensions to the relational model or data models influenced by the relational model in drawing concepts from the source domain.

2.4 Generate target domain constructs

Once ideas have crossed over from the source domain to the target domain in the form of metaphors, new domain constructs can be created. These may be of a wide variety of types including design processes, design models or structures for instantiations of IT artefacts. These may involve building a system based on the metaphors or describing the new model. What results is some artefact which can then be evaluated.

2.5 Evaluate domain constructs

A key element in design science and hence in any form of metaphor driven design must be an evaluation of the artefacts. A wide variety of approaches to evaluation may be considered. A key consideration should be utility. Does the construct solve the design problem? Is it useful to the client? Does it meet requirements? Is it more efficient and effective than existing solutions or is it just convoluted and inefficient?

Formal evaluation criteria should be generated for the metaphor generated artefacts and the artefact measure against them.

3. Testing the Metaphor-Driven Approach

3.1 The Nature of the Problem

A metaphor-driven approach was used to explore a difficult and fuzzy problem which was outside the scope of typical design approaches. The development of new data modelling approaches is an area of design research that should be addressed. As outlined below, the limits of current data modelling approaches are becoming more apparent as the demands of different for a greater variety of information increases.

With the demise of hierarchical and network data models, commercial data modelling is dominated by the relational model. The representation of data in flat tables limits both the flexibility of the data model to evolve and the ability to represent complex data structures where networks of connections may be required. Commercial applications may be forced to represent data in flat tables which do not reflect real-life concepts. Also, the relational data model is more suited to a methodology where the design of the data structure is fixed early on and the completed data model used for development. Such an approach does not support rapid application development, evolvability of the design nor individuality of data models. Neither does it support more graphic representations of data at the user interface nor networks of connections. Hence there is a need for an alterative paradigm of data design which aligns better with commercial system and knowledge management requirements, providing flexibility, adaptability and evolvability of data structures and aligns better with the requirements of graphical interfaces. This is a design problem whose characteristics suggest that an exploration of metaphors might be fruitful

It is a fuzzy area which the problem is not clearly defined and can only be expressed as a quite general need. It requires an alternative design paradigm, a new way of thinking which might be catalysed by generating ideas using metaphors. Exploring traditional computational or mathematical lines of thought may not yield the alternative approach required; although once some ideas for alternative data models have been generated, some computational rigor would be preferable.

3.2 Selection of a source domain

Since the problem deals with elemental, atomic data items and the low-level structuring of data model, the use of biological metaphors, which is the most common source of ideas in computer science, was not the first choice of domain. A more fundamental discipline was required which might yield parallel metaphors and still retain a large diversity of concepts. Quantum theory offered a view of primitive particles analogous to basic data items and a rich variety of concepts, some counter-intuitive and challenging usual ways of thinking. Furthermore, the set of concepts in quantum theory is wide-ranging, containing conflicts and alternative theories.

While some quantum concepts are easily understood, others are difficult to comprehend. Core concepts can be understood from popular literature and their application to data models explored. The study of quantum theory can start with an understanding of sub-atomic structure and move on to an understanding of interactions between them. A basic set of concepts can be extracted from the subject area and their implications for the design of data models examined.

3.3 Searching the source domain and applying to the target domain

In this step, the basic concepts from quantum theory were identified and summarised in a form that would enable their influence on the target domain to be considered. In studying quantum theory, the aim has been to gain some understanding of quantum concepts without being drawn into the underlying mathematics. Popular guides for beginners have been used (See Al-Khalili, 2003; Polkinghorne, 2002) also some insightful sources on the Internet have been referred to (See Bub, 2001; NSF, 1999).

3.3.1 Quantum Concepts

The following provides a broad overview of the major concepts in quantum theory. At this early stage in the use of metaphors, the primary goal is to generate a diverse set of ideas in information management by harnessing the maximum range of quantum mechanics concepts. The temptation to settle on one particular concept should be avoided. At a later stage, should one particular concept appear particularly fruitful, challenging or relevant it could be focussed on using a more convergent approach. Figure 1 describes a map of the selected quantum concepts and relationships between the concepts.

