

Transfer Report

Machine Consciousness and Digital Learning Assistants

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Abstract

The concept of a machine agent capable of supporting consciousness is considered, and a framework proposed on which to base further development. The proposed agent will be designed to support collaborative eLearning using a constructionist, connectivist pedagogy, behaving as an interested co-learner to work with the user. A multi-faceted design is described which reflects the natures of the individual, communities and the internal mechanisms of the mind, and which allows for the systematic implementation of the system, as well as a per-module upgrade plan.

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1 Introduction

Investigating potential designs of a framework for a caring e-Learning assistant that can facilitate the development of emergent Machine Consciousness (MC)?

The motivation for this is two-fold; not only is a conscious system seen as a viable method of providing a caring personal learning assistant (Self, 1999), but by embedding a system designed to be capable of developing consciousness in a life-long learning assistant, it is thought that the system should have enough interaction with people over its period of use to be able to develop fully. Whilst it is beyond the resources available to this project to be able to run such an experiment to completion, the aim is to design a system which should be able to support the necessary processes, and to test the proposed architecture and mechanisms to determine whether they allow the system to provide the practical functionality which would be necessary for the system to be adopted.

This project utilises theory in many areas of research; building on the ideas of caring learning assistants, open learner models frameworks such as SMILI (Bull & Kay, 2007), connectivism (Siemens, 2004), communities of practice (Wenger, 1999) and identity theory (Stryker & Burke, 2000) the system must be able to capture and exploit semantic relationships, and model the psychology of the learner and their learning support network. Additionally, the system needs to be developed in such a way that it is capable of supporting MCs.

The report is divided into chapters covering different topics, each with their own synopsis of the existing literature in the field, and where appropriate it outlines the research issues, aims, objectives and deliverables. These each draw out the context for the project relating to a specific field, and the topic areas are drawn together in Chapter 9, which outlines the project plan for the future. The project plan is described, taking account of the part-time nature of the research.

1.1 Structure of the report

Chapter 2: **Consciousness**, defines the working definition of consciousness used in this research, looking at some of the philosophical standpoints both from a human and artificial perspective.

Issue:

- The field of consciousness studies is fragmented, with many attempts to produce a single model.

Aim:

- Understanding the philosophical and practical aspects of the existing body of work on consciousness, with respect to application in MC and eLearning.

Objective:

- Organise and run an inter-disciplinary workshop on consciousness studies at the University of Reading.

Deliverable:

- Technical report and potential journal paper covering perspectives on consciousness research.

Chapter 3: **Identity, individuals, communities, roles and learning** covers theory relating to the learner as an individual, and how people interact in groups. It covers some areas of pedagogy, and introduces learner models and communities of practice. It describes informal learning, and the formation of dynamic transient learning support groups.

Issues:

- Existing ideas of identity in a digital context relate only to authentication and authorisation, but there is an increasing need to match ideas of digital identity to psycho-social models.

- Tools for modelling interaction between individuals, their communities and the tools they use are limited.
- Analysis of multi-faceted agent interaction in terms of roles in communities is lacking in existing approaches.

Aim:

- Understand the interaction of identity and community in both the human and machine domains.

Objectives:

- Frame the feedback systems involved in identity and community models in an eLearning context.
- Develop a model of roles adopted by individuals in *ad hoc* learning communities.
- Produce an analytical framework for communities and the tools they use based on Activity Theory.

Deliverables:

- Book chapter on digital identity and community (Appendix B, published by OdinLab and available online at <http://www.lulu.com/odinlab>)
- Paper on comparison between a social network as a learning environment and a traditional VLE (Appendix D)
- A paper on an analytic framework for *ad hoc* communities based on Activity Theory (introduced in book chapter, Appendix B).
- A technical briefing on modelling roles in *ad hoc* learning communities (introduced in book chapter, Appendix B)

Chapter 4: **Folksonomical file systems** introduces recommender systems, the folksonomical file system (FFS), trust networks, and vector space searches. It aims to illustrate how the proposed system should be able to support the user by finding relevant material to the work they are doing, and by communicating with their peer group within the trust boundaries set by the user.

Issues:

- User data and resources are becoming increasingly fragmented, both in terms of storage and authorship, and the concept of a FFS is explored.
- Can such a FFS be used as the foundation of a recommender system in the context of a learner support system?

Aim:

- Improve understanding of the place of tagging with respect to resources, individuals and groups.
- Describe how tagging and folksonomies can be used to facilitate individual and collaborative work and analysis of communities.

Objective:

- Produce a design and demonstration system of a FFS based recommender system.

Deliverable:

- Demonstration system of a simple FFS based recommender system, and evaluation report (JISC MeAggregator project report)
- Book chapter on the FFS (Appendix B)

Chapter 5: **Machine consciousness framework**, describes the MC framework, relating it to current work in the field. It develops a model of a cognitive system, building in the components thought necessary to support emergent consciousness. Existing research in the field is considered and areas for improvement are identified.

Issues:

- There are several existing suggestions of potential candidates for a framework for machine consciousness.
- Most work on consciousness involves physical embodiment.
- What constitutes the minimum necessary elements of a framework for a machine conscious capable agent (MCCA) (i.e. an agent capable of supporting emergent consciousness)?

Aim:

- Produce a framework for MC based on interacting agents.

Objective:

- A framework for MCCAs.

Deliverable:

- Design document for agent based system.

Chapter 6: **Perception, recognition and classification**, looks at the perception component of the framework and the concept of Digital Identity. It moves forward from issues relating to recognition and classification of audio signals, to the more general problem of recognising patterns in signals which can be represented as numerical vectors.

Issue:

- Cognitive and conscious systems need perception interfaces to their environment, and need to be able to abstract information from the data, and use it as part of their classification process.

Aim:

- Establish algorithms for automatic abstraction of information from data.
- Evaluate effectiveness of different pattern recognition techniques.

Objective:

- Identify a suitable method of automatic abstraction and representation.

Chapter 7: **Representation, reasoning and learning** examines the representation, reasoning and learning aspects of cognitive systems, and extends this to handle the self-referential aspects of conscious systems.

Issues:

- The self referential nature of conscious systems involves feedback loops which must be designed with care.

Aim:

- Analyse and understand the feedback systems introduced by extending a model of cognitive systems to a framework for a conscious-capable system.

Objective:

- Design and prototype a system which implements the necessary representation, reasoning and learning features.

Deliverable:

- Evaluation report of the prototype system.

Chapter 8: **eLearning and collaborative working** examines theory relating to eLearning and collaborative working, and examines the goodness of fit between the proposed system and models of computer supported collaborative learning.

Issue:

- Does the proposed architecture model have a sufficient goodness of fit with the model of the system it is designed to support?

Aim:

- Bring together the research streams and design agent based system architecture.

Objective:

- Design and prototype of system.

Deliverable:

- Evaluation report on prototype system.

Chapter 9: **Project Plan** integrates the various topic areas, and outlines the planned project schedule for the remainder of the project, covering design, development, evaluation and testing.

Chapter 10: **Future avenues** suggests areas of further development, and the potential for expanding the application domains of the work.

2 Consciousness

The nature of consciousness is the subject of much academic debate. The major philosophical positions on the subject are reviewed in the context of a working definition of conscious systems.

The current working definition of a conscious system, for the purposes of this document, is one which:

- Is aware of its surroundings
- Is aware of self (an autonomous entity distinct from environment)
- Is aware of others (as autonomous agents in the environment)
- Can hold a Theory of Mind of others
- Can have a Theory of Mind of self

However, there has been a debate about the nature of consciousness and of self which probably dates back as far as language does (Seager, 2007). Much of the current philosophy has its roots in positions held by the likes of Plato and Aristotle, and many great minds have contributed to the debate, including Leibniz, Descartes, Kant, Hobbes, Darwin, James et al, each exploring their own perspective. Consciousness is something which is unusually resistant to objective analysis, of course, being, as it is, at the centre of our subjective view of the world. Whilst subjectivism has been rejected by several schools of thought, the philosophy of mind keeps coming back to it as a tool for exploration of the nature of the conscious self.

Most, if not all, schools of thought relating to psychology, consciousness and the self have weaknesses. However, most of them also make a contribution to the overall understanding of the topic, and possibly the greatest failing in the domain is to be dogmatic about which underlying philosophy one follows. For the purposes of an

engineering solution which at least approximates consciousness well, the key thing is to remain pragmatic. As Noble notes

"Adopting his [William James'] use of the word 'expedient' I call this view of reality 'expedient reality'. Briefly, an object or circumstance can be said to 'exist' in the 'world', if its inclusion in our representation of that world, results in an improved ability to predict future experience" (Noble, 2003).

2.1 A review of psychological and philosophical standpoints

2.1.1 On reality and experience

In considering consciousness, it is necessary to look at the nature of experience. There is much focus on what it is *like* to be conscious (Nagel, 1974), and on whether we can truly imagine what it is like to be someone, or something, else. This leads to questions about whether something identical to us would be conscious in the same way we are, and the topic is frequently discussed in terms of Zombies (Moody, 1994).

This, of course, has roots in the subjective idealism of Berkeley, wherein the only reality is mental. Whilst this may be regarded as being an extreme position, it is the case that in a physicalist view of reality, the only way we can experience is through stimuli impacting upon our minds. We model an objective reality due to our perception of its persistence, but we could just as easily model such persistence even if it did not exist in the objective reality – indeed, change blindness would appear to be a simple example of this (Grimes, 1996). In Chapter 3 we examine the relationships between subjective, objective and consensual realities, and their bearing on society and learning.

2.1.2 Behaviourism

Essentially holding that all actions organisms perform, including thinking, should be considered to be behaviours, typified to some extent by Pavlov's work on conditioned responses, behaviourism has many 'flavours'. Importantly though, the main idea of methodological behaviourism comes from the need to be able to draw conclusions from

the observable behaviours of the samples being studied. When the only observable feature is a set of behaviours, it is helpful if the inner workings of the system under study can be modelled as a simple stimulus-response system. It is not unreasonable to consider that as physical beings our responses should be tied by some causal mechanism to the stimuli which help produce them.

Radical behaviourism accepts the existence of internal states of mind, but considers them to be processes rather than artefacts, and supposes that this somehow prohibits them from being causes of behaviour (Skinner, 1953). This differs markedly from the position of, for instance, a functionalist such as James, who introduced the term '*stream of consciousness*' into the language. However, the work of Skinner is highly influential, and covers many of areas of interest in the design and implementation of an eLearning system, whilst noting that it is also heavily criticised (for instance (Chomsky, 1971)).

Whilst Behaviourism provides some basis for modelling the internal workings of an individual, it denies the idea of an internal state of mind impacting upon behaviour, and does not account for social effects, such as the impact of peer interaction on one's perception of level of interest in a subject (Pasupathi, 2001). Therefore, it is necessary to consider some of the other philosophical positions.