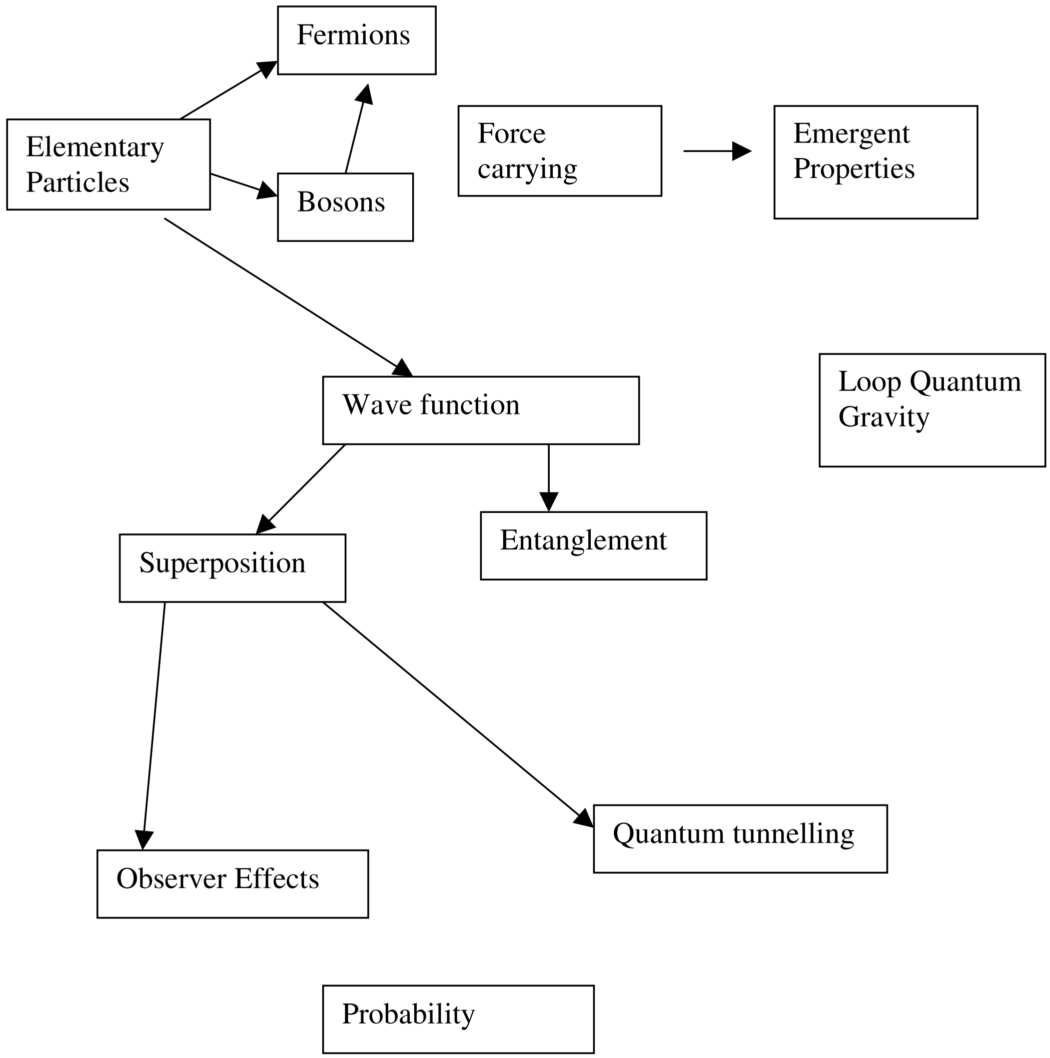

Figure 1. Map of Quantum Theory Concepts

3.3.1.1. Structure of Matter

Physics divides the elementary particles which make up matter into fermions, which make up matter and the bosons, which are force carrying particles. Fermions divide into quarks, which in various combinations make up particles such as protons and neutrons, and leptons of which electrons and neutrinos are varieties. Bosons include photons (the light particles) and gluons which cement together elementary particles in atoms. Atoms are constructed from interacting elementary fermions, held together by force carrying bosons. These structures then build up in a hierarchical way to produce larger compounds and chemical structures.