2.1.3 *Physicalism*

Predominantly mainstream in its simplest form, physicalism describes any phenomenon as being no more than the physical form on which it is based. It introduces the concept of *supervenience*, which is the idea that, for instance, if two minds are physically identical, and the mental supervenes on the physical, then they must also be mentally identical. However, it also holds the idea of *multiple realization* which means that the reverse need not be true – identical physical minds need not be mentally identical. Armstrong sets out an argument for the material mind (Armstrong, 1973), and highlights in it the reliance we place on rational consensus, which is a view supported by the analysis of the individual and community in Chapter 3.

2.1.4 Functionalism

Taking multiple realization from physicalism, but otherwise effectively providing an abstraction layer over the hardware of the mind, Functionalism argues that a mental state can be described solely in terms of what it does, its function. This can be extended to areas other than theories of mind, of course, and has clear parallels with some forms of identity theory, where the individual can be seen in terms of the roles that they fulfil within the communities of which they are a part. These features of the philosophical position have particular appeal for application in an engineering or computer programming environment, as they are closely linked to analysis of systems and design of object oriented software.

The functionalist position can trace its ancestry back to Aristotle's concept of soul, but should not be mistaken as being in any way spiritual. It is also allied to behaviourism, but clearly distinct as it allows for the idea of mental states. Probably the most famous application of functionalism, although not specifically referred to as such at the time, is the Turing Test, and more recently Functionalism is seen as being supported by modern neural scanning techniques (Gallagher & Frith, 2003).

2.1.5 Multiple drafts model

Dennet describes, in *Consciousness Explained* (Dennett, 1991), the multiple drafts model (MDM). This effectively describes consciousness as being continuously re-written. This model is perhaps best supported by a system similar to the Global Workspace (Baars, 1997), with the competition for conscious awareness having a possible implementation in the attentional mechanism. However, as Rosenthal points out (Rosenthal, 1995) the first person operationalism (FPO) which says that there are no fixed facts about whether a stimulus reaches consciousness unless they become associated with something and thus remembered or reported on, is inconvenient because it implies that a conscious event can only seem to be something, and not seem to seem to be. This would remove a layer of abstraction, and makes the idea of higher order thoughts harder to reconcile, but there is no intrinsic reason why accepting the MDM forces acceptance of FPO.

The MDM is a pragmatic approach, which is not to say that it may not also be theoretically correct. But having multiple independent agents, each specialised in a particular type of processing, and each capable of being the subject of awareness, is a powerful model to work with, and has the additional benefit of scalability through parallelism. Multiple independent agents model, to some extent, the idea of subconscious trains of thought. The term subconscious was used by Freud in relation to the unconscious mind, but both terms gain ambiguity from this association. Used here, unconscious means in a state of unconsciousness, not roused, and subconscious relates to the pre-conscious mind – those mental activities of which the subject is not consciously aware. Pre-conscious is avoided because of the implication of relating to minds that exist before consciousness is developed in them.

2.1.6 Dualism

With a rich history based in times when religion was more prominent than it is today, Dualism essentially holds that ‘mind stuff’ is different to ‘physical stuff’. It is the idea that there is a spirit which is somehow linked with our physical body, which houses the ‘self’. The obvious argument against this is one of conservation of energy, and the fact that a dualist approach leaves open the mind-body problem. However, many who claim that it is ‘unscientific’ fail to realise that the idea can be framed in such a way that it is testable.

There are many views of dualism, from Descartes view of the mind with a (virtual) homunculus viewing the experiences and providing conscious thought, to the more modern Morphic Resonance theory (Sheldrake, 1987). Whilst not discounting the possibility of the natural world providing us with a dualistic reality, it would be impractical to attempt to produce a machine consciousness based on dualism – at least, currently.

2.1.7 Phenomenal Consciousness

This term refers to the idea that separate from the direct perceptions of our sensory systems, and from the mental representations we form, there is another form of

consciousness, the ‘what it is like to be’ sort of consciousness. This is where the zombie argument is most used – if we can replace all the internal machinery that constitutes us with an exact copy, and we can imagine that this may not be conscious, then the conscious part must be something else.

The *qualitative feel* of an experience needed for it to be a conscious experience which is necessary for this separation of phenomenal consciousness from a physicalist one could, if it indeed exists, be entirely due to the experience being experienced consciously. The awareness due to the attentional mechanism of the mind can thus be considered as producing the ‘feeling’ that the experience is in some way special.

2.2 Summary

This introduction to some theories of mind covers the key areas with practical applicability for an attempt to create a machine consciousness, and includes dualism for comparative purposes. For this research, we follow Noble, taking a pragmatic approach where a part of a theory of mind is considered useful and practical if it helps us build a model which we can use to explore further. Moreover, the model we design will be intended to take a similar pragmatic approach to its analysis.

For a more in depth look at the issues relating to consciousness, the interested reader is directed to a brief history on the subject (Seager, 2007), the archive of papers maintained by Chalmers (<http://consc.net>), and the Stanford Encyclopaedia of Philosophy (<http://plato.stanford.edu>).

2.3 The proposed model of mind

It is the author’s contention that the mind consists of multiple autonomous components, some of which relate specifically to various input/output functions, and others which relate to abstraction, pattern recognition and modelling. The basic premise is that all input is filtered in a system which is comparable to a subsumption architecture (Brooks, 1986), with the most urgent patterns leading to reflexive responses, and more complex ones being able to take more processing time to resolve. With a short term memory, and parallel

abstraction of the data to provide a higher level view, including the potential for analysis of spatial and temporal pattern recognition, the system should be able to identify stimuli of importance to it. The system is, in effect, similar to a Global Workspace (Baars, 1997)

2.3.1 Models

Internally, the system maintains a number of models, which it learns through experiencing the stimuli from the environment and from its own proprioceptors. These models initially relate to the immediate environment, and how to interact with it, but once these are well established, the system can go on to try to derive models of other agents within the environment.

2.3.2 Filters

A critical feature of the system is that all inputs, and abstractions of the inputs, are tested against the various models. Each of these can be committed to memory if the model output indicates that this is the appropriate action. They can also specifically not be memorised. They can also be acted upon, or filtered out. The filtering allows the organism to ignore things it has learned are of no consequence, or which cause negative feedback from the environment.

2.3.3 Imagination

Various processes are continuously attempting to predict what will happen next in the environment based on the models, input, and some degree of internally generated noise. The system could probably work without the noise, but it is thought likely that it will help with finding suitable solutions in problem solving exercises and is thought of as a loose analogy to imagination. The filtering system which the organism learns through experience is also applied to the 'imagination' so that the effective input from it is in keeping with the previous experience of the real world.

2.3.4 Prediction

The predictive processes are rewarded for matching with the incoming input. They are used in training the internal models to fit the external stimuli. This means that when they

encounter something which appears to act for reasons other than direct stimulus, they will need to have the capacity to attempt to model this behaviour. It is suggested that the most energy efficient way of doing this is to model the other agent as a black box, and assume that it can have a range of possible behaviours. As it is impossible to know the stimuli acting on another agent for certain, this type of modelling is important as it can apply to any agent, even ones which respond in entirely behavioural ways.

2.3.5 Models of self and other

The basic premise of the model is that once it has developed the ability to model the ‘other’ relatively well, if the system is capable of associating itself with that ‘other’, perhaps because of similar looks or behaviours, then it is likely to model itself in a similar way. This leads to the idea of the consciousness of self being an illusion, but that is an idea which is well supported in mainstream cognitive neuroscience and consciousness studies (see, for example (Cotterill R. , 1998)), even if not welcomed by many ethicists and spiritual thinkers.

2.4 Alternative views and future work

It is clear that there are many other perspectives on consciousness, self and identity, and many fields of academic research in to them. Whilst it is obvious that philosophers and psychologists will have an interest in the field, sociologists, artists, linguists and many others have active research in the area.

In the book, “Folksonomological Reification” (Appendix B) Parslow et al argue that the self is a construct of society, in line with Symbolic Interactionism (Blumer, 1969), which in turn is derived from American Pragmatism, and that we define ourselves in terms of the meaning we infer from our roles in our communities. This fits with some social theory (Stryker & Burke, 2000), and the idea of a narrative self (Fivush & Nelson, 2004), and if correct, points to the importance of collaboration and community for a conscious agent.

Symbolic Interactionism (Blumer, 1969), an American branch of sociology, recognizes the pragmatic nature of self (after Mead (Mead, 1934)) as being an “object”. Taking a

pragmatic view, this allows the individual to act, reason and plan with regard to their 'self'.

3 Identity, individuals, community, roles and learning

Although it is conceivable that a fully conscious being could develop and survive without any social context, it is generally held that isolation is not good for mental health or development.

From an evolutionary perspective, it seems reasonable that the individual would benefit from being able to model those around it, at least for short term predictions. Being able to predict what a predator is going to do is an obvious survival advantage, and being able to predict what prey do will help a carnivore have a productive hunt. Even more, if an individual can predict what other members of its group will do the group benefits from improved collaboration, and so on.

No attempt is made here to claim direct evolutionary feasibility. The idea of plausible evolution (after Noble) is that such an evolutionary event can be imagined to have taken place, and can be evaluated in terms of the benefits that it would accrue for the organism.

The Multiple Drafts Model can be interpreted in terms of agents taking on roles in a community. Whilst this could be taken to extremes, and some all encompassing theory of universal consciousness developed, that is not the purpose of introducing the idea. The similarity between MDM and identity theory in a social context, social interactionism and social constructionism means that it is easier to develop a multi-agent model which can be used as a basis for both the development of the machine consciousness, but also of its own internal models about how other agents and collections of agents work. The abstraction involved in developing the model is also an instructive intellectual tool, which can help highlight both similarities and differences in the relationships in the models, and thus help deepen understanding of these types of system, be they related to the mind, to society or to collaborative computer agents.

3.1 Identity and individuals

Conscious individuals have a concept of self, an idea that they are a unique individual. It is probable, to the extent of near certainty, that they have had a unique set of experiences, from conception through to their current age, and each event in that lifetime can have been causal in changes in the way they think and the way their body works. Whilst it is theoretically feasible that two people might have the same patterns of neurons firing at the same time, it is extraordinarily unlikely, so it would seem reasonable to suppose that their subjective selves are, indeed, unique. However, having said that, it is also possible that the processes which lead to a sense of self have a large scale averaging function, and that even quite different objective experiences could lead to similar subjective ones. The subjective ‘feelings’ of experiencing things are referred to as *qualia* in the literature. The use of the word *qualia* is avoided in this report, as it tends to obfuscate the meaning of the argument, and subjectively it can be argued that there is no ‘feeling’ of seeing the colour red, to take a common example.

Although in the Western world, at least, we tend to adopt the folk-psychological view that we have a single sense of self which has chronological continuity, it is far from clear that this is actually the case. Indeed, the MDM suggests that whilst we appear to have a continuity of self, this is to some degree the product of post-editing – the conscious mind comprises itself from the elements of subconscious thought which ‘attract its attention’. Most people also report that they have periods, other than during sleep, when they are ‘operating on auto-pilot’. Unable to recall what they have been thinking, or what external stimuli have been present, they can still be capable of functioning at relatively high cognitive levels – driving a car, for instance, and in some cases possibly even engaging in conversation.

This suggests a form of punctuated continuity. Whilst we ‘feel’ that we are the same person as we were before the brief break in conscious awareness, we cannot be sure that we are, as, if the MDM or narrative views of consciousness are correct, we could build an internal model of ourselves which said we are the same person anyway.

The individual, however, is capable of maintaining multiple identities (Stryker & Burke, 2000), which can be associated with their roles in the community. One’s identity

as a friend, teacher, parent etc. all have a set of behaviours which go along side them, and switching between them is almost always automatic, being based on the context in which one finds oneself. For more on this, including background material, see Appendix B.

3.2 Digital Identity

The proposed domain of the eLearning agent is an online environment, active on the internet and capable of perceiving people through their behaviours online. Consequently it is important to have an understanding of how such interactions take place, and to be able to have a model of how people interpret the identity of others in such a framework. In the Eduserv funded This Is Me project (<http://ThisIsMe.reading.ac.uk>), we have defined Digital Identity (DI) as the persona an individual presents across all the digital communities that he/she is represented in.

In order to gain an understanding of the factors involved, we have collected data in the form of people's subjective stories of their own, and other peoples', experiences with their online identities. These have been analysed using a variety of Thematic Analysis to draw out common themes, and these form the basis of learning materials in the form of worksheets and games to help people discover and understand their Digital Identities more easily and fully.

This work supports the view that we project multiple facets of ourselves, and our interactions with others are influenced by them. Currently, the socially connected always-on computer mediated world is relatively new for the majority of people, and is consequently in a state of change. It is not immediately clear whether this will change, as the technology itself promotes the rate of change in the available tools for people to use, whilst simultaneously increasing the reach of individuals in terms of both acquiring information from others and of publishing their own material on a global scale.

Building on this work, which touches on the issues of trust, reputation, aspiration and recommendation, we have proposed a desk study of existing literature on what makes us trust online resources, and are in the process of formulating a proposal for developing an algebra of digital identity.

3.3 Community

In the typical situation, the individual develops and operates as part of a community. It is, presumably, beneficial to the individual or the species for these communities to exist, in evolutionary terms. To be beneficial in evolutionary terms only means that the trait is less harmful to the organism than the benefits of other things which are tightly associated with it. The balance is in the favour of the organism. As creators and users of tools, we can exploit our environment to our own benefit, and thus modify the niche we are in to better suit our needs. This, indeed, is merely an extension of the underlying concept in Lovelock's Gaia theory, that life adapts its environment to make it more habitable for itself.

As an individual, each of us can be a member of multiple different communities. We adopt one or more roles in each of them, and the ways that our roles in those communities interact gives the community itself a characteristic 'flavour', or organisational culture. It is useful, when looking at communities, to have a method of analysis, and as organisational, or corporate, culture has an impact on business, it is no surprise that there have been several frameworks for analysis suggested.

Putting aside simulation based analysis - in which one would model individuals within the community on the basis of psychometric tests and their operational environment, and then run a number of trials to determine behaviours and outcomes – which are probably a little heavy handed for the current purposes, there are a number of business oriented analysis frameworks available and a number of more theoretical, research based methods.

Hofstede (Hofstede, 2001) presents a method tuned to evaluating societies across national boundaries, focusing on five dimensions:

1. Uncertainty avoidance
2. Power distance
3. Individualism/Collectivism

4. Masculinity/Femininity

5. Long/short termism

The framework was not intended for use in analysis at the individual or small scale though, but there have been attempts to use it this way. The main drawback in trying to use it at a small scale is that the key dimensions of interest often differ radically between the communities one is studying. For the purposes of assessing small scale communities, it could be suggested that at least two other dimensions are perhaps of importance, namely Openness and Holism. Particularly when considering learning communities, these are pivotal features of individual and group beliefs and behaviours.

Hofstede's original work showed an apparent western bias. Hofstede has added a biographical element to explain his background and underlying thinking, which is important because no work is free from subjective bias in some way, so the most objective way of presenting it is to take ownership of the opinions and be up front about the potential for different interpretations.

By contrast, Handy (Handy, 1985) describes organisations in broad terms such as a Person Culture, or a Task Culture. These broad brush descriptions seem to lack sufficient detail for analysis of small communities, and appear to be more of an ends than a means. One of the problems of many of the offerings in this area is that they are designed by businessmen for businessmen, and typically aimed at the short attention span of management and consultants.

One option would be to use Semiotics analysis of organizations to examine the communication that takes place within a community. This has the flexibility of recognising communication takes place with different substrates, and allows the same mode of analysis to be applied to information systems and human organisations as well as hybrids (Filipe, Liu, & Sharp, 2001). The technique is not well suited to the notion of an adaptive tool, and the adaptation of the environment to the agents, however.

The social sciences, as might be expected, give a wealth of methods of investigating communities. Of particular note is Activity Theory, or, more accurately, Scandinavian Activity Theory, which is also promoted as a tool for analysing human computer interfaces (HCIs) (Kuutti, 1995). The emphasis on the interactions between individuals, tools, community and environment are useful for drawing out key issues, although some elements of the framework are not deemed necessary, as discussed in “Folksonomological Reification” (Appendix B)

In Symbolic Interactionism (Blumer, 1969), the individual is perpetually in a state of learning about the social group, as they must interpret the signs and signals used in communication acts and adapt to the situation. Individuals react to things depending on their own interpretation of the meaning of the event or object – if they did not do so, there would be no value in *having* such personal meanings anyway. Meaning arises as a result of social interaction - for instance, at an early stage we learn the language for things from our parents, but adjust the meanings of words as we move through life, encountering different social groups with their own uses for those words. Social interaction arises as a result of multiple individuals acting in a way that is perceptible to others.

3.3.1 Designed and transient, ad hoc communities

Although the main elements of community are similar in both designed and *ad hoc* communities, there are some differences. In a community which is designed for a purpose, such as might be the case in a team within an organisation, or in a trans-organisational community of practice (Wenger, Smith, & White, 2007), roles are established, at least to some extent, *a priori* and filled by appointment or some democratic means. In an *ad hoc* group, such as might be formed by students researching a specific topic for a seminar or coursework, the roles are more likely to emerge based on the skills and interests of the constituent members.

In the transient community, the overhead of creating specific roles and appointing people to them is one which seldom has sufficient benefit. Whilst the informality can mean that a role is filled inappropriately due to an overwhelming personality, or even due

to a member seeking to please, this is dealt with in the longer term by the evolution of the group. If someone is overbearing beyond the level of benefit they provide, an unconstrained team will simply avoid working with that individual the next time they have cause to work together. And if someone is accepting roles which are beyond their capacity, they too will either be avoided or another member is likely to take a mentoring role, because community ownership, and responsibility for the outcomes of the community, are distributed.

The *ad hoc* community is probably more inclined towards operating as a meritocracy due to its transient nature - there just isn't time to set up formal procedures and inappropriate behaviour will tend to be 'punished' by subsequent selections.

3.4 Roles

The individual, we observe, can take up different roles in different social contexts. This may involve being in different communities, or even within one community when the situation is such that a different role needs to be adopted. For instance, the research assistant may switch roles to first aider in the event of an accident in the work place.

In addition to the methods of analysis above, it is suggested that a role/domain approach be used to identify stereotypical roles within communities. This can be used as an adaptation of, for instance, Wenger's work on Stewarding Knowledge as presented in Appendix C.

The roles are simple one word (generally) descriptors of the nature of the sort of thing the individual does in the context of the group. For instance the **Explorer** finds new resources and reports their existence to the group. The **Reviewer** examines resources available to the group and evaluates them, writing a brief review so that others can easily see what relevance they have. In each case, the role can have an explicit domain, such as the **Technology Reviewer**, who specialises in producing reviews relating to technology.

Given a taxonomy of suitable role and domain names, it is relatively simple to envisage a method of analysis which first categorises the different types of roles involved, and the

way in which information passes between them. The analysis of information flow can be through Semiotics, or any typical workflow method preferred. For some examples of an initial set of role names, see Appendix B.

3.5 Learning

Learning is the creation of meaning, and meaning is the significance something has in a particular context. In Constructivist terms, learning is about the creation of meaning by making associations between new knowledge and the learners existing knowledge. In Connectivism (Siemens, 2004), it is about the knowing where to find information via connections, be they human or technological. It is a life-long process, although much of it probably goes unnoticed, and includes acquiring all the skills necessary for day to day survival, and much of it happens through interaction with other people.

Zull (Zull, 2002) describes learning in terms of cognition and demonstrates the relationship between the theoretical concepts of how learning occurs and the biology of the brain. This treatment emphasises the physical structure over the dynamic nature of activation in the brain, and is, in itself, a good example of ascribe significance to events and patterns which match with expectations or other experience. However, the underlying premise that teaching is the ‘art of changing the brain’ is well founded, and Zull covers many issues which relate to community, collaboration and maintaining balance.

However, more academic types of learning are also improved by community. Dialogic learning (Ravenscroft, 2007), communal play, collaborative project work – all are examples of ways the individual can learn about a subject more readily by being involved in a community. Indeed, Communities of Practice are about learning together, and exemplify the way interactions between people can help each learn more, whilst also achieving some primary goals.

A collaborative learning support system requires four key elements (Kleanthous & Dimitrova, 2006), and any learning system can be considered to be collaborative if one adopts the MDM. These are Transactive Memory (TM), Shared Mental Models (SMM),

Cognitive Consensus (CCs) and Cognitive Centrality (CCen), and these ideas will be covered in more detail later.

3.6 Social Networks and Learning

Anecdotal evidence points to students learning through Facebook, a social network which is neither designed to support learning, nor has any academic content to support it. In order to determine the veracity of the evidence, we designed a survey to gather information on the extent to which students at the University of Reading (UoR) perceived they were able to use Facebook as a learning tool. The resulting paper is presented in Appendix D, and it indicates that the anecdotal evidence was correct to some degree. Indeed, the same proportion of students report learning from Facebook as believe they would learn from BlackBoard if the academic content was not present there.

Students report using the social networking tool for discovering course mates who they would otherwise not be in contact with, and for discussing course related material. It is believed that this supports, to some degree, the idea that a lot of learning is about the connections we make, and about knowing how to find information out, rather than about the ‘hard facts’ themselves.