3.3.1.2 Superposition

Atomic particles, like light, behave as both particles and waves. When atoms are shot though the slits they behave as waves, forming interference patterns, although each mark on the second screen will be the result of one particle hitting the screen. If individual atoms are fired through the slits, one at a time, although each makes a single mark on the second screen, an interference pattern builds up. A particle is fired from a gun, the particle registers as a distinct dot on the screen, but in between it shows wave-like properties. In order to get the interference pattern, the atom must be going through both slits at once. In addition, if we put a detector between the slits and the second screen, the interference pattern is lost

3.3.1.3 Entanglement

Two particles, produced by a common source, travelling in opposite directions, remain connected or entangled such that changes in the state of one particle, for example the polarity of a photon are immediately duplicated in the other, and measuring one particle's state also tells us what the state of the other particle is. Their wave-functions can be described as entangled. This entanglement does not result from classical communication since the distance cannot be classically traversed to share any information. This property leads physicists to describe the phenomenon as weird or spooky. However, it is a real phenomenon which has been demonstrated, photons and larger particle have been entangled over very short microscopic distances.

Quantum entanglement creates new correlations. Large amounts of information are then embedded within the entanglements and relationships. A book expressed in classical bits can be read one page at a time. In a quantum book, nearly all of the information resides in the correlations among the pages (NSF,1999)

3.3.1.4 Observer Effect

Observation has an effect on the quantum system. An atom remains in superposition until it is observed. Once observed it appears to have gone through one or other of the slits and the interference patterns disappear.

In classical mechanics, the state of a system is represented by a list of the systems properties which define the state of the system. In quantum mechanics, the state of the system is understood as a catalogue of what an observer has done to the system and what has been observed. State is then expressed in probabilities of outcomes from future observation of the system.

3.3.1.5 Schrödinger's Equation

Such characteristics as the wave behaviours of atom and uncertainty as to the atoms position are encapsulated in the atom's wave function as described in Schrödinger's equation. Every particle has a wave. Quantum physics considers that the atom or subatomic particle is its wave function.

Schrödinger's equation, defining the wave function, involves the mass of the particle, a description of how the wave function changes from one place to another, a description of the forces acting on the particle and a description of how the wave function changes over time.

3.3.1.6 Quantum Tunnelling

Quantum tunnelling concerns a particle traversing a barrier. To get over a barrier the particle must have enough energy to climb to the top of the barrier and down the other side. In quantum mechanics, there is a probability that a particle can jump across a barrier by borrowing energy from its surroundings and giving back the energy within a very small amount of time set by the uncertainty principle. Quantum tunnelling is the basis of alpha particles escaping from atoms and a wide range of biochemical processes.

3.3.1.7 Loop Quantum Gravity

Quantum theory explains the make up of matter at the smallest possible level and describes its composition as discrete bits. There is, however, also a need to investigate whether space and time, as explored in the theory of relativity, are also made up of discrete pieces. Mathematical models, which combine the theory of relativity and quantum theory, suggest that, at the scale of the Plank length (10-33 centimetres), space, the geometry of space can be described in discrete units (Smolin, 2004). Volume and area comes in discrete packages. Space can then be described as a network of nodes and lines, described by graphs. Graphs can be connected in strange ways, describing curves and distortions in space which, according to the theory of relativity, give rise to gravity; and hence combining relativity with quantum theory. The networks of space are called spin networks. Particles move between nodes in discrete steps. Nodes in the spin network are then labelled to show the presence of a particle.