A thematic analysis of the responses to an open ended question in this questionnaire was developed into a concept map of key features for an eLearning platform (fig 1):

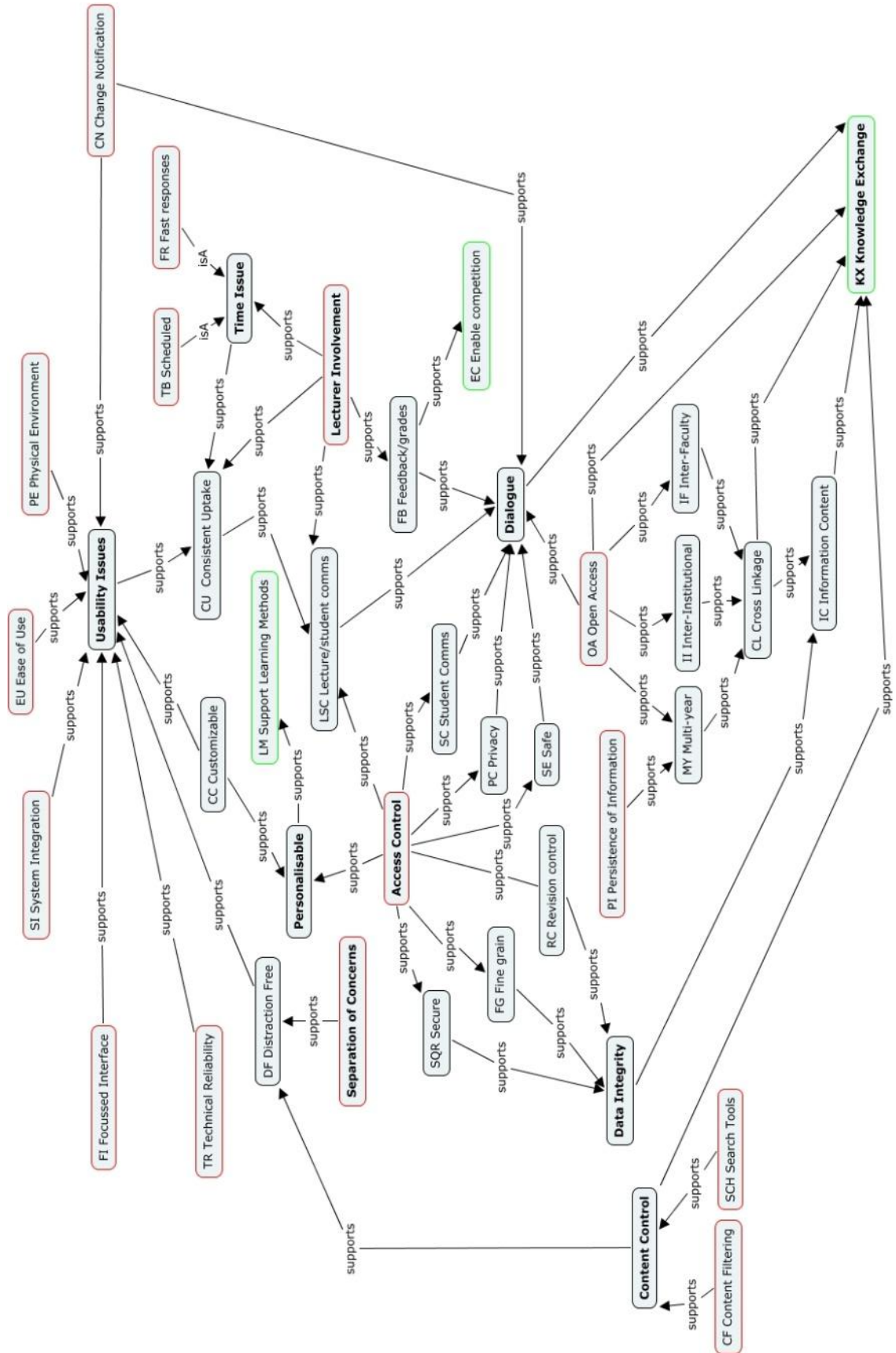


Figure 1 Concept Map from thematic analysis of user responses

3.7 Future work

A more complete review of existing eLearning solutions and research is required. Additionally, further development and validation of both the modified Activity Theory method of analysis of communities and their tools, and the role based method of analysis are necessary.

4 Folksonomical file systems

4.1 *Folksonomical file systems*

The idea of a Folksonomical File System (FFS) is based on the idea of tagged file systems (for example, tagsistant for the linux kernel (<http://home.gna.org/tagfs/>)), firmly grounded in the MeAggregator™ project, and is covered in more detail in Appendix B.

The concept of the file system is extended to include the resources the user utilises, including, for instance, web resources and even other people. Consequently, it refers to a distributed set of resources, rather than just those found locally on the user's computer. Additionally, it works on the basis that the user has content they want to share with others, albeit it restricted by their preferences about who can see, access and write which resources.

The FFS utilises the idea of communal tagging, across the users' resource collections, to allow extra meaning to be gleaned from the tags applied by other users. Whereas other tagged file system approaches have worked from the communal tagging efforts found on sites like del.icio.us (<http://delicious.com>) and provided flat tagging systems for the local user on their machine (or in some cases, for multiple users on the same machine), the concept of the FFS allows this to be extended across multiple domains via either a client server based architecture or a peer to peer one.

4.2 *Trust and recommender systems*

A key concept in the FFS is that of a trust network. The users must be able to trust the system to keep information securely, within the permissions they grant to other users, but also to be able to express the level of trust they have in other users' tags on resources.

The working premise is that the user will be able to set the level of trust they have in a particular resource, which may be a website such as Wikipedia (<http://www.wikipedia.com>), or another user, in relation to a particular subject or context.

Additionally, in order to help the user in cases where they do not have enough information to make such a decision, the system should be able to evaluate other users' levels of trust in the resource, and make recommendations based on this. The system should be able to take into account the possibility that there may be distinct groups who trust different resources, and also the behaviours of the members of the community involved in terms of their tagging. This is covered by means of an example in Appendix B. Typically, there has been a tendency to work with logical operators when dealing with trust and belief networks. This has several drawbacks (Grégoire, 2005), which will need to be considered in the design.

A recommender system should find content which the user will find interesting and which they will trust. The aim of the work in this area is to develop a recommender which uses vector space matching to identify resources of interest, and the FFS trust mechanism to identify which ones the user will be able to trust.

4.3 Future work

4.3.1 A recommender system

The plan is to build a recommender system using the FFS of the MeAggregator™ as a basis, or one built to a similar design (for comparative purposes). This system will have limited senses, and operate in a digital, online, domain in conjunction with the user. It will attempt to classify documents and user browsing behaviour using techniques similar to those developed in Chapter 6.

This system will be tested in trials on volunteers, and a report on the system's efficacy will be disseminated.

5 Machine consciousness framework

Cognitive systems perceive, represent, reason, act and learn. Proposals for conscious systems extend this, and build theories of mind (ToM) for both themselves and other agents (biological or artificial) they encounter.

Perception is dependant on the system and its environment. A physically embodied robot, for instance, may have audio/visual sensors and a somatosensory system (touch/heat etc. and proprioception), whilst a text based agent may have only a limited textual frame with which to sense its surroundings. In both cases a sense of time is valuable, whether provided internally or externally.

In order to be able to efficiently represent information, it is necessary for systems to be able to classify the signals they perceive (experiences). In addition to classification, some form of rudimentary modelling (abstraction) is desirable. Storing model parameters is less costly than storing stimulus signals, and lends benefits to subsequent levels of processing. Pattern recognition and abstraction therefore play a key part in any such system.

Reasoning requires both classification and abstraction, but also necessitates the representation of relationships. Meaning is bound to context, which can be expressed in terms of temporal or spatial relationships between experiences.

Action, like perception, is heavily dependent on the purpose and environment of the agent. However, in terms of the controlling system, actions relate to the control signals sent by it to actuators. Whilst these will include mechanical devices in an embodied robot, a software agent operating in a text only environment can act through a screen or speech synthesiser.

Learning involves the manipulation of relationships. In expert systems this means modifying rules, and in connectionist systems it is modifying weights. These changes are made either through supervised learning, where stimulus-response pairs are presented, or unsupervised learning, where the representation produced by the system is not pre-

determined. In both cases, however, the basic method is that behaviour close to the desired, or which produces positive outcomes for the system, reinforce the behaviour, and negative outcomes incur a penalty.

An implementation of a cognitive system allows for a greater degree of open ended functionality than traditional systems. The system should be able to adapt to previously unknown environments and improve through experience. The suggested benefit of a conscious system over a cognitive one is that it should be capable of interacting with a variety of other agents in its environment, including both artificial and biological ones. In both cases, the ability of the system to adapt to its operational environment should make the overall lifetime cost of the system less, and incur less of an overhead in terms of expert maintenance. This is also true in the case of system degradation due to minor faults, when it should be able to learn how to continue operating, and minimise any further damage to itself.

5.1 Other work in the field

A good summary of the field as it was in 2003 can be found in Holland's book "Machine Consciousness" (Holland, 2003), and the key players are still broadly the same, apart from the sad loss of Rodney Cotterill who died in June 2007.

Cyber Child (Cotterill R. J., 2003): The research project of Cotterill, a computer simulation of parts of a nervous system as a test bed for consciousness research. Whilst the project was unable to present any positive findings as of 2003, the methodology seems sound. Of course, if the dualists are right, this approach would not ever find signs of consciousness, but on the other hand, it might take a long time to achieve results even if the physicalists are right.

The kernel architecture proposed by Aleksander (Aleksander I. , 2005) coupled with five axioms of consciousness (Aleksander & Dunmall, 2003), are described as a phenomenalist approach. The work is based on an abstraction of the human brain, and has at its core a depiction system. The depictive system associates a representation of a stimulus with a representation of where that stimulus comes from in the environment.

This locational representation is built from other stimuli in the context and the systems own proprioception. The work (Aleksander & Morton, 2007) is, rightly, based on introspection, but unfortunately goes on to suggest that testing for consciousness should be based on whether a system implements the kernel architecture and supports the axioms.

CRONOS (Holland, 2007) is an ‘anthromimetic’ robot, with a primarily visual sensory system which is designed as a test bed for consciousness studies. The robot maintains an internal model of its own body (humorously, and accurately, named the Internal Agent Model, or IAM) although it is not suggested that this is a sufficient level of modelling to support consciousness. This internal model uses a 3D physics engine to produce a visual rendering of the model from the robot’s perspective, which it can compare with the view it obtains from the external sensors. The system will then continuously calibrate the mapping between internal and external worlds, although no mention is made of using the necessary changes in calibrations to model the world-robot relationship. The system uses monoSLAM, a single camera variant of SLAM (Simultaneous Location And Mapping).

SLAM and ratSLAM (Milford, Wyeth, & Prasser, 2004) are mapping techniques for robots, which allow an autonomous robot to build and use a map of its environment. Experiments with ratSLAM also involve the robots building their own vocabulary to communicate with one another about the environment and their maps. These experiments are regarded as steps towards robot consciousness (Wyeth, private correspondence, 2007), and the techniques are also being used in situated, non-embodied environments such as are proposed here.

Hugh Noble proposes “Operational Consciousness” in his book of the same name (Noble, 2003). I describe the model proposed by Noble in an online review (<http://brains.parslow.net/noble>):

“Noble’s 5-layer model consists of 5 semi-autonomous layers which each build on the functionality of the earlier ones. This is similar to the concept of a subsumption architecture.

Layer 1 A stimulus-response automaton, providing sensory mechanisms. This also manipulates the data in simple ways, and provides for ‘programmable’ responses.

Layer 2 A memory layer, which can be used to anticipate a limited range of events, and which can pass data on to subsequent layers. This is similar, I believe, to our short term memory.

Layer 3 An abstraction layer, driven primarily by compression techniques. By recognizing repeated patterns in Layer 2, and representing them in a 'concept store', the data volume is reduced, and some level of abstraction is produced. In my view, this is probably a layer which may have multiple self similar layers, each acting on the previous one, possibly still with inputs from Layer 2. This layer is described as constructing a predictive interpretation of events.