The geometry of spin networks then changes with time as the bends and curves of space change as matter moves. The graphs in loop quantum gravity change through a succession of moves. Time is then represented as another dimension. In the spin networks, lines become two dimensional surfaces and nodes (represented by points in spin networks) become lines. A slice across such a spin foam is a spin network. Time is also discrete not continuous. Space and time can only be defined in terms of the relationships between different events. Distance between two points only exists because the two points exist.

The search space provided by quantum theory is wide-ranging. Concepts concerning structure provide a simple link with data management. However, more complex ideas such as superposition, entanglement and quantum tunnelling have less immediately obvious application to data management.

3.3.2 Database Concepts

The following identifies the ideas suggested when database concepts are generated from quantum concepts. At this stage the concepts may be quite sketchy. Further work will be needed to refine the concepts. However, I focus here on the generation of concepts since divergence and the generation of ideas is the main challenge in software creativity which this paper is addressing. Figure 2 maps the data modelling concepts suggested by the quantum metaphor and Table 1 shows the relationship between the quantum concepts and the database concepts.

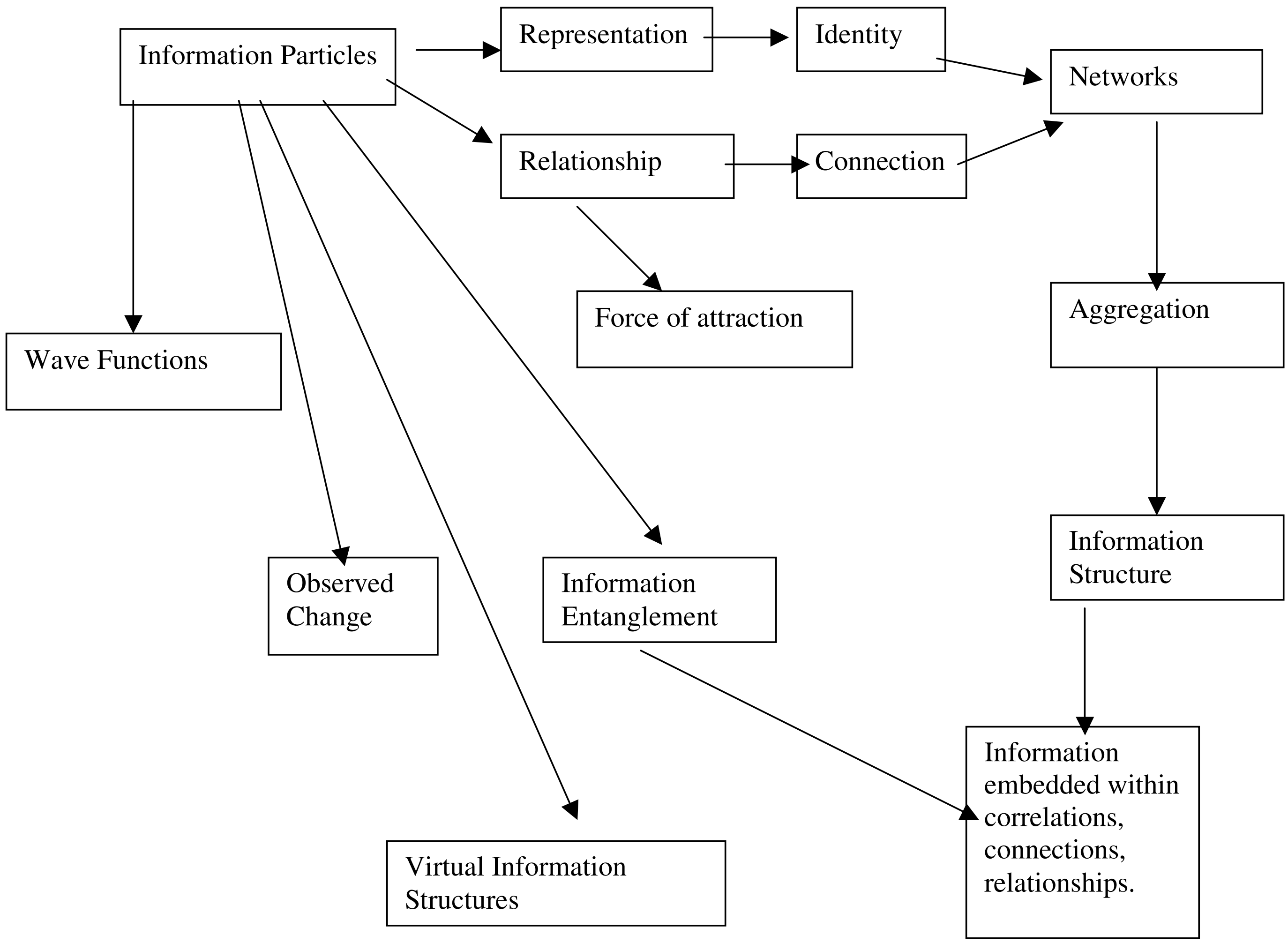

Figure 2. Map of Data Management Concepts

Two key functions of a database are establishing identity and producing relationship.

Data systems should be built up from networks of connected information particles.

Complex information structures are built up from networks of simpler structures and hence form networks of elementary particles held together by relationships which create connectivity. Complex structures are hence aggregates of simpler structures.

Relationship particles define the force of attraction between two information particles. That force may be variable and may have an element of uncertainty associated with it.

Consider non-local information particles, defined by their wave functions, which can be at any or multiple locations in a network and only become localised and physicalised when we request them and view them. Such a concept would suggest the information particle could be spread over the network and may not be lost in the event of the failure of parts of the network.

An alternative application of the superposition metaphor might involve having one information source or particle which may be split several ways according to the interpretation placed on it. The information particle may be displayed in different places with different meanings. Superposition would provide a model for recording multiple meanings and variations in the same piece of data.

Information entanglement involves the linking of related information particles, created at the same time and place, but now remote from each other in a network. Changes in one information particle should be appropriately reflected in the other entangled particle.

Information resides in connections even more that attributes of the data, tables or classes. Connectedness is a concept that needs much greater exploration in data management.

Relationships and connections should dynamically vary. There should be no absolute certainty that a customer connects with a particular address or a particular product preference.

More consideration should be given to actions done on data and the effect of these actions.

Observer phenomena suggest an integral link between the observer and what is observed. New database forms should have integration and inseparability between the data storage and the data display.

Elementary information particles are made up of common measurable or structures. There are no such things as attributes, only common properties which completely describe the information particles behaviour.

Attributes relating to an object are built up from elementary information particles glued together by relationship particles. Each information or relationship particle must have exactly the type of physical numbers associated with it, drawn from it wave function.

Information structures are built up from networks of connected information and relationship particles. Information particles from other sources in the network may arrive and dislodge particles in the information structure, replacing them or resulting in an altered information structure.

Information structures might express some autonomy by being able to draw on other information particles and networks to fulfil requests.
Information should be represented as networks, where nodes represented information identities and lines represent relationships.

Information structure may sit on a physical or logical substrate (the spacetime) itself consisting of nodes and lines. The regular structure of the underlying physical or logical (spin) network provides scaffolding for structuring information networks.

Information networks will take on particular geometries or structures which may be as complex as are required to represent the information structure or aggregate.

These information structures – analogous of spin networks – are dynamic, not static. They change as information particles change according to discrete moves.

Changes may add information particles, but are more likely to alter information network structures through changes in connectivity.

Networks of information particles, in information aggregates, will have their own distinctive shapes which can be analysed using graph theory and represented visually in geometric graph structures.