Layer 4 A layer which enables the system to hold a Theory of Mind for other animate objects it encounters and produces models of in the lower layers. This layer also provides some level of introspection, and maintains a model of 'selfmind'.

Layer 5 Language layer - built on its predecessors, this layer introduces a mechanism for language, and the idea of a meta-concept, necessary for the development of language in the system."

This has strong similarities with the system proposed here, though phrased in terms of layers rather than interacting modules. The design and approach resemble a mix between Aleksander's axiomatic approach and a subsumption architecture, and appear to support Craik's description of an internal model (Craik, 1943).

5.2 *Sub problems*

The research area covers many sub-problems. Indeed the original work was motivated by the perceived need for remote species identification methods, which can be viewed as a sub-problem of the sense-and-classify components. The separate areas of research map to the core elements of cognitive systems, plus an 'imagination circuit':

5.2.1 *Perception*

Perception is dependent on the environment and necessary for responding to the environment. It can involve pattern recognition and can be linked to low level response

mechanisms (reactions). In a robotic system it is essential that the low level responses be in place to enable collision avoidance and other survival reflexes. However, in a situated but not embodied system, with no physical actuators, this need for reflexes is reduced, if not obviated.

5.2.2 Representation

The area of representation includes abstraction, because it is necessary to extract salient features and to compress the amount of data for subsequent processing. It can include further pattern recognition, and be linked to reactions. This area includes interaction with the model generation system. Together with the perception element, this works to produce a Sense-and-Classify component, using internal models to identify stimuli. This also covers the long term memory of the system, and in conjunction with the Learning components this allows for the system to update its models on the basis of experience.

5.2.3 Reasoning/Planning

Reasoning and planning can be based on rules-based, connectionist or a mixed artificial intelligence technologies. The module has access to the internal imagination circuit, which is used in the design to provide a simulation of intentionality.

5.2.4 Action

The Action module is responsible for activating actuators for both internal and external actions, including both interactions with the environment and with other system sub-units.

5.2.5 Learning

The Learning module guides the building and maintenance of internal models, including changes to reaction rules and higher level reasoning rules. This is likely to involve a mix of machine learning technologies.

5.2.6 Imagination circuit

To provide some degree of independent action and appearance of intentionality, the system is designed to have an imagination circuit. This generates a noise signal, by the

simple expedient of generating random vectors of a suitable length to be used by other components in the system. These are subject to filtering in the same way that the external stimuli are, to ensure that they have some degree of relevance to the experience based models the system uses. When applied as ‘drives’ these work as an intentional mechanism, and when applied as ‘sensation’ they work as a form of problem solving system to avoid local minima. Drives may be modelled as internal sensations (for instance analogues of hunger, boredom etc).

5.2.7 Emotion

Increasingly mentioned in the literature, for example (Aleksander & Morton, 2007), emotion is taken to include basic drives, not normally encompassed by the term, such as hunger and pain. Unfortunately this confuses the issue. Whilst it seems reasonable to suppose that a conscious agent will be more human-like given it is capable of feeling and expressing emotions, it remains doubtful as to whether they are a requirement for consciousness. The other basic drives are also useful in motivation for an agent, but it is hard to see them as being required for consciousness. Would I not be conscious if I could not feel hunger? Similarly would it preclude consciousness if I was unable to be happy?

However, emotions do appear to have their place in providing motivation for action, and for both learning and memory (Zull, 2002). Levels of fear, for instance, can either increase the effectiveness of learning, or decrease it, depending on the degree of the emotion experienced. Pleasure seeking behaviours can inhibit learning, but pleasure gained as a result of problem solving or other learning outcomes act as an incentive. The model proposed does not explicitly use emotion, but it could be included at a later stage as a module, to determine whether it improves or lessens the effectiveness of the system.

5.3 Outline design diagram

It is proposed that the system is designed in terms of models and a set of learning algorithms, but relationships of the aspects of the system can probably be best understood diagrammatically in terms of the functional components of a multiple internal model system (fig 2):

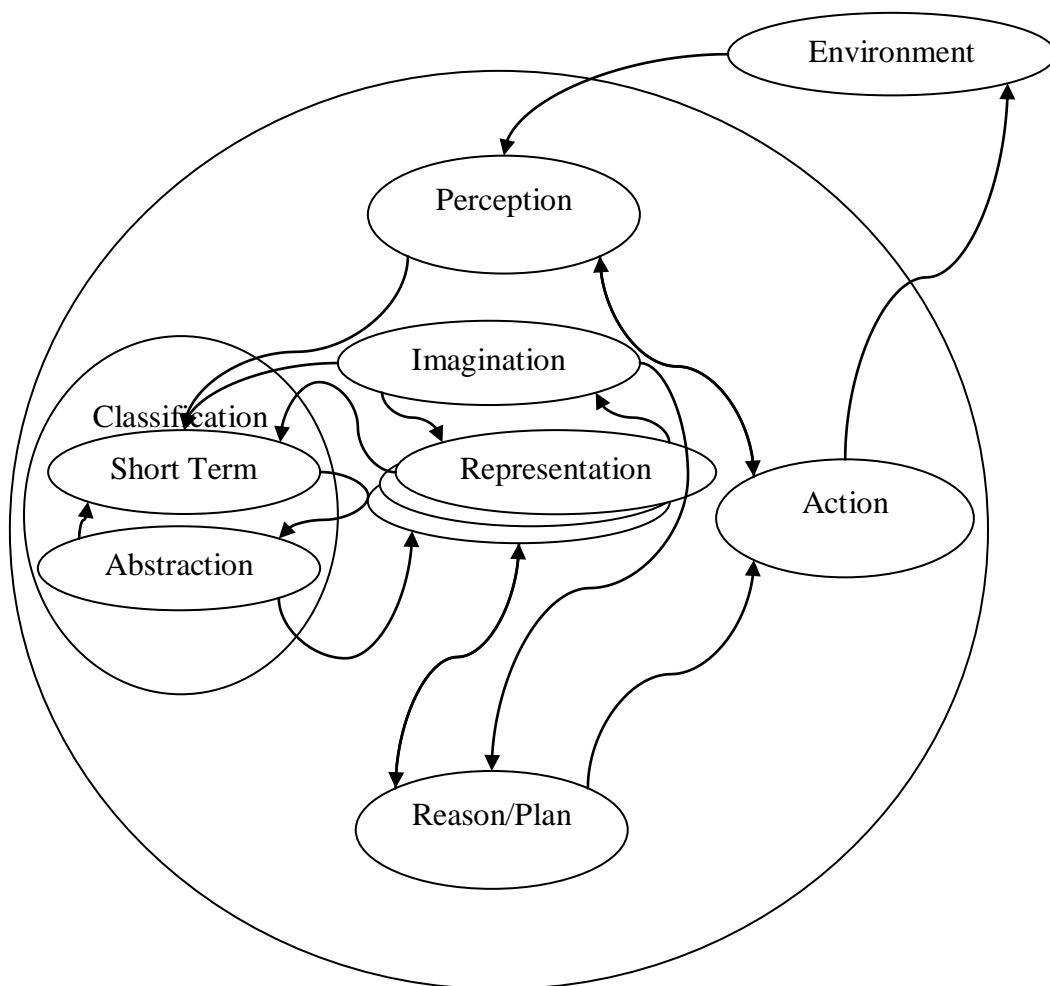


Figure 2 Multiple Internal models of cognitive system

Note that there is no component for Emotion, and that Learning is incorporated within the Representation module – in other words, the production and maintenance of the internal models *are* the way the system learns.

6 Perception, recognition and classification

The methods of perceiving, recognising and classifying information, necessary for the proposed system to be able to interact with its environment, including the people and other agents acting in that environment, build on the author’s earlier work in bio-acoustic species recognition (summarised in Appendix E). The processes of recognising and

classifying inputs and internal models involve creating abstractions of the base data (as per Noble).

Proposed methods include using a coding mechanism, which provides a level of abstraction, for textual material with which the system interacts. Pattern recognition can then be used on this coded form, and clustering techniques used to provide further levels of abstraction. If the system is later extended to include an audio interface, the previous work on human mood recognition could be further investigated and extended to attempt to detect the emotional state of the user.

In order to assess the ‘meaning’ of a particular piece of text, the system will have to determine the context in which it is both found, and referred to. One possible practical outcome of this is that if the user has referred to an item in a different context to the way it was originally presented, the system may be able to indicate to the user that there is a cognitive disjoint and re-present its own internal measures of concept space to the user to allow them to evaluate whether the mismatch is due to them or the system itself. In either of these cases, the event should present learning opportunities to both the learner and the system.

Although the system will be dealing primarily with text, it should be able to identify the presence of an agent responsible for the creation of the text. In order to be able to provide representations of Cognitive Centrality and Cognitive Consensus (Kleanthous & Dimitrova, 2006) (see Chapter 8), the system needs to handle models of individual agents (people, in general). The ways people represent themselves online are many-fold, and evolving in response to changing technologies and social norms. We call the online representation of self Digital Identity (DI) (Parslow, Øster Lundqvist, Porter-Daniels, & Williams, 2009).

6.1 Digital Identity

Following on from “Folskonomical Reification” (Parslow, Øster Lundqvist, Porter-Daniels, & Williams, 2009), we identified a gap in current understanding of online identity. In order to explore this area further, and to offer immediate help for people who

are living through the fast paced dynamic world of technological progress in online communications, often dubbed “Web 2.0”, the This Is Me project (sponsored by Eduserv) was designed to produce learning materials. The method used was to collect narratives from people about the way they represent themselves online, whether they have given it particular consideration or not. These stories were then analysed, using a form of Thematic Analysis, to draw out both the common and more important points. The learning materials themselves were then synthesized from the findings, and a number of worksheets and activities devised. These were published via the online publisher Lulu (www.lulu.com) (Parslow, Williams, Fleming, & Hussey, 2009), using a Creative Commons license.

Research into Digital Identity revealed the presence of a faceted view of an individual, with the information available to an observer being limited by a number of factors. The information which is available to inform peoples’ opinions can be created by the subject or by others, and may be explicit or implicit. For instance:

- I may post information about myself (self published, explicit),
- Someone else may post something about me (3rd party, explicit).
- I may only post at certain times of day (self, implicit),
- Others may only address posts to me in response to my own posts, rather than initiating contact (3rd party, implicit).

There are other ways of classifying these types of information (Schneier, 2009), emphasising different criteria (for instance, information included in the “Service Data” such as username, or email address). A caring personal agent should be able to recognise these different types of information, and use them to inform its internal models of the user and others in the user’s community.

6.2 Parallels between documents, people and communities

In order to be able to use a common set of classification and recognition tools, it would be beneficial to be able to abstract different types of entity in similar ways. From this

perspective, it is fortunate that there are a number of similarities between entities, when viewed from a text-based perceptive framework. It is hypothesised that it should be possible to create a common model framework for the system to use when analysing documents, people and communities, which has the benefit of adhering to Ockham's Razor that "entities must not be multiplied beyond necessity".

Documents comprise a set of words which can be tokenised and analysed using techniques such as Latent Semantic Analysis (LSA) (Scott Deerwester, 1990). The basic technique involves using a 'bag of words' approach, which can be represented as a vector. Extensions to this, currently being investigated, include a 2nd order representation where each token is replaced by a vector of vectors representing exemplars of the words typically found in the context of that token. This allows for the potential of multiple meanings, which, in theory, can be deduced by the context in which a word is found. Another alternative is to extend the mechanism by including Bayesian analysis, and inferring the intended contextual meaning. Documents are written by, and read by, people, and can be in response to other documents.

People, amongst other activities, produce written content. They each have a preferred lexicon, and at a given point in time can be represented by what they have written. In addition, there are time-based elements to their DI, and they have interactions with both documents and other people. The same 'bag of words' approach can be applied to classifying and recognising people as with documents. Communities, as collections of people acting because of a common interest, can also be represented in the same way.

6.3 "Concepts"

The LSA approach is a computational method for tracking 'concepts' (Skoyles, 2001), which may also be used for analysing a person as a 'concept', or a community as a 'concept'. Representing a concept-space in a way which is readily interpretable by a human is a non-trivial task. Ideally, for many users, a simple graphical view would be beneficial, but the nature of word-space, people-space, community-space and concept-space is highly dimensional, and so far efforts to provide a suitable form of dimension

reduction have shown that important information is lost when attempting to ‘squeeze’ these spaces into a limited number of dimensions for graphical representation and communication.

Further work, however, is envisaged in this area, to allow the system to provide a simple way of conveying inferred information to the user. An alternative to a graphical method would be to engage in a dialogue with the user, or to attempt to express relationships and attributes such as cognitive distance from the centre of a community in terms of simple textual descriptions.

7 Representation, Reasoning and Learning

The areas covered in this chapter are future work aspects of the project, giving an introduction to the planned features of the architecture, design and implementation.

7.1 Representation

Representation is still very much an open question. The main body of represented knowledge in the system will be embedded in the models of the external environment, other agents and the model of self. A pragmatic approach to modelling will be taken, with no claims about their biological analogues (such as in (Coward & Gedeon, 2005)).

In general all data stored on computers is in the form of vectors. Where feasible, data will be abstracted to a vector form, which is particularly useful for many AI algorithms and for concise storage. The abstraction can be seen as having a two-fold purpose; both to attempt to model a higher level view of the data, and to compress the necessary data size. From the perspective of abstracting higher level, semantic data from textual sources, initial plans were to use a combination of clustering and Markov chain modelling, inspired by taxonomical classification of DNA, but alternative methods such as analyzing linguistic morphs are to be considered (Creutz & Lagus, 2005), along with other methods of representing data concisely (Lagus, Alhoniemi, Seppä, Honkela, & Wagner, 2005).

Additionally, a method of population distribution modelling, Climate Space Modelling (CSM) (Robertson, Caithness, & Villet, 2001) is thought to be a good candidate for modelling the presence of ‘concepts’ in particular data sets, and will be explored in more depth. Previous work on producing explanatory models from population models resulting from CSM will be utilised in this investigation.

The system will also take advantage of the FFS developed for the MeAggregator™ project. Whilst this will form an important technology for the implementation, it may also be considered as being a part of the toolset the resulting agent will have at its disposal, rather than be the core method of representation. The lower level representations will provide the syntactic and textbase levels of representation, and the FFS will be used primarily for a situational representation for the agent (Frank, Koppen, Vonk, & Noordman, 2007) (Hirsimäki, Creutz, Siivola, & Kurimo, 2005). Where possible image data will also be represented and statistical models used, and consideration will be given to automated knowledge extraction techniques (Karkaletsis, Paliouras, & Spyropoulos, 2005).

7.2 Reasoning and Learning

Methods of reasoning are dependant to some extent on the representations chosen. Where information is stored in an ontology, such as is the case with the FFS, it is possible to use inference engines to extract information. However, the system should also be capable of using its ‘imagination circuit’ to consider hypothetical actions, or hypothetical goals and evaluate them in the context of its internal modelling system.

The architecture allows for a combination of algorithms for this, ranging from rules based to connectionist and evolutionary, and it is important to ensure that the underlying representation supports these. The system will be implemented to allow different reasoning modules to run alongside one another, and use the internal modelling system as a global workspace, thus providing an internal competitive market for the different technologies.

Some of these reasoning systems will be machine learning systems, whilst others will be logic engines. The comparative efficacy of the systems will be an interesting research result in itself, as whilst there may be some time constrained decisions to be made, the system will still be able to benefit from methods which take longer but which produce a more useful result.

7.3 Design and Implementation

During development, the various modelling, reasoning and learning modules will be prototyped and tested, and it is hoped that this will lead to some interesting findings on relative performance and possible benefits of multi-modal data processing. Consequently, it is expected that tests will be run on one machine whilst development of other modules continues on another, in order to improve the efficiency of use of human resources.

The agent will be designed to try to model and learn from all the events it experiences, so it will not be seeking just to learn how the user interacts with resources and model them, for instance, but also how it the user chooses to configure it, how modifications occur to its own Open Learner Model (Bull & Kay, 2007), and when it has enforced downtime. It is also unlikely to be feasible to perform the amount of modelling activity the system will require during periods when the user is using the computer, so the system will be designed to use periods when it does not have to monitor activity as opportunities to do this modelling. This is thought to be similar in nature to the activity of the brain during sleep cycles.

8 eLearning and collaborative working

The primary purpose of the deliverable agent is to support learners. A first stage is a recommender system, and subsequent models should support a limited dialog engine to encourage retention of interest in a subject, and eventually a dialogic learning system to allow the learner to collaboratively learn with the agent.

In order to support the learner, it is desirable to create and use a learner model, and an efficacious way of doing this whilst enabling the learner to retain control is through an Open Learner Model (Greer & Bull, 2003). From this perspective, it is envisioned that the system will maintain an OLM of both itself and its learner, and both participants will be able to update their own and make suggestions on what should be changed in the other party's model.

8.1 Collaborative working - requirements

As mentioned above (Chapter 3) Kleanthus et al bring together the required components for a system designed to support collaborative working. These can also all be viewed in the context of a design for an agent based cognitive system, and thus also of a machine consciousness capable system. These are (Kleanthus & Dimitrova, 2006):

- **Transactive Memory (TM):** Supporting the way information is transmitted between participants in the community.
- **Shared Mental Models (SMM):** Representations of models of the shared context the team members have.
- **Cognitive Consensus (CCs):** Representing the shared conceptualizations and their meanings. The represents the consensual reality of the group, and the lexicon they use for communication.
- **Cognitive Centrality (CCen):** Support for maintaining the movement of individuals between the centre of the community's thinking and the edges. Whilst the central position is important for maintaining the purpose of the group and a degree of predictability in their working practices, having those near the periphery is important for challenging the status quo, maintaining a flexible community and enabling cross-over with other communities.

From the perspective of the agent as part of a collaborative team (the user and it, at the least), it should, as a whole, support these facets. However, they should also be useful in the design, and design decisions will be checked against this list.

8.2 *Pedagogy*

It is currently assumed that the agent will be designed to support a constructivist pedagogy, as a collaborative learning partner, supporting a connectivist learning environment. In other words, it will support the learner in creating academic work to be viewed by others, and will help provide knowledge on where information can be found, how relevant it is to the current task, and how trustworthy the learner is likely to find it.

The prototype system will be assessed on the support it provides as a learning aid, in addition to the primary comparison between versions of the system with and without attempts to develop consciousness, because obviously this is a key element in the system gaining wide enough acceptance to be extensively used.

9 Project Plan

9.1 Ethical considerations

Feedback from conference delegates at Durham University's 8th Annual Blackboard Users Conference, focussing on eLearning and Connectivism, indicated that delegates believed that the design and use of this sort of agent would be ethical, as long as the ethical rights of the potentially conscious agent were taken into account. This result was as the assumption had been that educators and educationalists would be more likely to consider the system as 'just a machine' and to prioritise even minor ethical considerations with respect to using student volunteers to test the software. It is important to ensure that a request for ethical approval is made to enable the research to continue without subsequent interruption, highlighting

- a) the potential ethical issues relating to testing the prototype with students, and
- b) the rights of the software in the event of consciousness developing.

9.2 Integrating the parts

Within the context of the project, the background on consciousness forms the framework for the development of a machine agent capable of supporting an emergent consciousness. This is supported by the work on communities and roles, with the idea of the conscious self being an emergent property of individuals within a community. The use of a folksonomical file system to provide the agent with tools for manipulating knowledge provides a short-cut, enabling ease of development as the agent can externalise the representation of the resources which it experiences, develops and exploits.

These components lead to the development of a machine consciousness framework, based on the main features of cognitive systems. The initial work on perception, recognition and classification go towards the agent's internal modelling mechanisms, and its interaction with the environment. In order to be adaptive, the system has to be able to learn, and this is embedded in the modelling sub-system. Reasoning is necessary for the

system to be able to interact with other agents (human or machine) and is based on both rules based and connectionist theory, although it still has to be fully developed.

9.3 Gantt chart (future work)

Task	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr on
Literature review (ongoing)														
Assistant spec & design	5.1													
Implement prototypes														
Design systems test														
Run prototype tests														
Evaluate and re-design						1.7								
Paper on initial test results							1.6							
Design new prototype														
Implement new prototypes														
Test prototype, evaluate, maintain												1.8		
Evaluate													1.7.4	
Write up														

10 Future Avenues

10.1 Consciousness Studies

In the short term, the agent will give a tool for simple studies into whether there non-embodied system can show any signs of developing ‘symptoms’ of consciousness. Additionally, the agent architecture can be used as a framework for fully automated agents existing in an environment without humans, in a mixed artificial consciousness/artificial life simulation experiment. Both of these can be envisaged with only minor amounts of further software development.

In the medium to long term, the system should provide a test case for various experiments, and if it does demonstrate elements of consciousness, can be used in multiple ways to support education and to simulate people in environments which would be inappropriate for real people to be put in (assuming ethical approval can be obtained).

Modular replacement should also allow for experiments to be designed to test the dynamic nature of cognition and representation (Stamovlasis & Tselfes, 2005), using the system as a platform for further research.

10.2 Collaborative working and eLearning

Analyses of group working can offer a potential benefit to the industry, service and education sectors. Recent work using self organising maps show some benefits (Russell & Honkela, 2005) and it is hoped that a conscious agent working alongside group members, or many as partners to each member could also work in an ethnographic role, allowing for less ‘invasive’ group studies to be performed.

The system should also be suitable for further development as a core member of a collaborative group, working to convey information between team members, manage members’ relationships with the group and encourage a central consensus – covering, in fact the core components brought together by Kleanthous.

10.3 Conclusion

This report has drawn together the work on eLearning, communities, folksonomies, Digital Identity and consciousness since October 2007. Whilst the initial work on bio-acoustic recognition met with some problem areas, the opportunities it provided for developing codebook generation techniques and clustering experience are invaluable.