Quantum Concept	Database Concept
Structure of Matter Elementary particles Force carrying particles	**Identity and relationship** Data systems are networks of connected information particles. Relationship particles Information particles
Superposition Atomic particles behave as both particles and waves. Slit experiment	**Multiple meanings** Information particles spread over the network Information split several ways according to the interpretation
Entanglement Changes in the state of one particle are duplicated in the other. Information resides in the correlations among the pages.	**Information entanglement** Information resides in connections
Observer Effect Observation has an effect on the quantum system. State of the system is a catalogue of what an observer has done to the system Expressed in probabilities of outcomes.	**Relationships and connections dynamically vary** New database forms have integration and inseparability between the data storage and the data display.
Schrödinger's Equation Mass of the particle, Description of how the wave function changes in place and over time. Forces acting on the particle.	**Common measurables** Elementary information particles are made up of common measurables or structures.
Quantum Tunnelling Particles traversing barriers. Particles can jump across a barrier by borrowing energy from its surroundings Uncertainty principle.	**Information** structures express autonomy. Drawing on other information particles and networks to fulfil requests.
Loop Quantum Gravity Network of nodes and lines, described by graphs. Spin networks. Time is discrete.	**Information Networks** Scaffolding for structuring information networks.

Table 1. Quantum Concepts and Ideas in Data Management

3.3.3. Design Themes

It quickly became apparent that the use of metaphors was not necessarily going to generate concrete design proposals but may suggest design themes, strategies or policies. Four design themes are described below.

3.3.3.1 The Importance of Identity and Relationship

Studying concepts from quantum mechanics pointed to identity and relationship as the basis for structuring data. The identity should be describable in common terms which can distinguish it from all other material elements whether related or not. Equivalent descriptions should be possible for any material element using the common descriptors in the same way as any particle can be defined by its wave function. Descriptors analogous to the mass, time, space and change descriptive components of Schrodinger's equation should be definable for any identity element stored in a database

The standard model of the atom in physics suggests that relationships and the attracting force of relationships are of key importance in building atoms and molecules. Information and meaning resides as much in the relationships between data elements as the data elements themselves. In considering the quantum metaphor, it seems that relationship should be given equal status with identity. Hence a data model should have separate physical entities representing and recording relationship. Such relationship particles would bind together identity particles to form data networks representing any size of material element.

3.3.3.2 The Importance of networks.

Since more information may reside in the relationships and correlation between particles as in the particles themselves, network structures of identity and relationship particles form to provide a complete information profile for a material element. Complex structures are built up from aggregations of individual particles held together by forces. Properties which fully describe the material element or object emerge from the interaction of these particles. Information is then defined in a network of connections. Meaning may be encoded in links through the network and patterns of change that may be propagated in the network. Networks can be dynamically changed through changing connections.

3.3.3.3 Information Entanglement.

Ways of connecting the fate of information items based on shared meaning should be explored. Business changes should affect other related data depending on the nature of databases. Information entanglement is concerned with connecting data through meaning across distributed networks. Data may be linked by association, by origin, by meaning. Hence information entanglement is about linking the outcome and fate of data.

3.3.3.4 Observer Effect.

Information in a database records what the observer or user has seen and interpreted from the 'real world'. The information is selective and affected by the user's motivation and view of the world. Indeed, the real meaning of the data is difficult to find without the presence of an involved user to interpret.

In Quantum physics the outcomes of certain experiments appeared to depend on how, when and from where the particles were observed. Superposition is disrupted by observation. Similarly, recorded attributes of a particle such as an electron depend on when and where it is observed. The state of a quantum system is expressed in terms of what an observer does to the system and what the outcome of that action is Perhaps the focus on describing the properties of a data element including its attributes could be shifted towards a focus on charting system change and looking at actions done to data elements and the outcome of those actions

3.4 Generating target domain constructs

The use of quantum metaphors has produced a number of ideas, concepts and constructs as mapped in Figure 2. It has given us some new design principles as well as ideas for functions which could extend a data model. However, some of these ideas create new problems. What, for example, might be envisaged by information entanglement? And how might that be implemented? Is there utility in connecting remote data on the basis of an entanglement that results in changes in one data item being reflected in another?