Feedback from conference indicates that there is a degree of support in the eLearning community for this type of research, and that there is a reasonable level of confidence that it will be able to provide support for at least some categories of learner.

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Colleagues from around the UK HE and FE sector and beyond, who have generously given their feedback and encouragement at conferences and JISC meetings.

My Personal Learning Network of individuals from around the world involved in eLearning, community and consciousness studies. There are too many to mention, but many of them can be found on my “following” list on Twitter (<http://twitter.com/PatParslow/following>)

Training record

- COGRIC workshop, 2006
- Endnote training
- Statistics course (2 day)
- Approximately 20 School Research Seminars
- Approximately 8 IRC Research Seminars, plus presentation of 3 further sessions
- Teaching of MSc modules “Applied Informatics” and “Research Methods” 2 days (supervised), plus approx 3 days unsupervised
- Setting and marking examinations and coursework for MSc, with half day training
- Intellectual Property training (CSTD)
- JISC training on project evaluation (1 day)
- JISC workshops on open source development and dissemination (1 day)
- Practical project proposal writing, with Dr Tang and Prof. Liu, and subsequently with Dr. Williams and Dr. Browne
- Communications in meetings, consultant J. Smith
- Open Source training, OSSWatch (half day)
- Open Source License evaluation (self, based on materials from OSSWatch)
- CoP3D events, and explorative learning in 3D environments
- Focus groups for RedGloo, the Systems Engineering learning landscape
- JISC workshops on Personal Learning Environments
- Mentoring students with disabilities
- CDOTL University Teaching and Learning Days (2 days)
- Training for peer reviewing papers with Dr. Williams
- Writing Successful Research Proposals (CSTD)
- Research Ethics for Research Staff (CSTD)
- Project Management (CSTD)
- Moving to a University Lectureship (CSTD)
- Supervising Research Students (CSTD)
- Management Skills (CSTD)

- CMALT accreditation (Association of Learning Technologies)

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http://www.lulu.com/items/volume_67/8327000/8327319/2/print/8327319.pdf
- Pat Parslow, Sarah Fleming, Shirley Williams, "This Is Me", 2009, 2010 (2nd ed), OdinLab, Lulu
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- Pat Parslow, Sarah Fleming, "Understanding Digital Identity", Workshop LTEA 2009 University of Reading,
- Pat Parslow, "This Is Me - Exploring Digital Identity", Workshop 4th Plymouth e-Learning Conference 2009 University of Plymouth,
- Pat Parslow, "Collaborative software", IT Supporters conference 2009 University of Reading,
- Pat Parslow, "Social Networks supporting eLearning in Enterprises", online EVOLVE/EduCamp seminar 2009,
- Pat Parslow, "Digital Identity for Researchers", Workshop Web2.0 Technologies NeSc Edinburgh 2009,
- Patrick Parslow, Karsten Øster Lundqvist, Edwin Porter-Daniels, Shirley Williams "Folksonomological Reification", 2009, OdinLab, Lulu
- Shirley Williams, Pat Parslow, Karsten Øster Lundqvist, "Position paper on the Future of Social Networking", W3C Workshop on the Future of Social Networking Barcelona 2009,

- Pat Parslow, "Digital Identity", Workshop, ThoughtFest09 EVOLVE Manchester 2009-09-03,
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- Shirley Williams, Karsten Lundqvist, Robert Ashton, Michael Evans, Patrick Parslow, Edwin Porter-Daniels, "Developing Community via the RedGloo Learning Landscape", AOIR9.0 Copenhagen 2008,
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- Rob Ashton, Shirley Williams, Pat Parslow, "The use of online metrics in online communities", AOIR9.0 Copenhagen 2008,
- Pat Parslow, Shirley Williams, Mike Evans, Karsten Øster Lundqvist, Rob Ashford, Edwin Porter-Daniels, "E-Learning Communities and Spaces", AOIR9.0 Copenhagen 2008,
- M.P. Evans, S.A. Williams, P. Parslow, R.P. Ashton, K. Ø. Lundqvist, and E. Porter-Daniels, "The MeAggregator: Personal Aggregation and the Life-Long Tail of the Web", International Symposium on Human Aspects of Information Security & Assurance 2008,
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Appendix A – Personal statement

Attempts can be made to be objective, but it is an unfortunate fact that all our experience is coloured by our previous experiences. Our perceptions of an outside, objective reality are only ever available to us in the form of our filtered, subjective models learned through a lifetime of interaction with our environments.

Scientifically, whilst we strive to observe, measure and explain the objective, we must keep in mind that our experience has an impact on our interpretation of new stimuli. It is becoming quite conventional to consider consciousness introspectively, and I consider that it is therefore important to use language to express the level of subjectivity or objectivity of observations when writing.

Using a passive, third person writing style to emphasise the purported objectiveness of a paper is, I would argue, often a mistake as it conveys a level of objectivity which cannot be supported by the underlying facts. In the social sciences, and in philosophy, there is a gradual move towards adopting a more honest style of writing, using the passive, ‘scientific’ style where appropriate, but using the first person to indicate that the author accepts that there may be subjective views being expressed.

In this document, I have in general used the normal passive style, but on occasion there are some aspects where I am conscious that my personal views on the subject are being expressed. In order to allow the reader to decide on the level of subjectivity and evaluate for themselves the validity of such material, I have included a brief biography:

I am a white British male, born in 1966 in Kingston, London. I took an early interest in the Sciences, and initially studied Cybernetics and Computer Science at university. However, due to personal circumstances, I did not finish his first degree, and went on to work in computing, land survey, and civil engineering for twelve years. During this period I studied civil engineering, mathematics and computing at university level, before returning to full time university education.

I read Intelligent Systems (BSc, Hons, I) and Applied Informatics (MSc, Distinction) motivated by a desire to study and research the possibility of machine consciousness. I am essentially physicalist in outlook, although this leads me to an idealist point of view after considering the experience based nature of the mind. I do not firmly reject the possibility of a dualist reality, chiefly because I do not consider that the evidence has been sufficiently well examined.

Appendix C

Based on work by Etienne Wenger, kindly drawn to my attention by John Smith. The summary this is based on can be found at

<http://groups.yahoo.com/group/com-prac/message/1559>

Type of leadership	Definition	Typical activities	Role analysis
<i>Coordination</i>	Keepers of the community	Organize events, talks to members, keeps the pulse of the community	Community/Pastor & Community/Secretary
<i>Networking</i>	Keepers of relationships	Connect people, weave the community's social fabric	Networking/Socialite
<i>Facilitation</i>	Keepers of conversations	Set agendas, watch over conversations, keep notes, provide pointers and summaries	Community/Bureaucrat
<i>Documentation</i>	Keepers of the repository	Organize information in order to document practices, update and clean up the knowledge base	Information/Librarian & Information/Reviewer
<i>Expertise</i>	Keepers of the heritage	Thought leaders and recognized experts uphold and dispense the accumulated wisdom of the community	Knowledge/Elder

<i>Learning</i>	Keepers of insights	Watch for nuggets, collect emerging pieces of knowledge, standards, and lessons learned	Information/Harvester & Novelty/Librarian
<i>Inquiry</i>	Keepers of questions	Notice emergent questions, keep them alive, outline a learning agenda, and shepherd "out-of-the-box" initiatives	Learning/Champion & Dialogue/Facilitator & Novelty/Champion
<i>Boundary</i>	Keepers of connections	Connect the community to other communities or constituencies, act as brokers and translators	Community/Ambassador
<i>Institution</i>	Keepers of organizational ties	Maintain links with other organizational constituencies, in particular the official hierarchy	Organisation/ Ambassador

The idea being to evaluate the role separately to the domain, and enable a richer description of roles within the community as a result. Additionally the separation should make comparison between communities easier, and allow for better comparisons within a community, including finding areas of potential synergy.

Appendix D

Facebook & BlackBoard: comparative view of learning environments

Ashton, R., Evans, M., Lundqvist, K.O., Parslow, P., Porter-Daniels, E., Williams, S.

Abstract

For several years, online educational tools such as Blackboard have been used by Universities to foster collaborative learning in an online setting. Such tools tend to be implemented in a top-down fashion, with the institution providing the tool to the students and instructing them to use it. Recently, however, a more informal, bottom up approach is increasingly being employed by the students themselves in the form of social networks such as Facebook. With over 9,000 registered Facebook users at the beginning of this study, rising to over 12,000 at the University of Reading alone, Facebook is becoming the de facto social network of choice for higher education students in the UK, and there was increasing anecdotal evidence that students were actively learning via Facebook rather than through BlackBoard. To test the validity of these anecdotes, a questionnaire was sent to students, asking them about their learning experiences via BlackBoard and Facebook. The results show that students are making use of the tools available to them even when there is no formal academic content, and that increased use of a social networking tool is correlated with a reported increase in learning as a result of that use.

Introduction

In many Universities, students are given access to an institutionally provided Virtual Learning Environment (VLE) such as Blackboard. With the widespread adoption of social networks such as Facebook, however, an increasing number of students have begun to use what is termed a Personal Learning Environment (PLE): that is, a suite of tools chosen by the students themselves to support their learning (Conole et al 2006).

The impact of the PLE and its effectiveness in learning is important to assess from an educational point of view, as the most effective eLearning tools need to be supported in order to maximise institutional resource use and accessibility for learners. We have therefore designed a study to assess both the way in which a VLE is used by students at the University of Reading (UoR), and how it compares with the students' use of a PLE. Specifically, we compare the Blackboard VLE, which is provided to all students of the UoR, with the Facebook social network, which anecdotal evidence has suggested is becoming increasingly used as a PLE by students (although not necessarily as an intentional study tool). The study was designed to determine whether or not the anecdotal evidence is correct, to assess the perceived educational impact of the PLE vs the VLE for learners, and to examine whether there are any differences in use due to gender.

Background

Facebook (<http://www.facebook.com>) was launched in 2004 as a social network platform, and was initially only available to people at educational institutions. In September 2006 it broadened its user base, accepting anyone with an email. It follows the so-called Web 2.0 paradigm of providing its users with simple publishing and asynchronous communication tools. It also provides a limited, and slightly esoteric, permissions model, allowing control of access to various content at a group level. However, groups themselves are defined by the information people put on their profiles. For example, if someone wants to be within the staff group of a university (college) network, they need only edit their profile to say that they have a job there.

In contrast, Blackboard (<http://www.blackboard.com>) was designed from the outset as a dedicated VLE, and is provided by institutions such as Universities specifically for their staff and students. All content is arranged by courses, which map to the modules students are enrolled on. Wiki and blog tools are available, and are only viewable by people enrolled on the course specific to a particular blog or wiki. Students do not have control over access permissions, although they can modify the privacy settings for the personal information.

Anecdotal evidence points to students avoiding Blackboard because they feel it is restrictive, confusing and that they are being watched. Ironically, whilst it could be reasonably argued that the plethora of tools on Facebook is confusing, and people reveal much more personal information there than on the VLE despite knowing that staff also use the service, the same feelings do not apparently apply there.