The use of metaphors does not reduce the information system designer's task because the metaphor driven approach does not advocate a mechanical one-to-one translation of ideas and artefacts from one discipline to another. Rather it involves triggering off new ideas in the designer's mind and challenging fixed assumptions about the nature of the design problem and possible solutions. Hence the output of this particular exercise is a philosophy for a 'quantum database model', outlined in table 2 and some specific requirements which provide a start for implementation.

Philosophy	Minimalist structure Just information particles and relationship particles No database design Database evolves Start with initial ideas Create particles, clone particles. Importance of interface structure Database structure and content emerge bottom up. There is only a growing and developing network structure.
Structure	Detailed structure of the fundamental particles.
Interface	Design of interface for creating and cloning information particles.
Process	The process, using the interface by which particles and network of particles are created.

Table 2 Philosophy of Quantum Database Model

The design requirements that might lead to a more detailed model which could then be converted to an IT artefact are described below.

3.4.1 Structure of a Quantum Database

A database structure inspired by quantum mechanics should use an absolute minimalist model to start. It should be based on a minimal set of fundamental information particles and should be structured as a dynamic, flexible network. The database and the interface structure it is observed through should be integrated

3.4.2 Structure

A quantum database may be envisaged with two fundamental information particles:

Identity particle. Identifies a particular object or concept. Contains identifier, mass description, time description, space description and change description (analogous to the quantum particle's wave function) May also contain a semantic description.

Relationship particle. Describes a link between identity particles and provides the linking force. Contains identity particle identifiers, its own identifier, space description, time description, change description, strength indicator and power/ direction indicator.

The definition of a relationship particle flags the importance of relationships as the glue that creates networks of information and the aggregation of parts into wholes. The basing of information content of the particles on the elements of the wave function may be sufficient to cover user information requirements. However, this would need to be tested in implementation.

3.4.3 Interface

The interface must support the creating and cloning of identity and relationship particles. It should enable the building up of networks of related particles to form large, dynamic network information structures. It will contain the mathematical engine to drive the navigation through data pathways. It should also be visually-based. Additional meaning can be defined in the interface for the specific application.

3.4.5 Process

The process of building a quantum database would be a bottom-up process. Assemblies represented by pathways. Assemble from parts graphically.

Parts can be classified in (variant) groups by pathways of relationship particles. Construction and representation of the assembly or variant group is done 'on the fly' by the interface system.

Define part as an identity particle. Define mass, space, time, change

Define relationship particles to create assemblies.

3.5 Evaluating Domain Constructs

Evaluation, as a critical part of the design process can work at several levels. Evaluation of the utility of the metaphors, of the concepts, constructs and design policies, and of the resulting model or IT artefact are all important. The utility of the metaphors and the source of metaphors may be judged by the richness and relevance of the metaphors to the target domain. Also, the variety of target ideas that could be generated should be considered. In the case, it can be suggested that, subjectively, quantum theory was a good source of ideas for data models. However, a more objective evaluation depending on defined criteria and metrics will be needed to determine this. The usefulness of each idea, concept, construct or design policy in solving the design problem will then need to be considered. In this case study ideas derived from the structure of matter may be more useful than ideas derived from the concept of entanglement. However, such a judgement may be made on the basis of the immediate applicability of the idea. Since entanglement is non-intuitive and remote from the discipline of data management, the exploration of the derived concept of information entanglement may be more fruitful in the long term since it is more challenging to data modelling that the more straightforward structural models. Finally, the utility of the resulting model or artefact needs to be evaluated. This evaluation process is outside the scope of this paper and would involve a number of steps in developing criteria, and in benchmarking the solution against existing data models.

4. Conclusions

A structured approach to the application of metaphors in developing design solutions to non-standard information systems developments may be a valuable activity for the designer. The use of metaphors to trigger off new ideas and create information systems which adopt different paradigms or approaches is just as valid as using familiar metaphors to help in user acceptance of information system designs. Its use to breakout of current design approaches and to highlight the assumptions that are made in the information systems design process.

This paper has outlined a number of steps needed in a metaphor-driven design processes and tried them out on a creative but intractable problem concerning approaches to data modelling. The outcome has been expressed more in terms of different concepts, approaches and guidelines for designing data model, rather than specific designs for artefacts. Clearly more work is needed to prove the value of a metaphor-driven approach. This will involve examining other information systems problems and evaluating the value of metaphors in generating solutions. There is also a need to develop rigorous approaches to evaluating the outcomes of a metaphor-driven approach.

5. References

Al-Khalili, J (2003) Quantum. A Guide for the Perplexed. Weidenfield and Nicholson, London.

Avison, D and Wilson, D. (2001) A Viewpoint on Software Engineering and Information Systems: What We Can Learn from the Construction Industry. Information and Software Technology 43, 795 - 799.

Bub, J. (2001) Quantum Entanglement and Information. Stanford Encyclopedia of Philosophy. http://plato/stanford.edu/entries/qt-entangle Accessed 22nd May 2003

Couger,J.D. (1989) Ensuring Creative Approaches in Information System Design. Working Paper 89/2 Centre for Research on Creativity and Innovation, University of Colorado.

Couger,J.D. (1996) Creativity and Innovation in Information Systems Organisations.. Boyd and Fraser.

Couger,J.D. (1997) Results of a Trans-Discipline Research Structure for the Study of Creativity/Innovation in Information Systems. Proceedings of the 30th Hawaii International Conference on System Sciences.

Dallman,S.; Nguyen, L.,Lamp,J. and Cybulski.J. (2005) Contextual Factors which Influence Creativity in Requirements Engineering. Proceedings of Xth European Conference on Information Systems (Location).

Hamilton, A. (2000) Metaphor in theory and practice: the influence of metaphors on expectations. ACM Journal of Computer Documentation 24, 237-253

Handy,C. (1978) Gods of Management.. Oxford University Press.

Hirschheim,R and Newman,M. (1991) Symbolism and information system development: myth, metaphor and magic. Information Systems Research 2, 29-62

Hevner, A.R, March, S.T., Park, J and Ram,S (2004) Design Science in Information System Research. MIS Quarterly, 28 (1) 75-105

Kaarst-Brown,M.L. and Robey,D. (1999) More on myth, magic and metaphor. Cultural insights into the management of information technology in organisations. Information, Technology and People 12, 192-217

Kendall, J.E. and Kendall, K.E. (1993) Metaphors and Methodologies: Living Beyond the Systems Machine. MIS Quarterly June 1993, p 149 – 170.

Markus,M.L., Majchrzak,A., and Gasser,L. (2002) A Design Theory for Systems That Support Emergent Knowledge Processes 26(3) 179-212.

McBride, N (2003). A Viewpoint on Software Engineering and Information Systems: Integrating the Disciplines. *Information and Software Technology* 45, 281-287.

National Science Foundation (1999) Quantum Information Science http://www.nsf.gov/pubs/2000/nsf00101/nsf00101.htm Accessed 22nd January 2004

Polkinghorne, J. (2002) Quantum Theory. A Very Short Introduction. Oxford University Press, Oxford.

Rosson,M.B. and Carroll,J.M. (2002) Usability Engineering. Morgan Kaufmann, San Francisco.

Travis,D. (2003) E-Commerce Usability. Taylor and Francis

Wong,W and Paynter,J. (2001) Software Creativity: Why and How? Innovation, Management Policy and Practice 4, 196-208.