Recent work at Durham University (Cameron and Fox 2007) has combined a case study with an online survey of students. There is evidence that informal learning, including book reviews and subject related dialogue, is taking place on Facebook, alongside the social discussions one expects in an un-moderated forum. Approximately 25% of their respondents are conscious of learning through informal use of Facebook. The Durham study was motivated by a noticeable decrease in discussion activity on Blackboard, and the observation that Facebook was being used.

Survey design

The initial UoR study was designed such that alongside basic demographic data (age, year at University and gender), respondents were asked to answer 10 questions about their experiences with both Facebook and Blackboard. The two sets of questions were identical, except for the name of the software ('Facebook' and 'Blackboard') and were presented as separate surveys, so that the respondents were not directly comparing the two. However, to maximise the number of useful responses, each respondent was asked to complete both surveys.

For Facebook, the questions asked and the range of options are presented in Table 1.

Table 1: Survey questions

1. During term time how often (on average) do you consult Facebook?
Several times a day, Several times a week, Once a week, Less than once a week
2. How often (on average) do you post stuff on Facebook?
Several times a day, Several times a week, Once a week, Less than once a week
3. Do you feel Facebook is an appropriate place in which to learn?
Yes, No, Maybe, Don't know
4. Have you ever discussed coursework on Facebook?
Yes, No
5. Have you found people on your course in Facebook that you wouldn't normally speak to?
Yes, No
6. Would you be happy discussing coursework with a lecturer via Facebook?
Yes, No
7. If you posted something about your course, would you want it to stay on Facebook for later years benefit?
Yes, No, Maybe, Don't know
8. Would you say that anything you read on Facebook helped you learn?
Yes, No, n/a
9. Would you say that anything you posted on Facebook helped you learn?
Yes, No, n/a
10. What do you think would make a good eLearning environment?
(open ended)

The survey was offered to approximately 200 respondents online, using SurveyMonkey (<http://www.surveymonkey.com>), which obtained 33 responses (response rate ~ 15%). However, only 14 respondents answered both surveys, with seven answering just the Blackboard survey, and 12 answering just the Facebook one.

Further returns were obtained by canvassing students at catering outlets on campus, and this produced a further 23 paired sets of data (response rate 85%), and respondents' comments whilst completing the surveys were considered as providing further explanatory data. A small number of follow-up interviews were also held to gain an impression of possible reasons for observed features of the results.

Based on the initial responses a new survey was designed that asked respondents about both Facebook and Blackboard, along with some general questions (see Appendix A for the list of questions), and improved demographic details. The link to this survey was sent to a university wide list of administrative/academic contacts in each school with a request that they pass it on. This achieved 354 responses in 5 days. Although the sample size is better than the original prototype survey response, the analysis remains in general terms as there is likely variability across subject areas and individuals as to who received the survey and who chose to respond.

Basis of comparison

Blackboard and Facebook are not designed with the same criteria in mind, and therefore it is not reasonable to perform a direct comparison of the two. However, both are being used by students as part of their personal learning environments, and the survey shows that both are contributing to their learning.

Two main factors influence the effective use of a learning environment: its technical capabilities, and the policies governing its use. As far as technical capabilities are concerned, both Facebook and Blackboard provide users with the ability to access information, to discuss topics of interest, and to post material for others to view. Both environments are also extensible, though in different ways.

Facebook has introduced the open Facebook Platform, which is free to develop for, requires no license, and which has resulted in many third-party plug-in applications being developed, supporting a range of publishing options, including embedding music and video in a page. Blackboard also supports the development of third party plug-in applications through the use of its Blackboard Building Blocks technology, but although an open system, the majority of third party Building Blocks are expensive, and must be supported by the institution hosting Blackboard.

With respect to policy, Facebook discourages the most undesirable of behaviours, but the lack of direct surveillance by academic staff makes it more suitable for self-organising communities to be able to set their own standards in user made groups. In contrast, an institution's policy naturally impinges upon students' freedom of expression in an institutionally provided system such as Blackboard, which helps provide a safe environment, but at the cost of frank and open discussion.

One other area of interest is the role each environment plays in enabling a student to locate other students with similar interests. Facebook, for example, is designed to encourage users to build their social networks, enabling them to meet friends of friends, and to expand their online social groups beyond the boundaries of a particular module. Equally, the existing implementation of Blackboard at UoR does provide some methods of accessing email addresses of various subsets of other users, including those who are enrolled on the same modules. However, other personal information fields are not populated, which is reasonable on the basis of privacy concerns, but there is no way for the user to fill them in, which therefore restricts the potential for exploring the learning community.

Results of the comparative analysis of Facebook vs. Blackboard

Assessing usage of Blackboard and Facebook

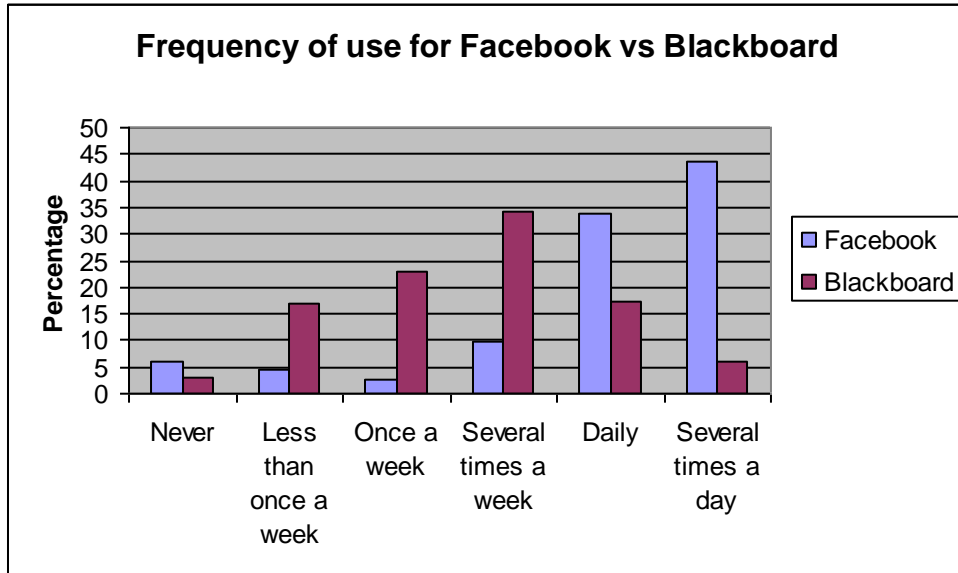


Figure 1: Frequency of use for Facebook vs. Blackboard

As can be seen from figure 1, Facebook is used much more frequently than Blackboard, with the majority of students using it several times a day, compared to Blackboard, which is most often used several times a week. This reflects the different uses of Facebook, though, as Blackboard only has one purpose – eLearning – whereas Facebook is much more of a social tool than an eLearning environment.

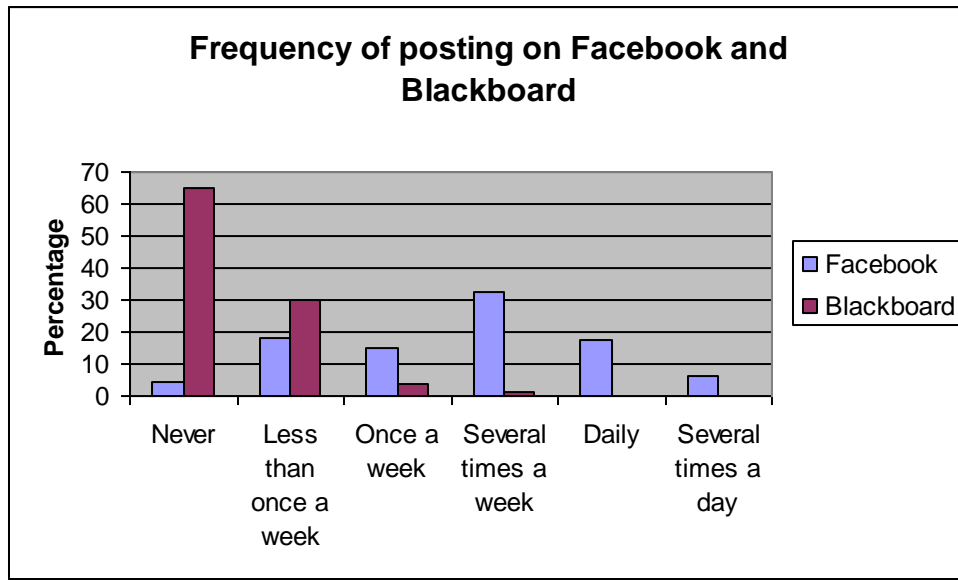


Figure 2: Frequency of posting for Facebook vs. Blackboard

In terms of how frequently students post information in the different environments (a reflection of their engagement), again students engaged in Facebook’s communities much more than in Blackboard’s. As figure 2 shows, students are much more engaged with Facebook than they are with Blackboard, with the most popular frequency of posts being several times a week for Facebook, compared with never for Blackboard.

There could be two reasons for this. Firstly, not all Blackboard modules are set up to enable students to post information to them. Indeed, 27% of students said that none of their modules enabled information to be posted. Secondly, Facebook is designed as a community system, with information sharing between friends being integral to its operation.

The usage of Blackboard follows more of a one-way broadcast paradigm, whereby the lecturer publishes information that the student reads. It is recognised that UoR have not been early adopters of some of the web 2.0 tools (e.g. blogs, wikis and social bookmarking) available within the BlackBoard academic suite, and that use of these may dramatically influence the nature of communication using the VLE.

As far as usage and interaction is concerned then, Facebook is used more often than Blackboard in a general way, and students are far more engaged with it than they are with Blackboard.

Assessing students' perceptions of Facebook as a learning environment

We asked our students if they felt that Facebook and Blackboard were appropriate places in which to learn. Only 7% felt that Facebook was an appropriate place to learn, with 42% responding maybe, and 41% stating a resounding no.

In contrast, 75% of students felt that Blackboard was an appropriate place to learn, with 21% responding with maybe, and only 3% stating no. Clearly, Blackboard is seen as the most appropriate place in which to learn, while Facebook is perceived mainly as a place in which social interactions occur, and not learning.

This, too, is unsurprising, as Blackboard is an institutionally-provided system, and as such, is introduced to the students explicitly as a learning environment. In contrast, Facebook is adopted by the students by their own choice, and is designed as a social network, and not as an eLearning tool. The students' perceptions, therefore, follow closely with how each system is sold to them.

However, despite their perceptions, what was revealing about this study was just how many students do in fact learn through using Facebook, despite the majority of them seeing it as an inappropriate place in which to study.

Assessing Facebook and Blackboard as learning environments

Our study revealed that more students have discussed coursework on Facebook than on Blackboard (51% vs. 30%), despite students not seeing Facebook as an appropriate environment in which to learn. Intriguingly, 89% of students would be happy discussing coursework with a lecturer on Blackboard compared with just 57% on Facebook, yet Facebook still remains the most popular environment for discussing coursework.

Possibly more interesting still are the reasons given for not being happy discussing coursework with a lecturer on the two services. Privacy issues featured more highly for Facebook users – 49% cited this as a reason, whereas only 29% of BlackBoard users considered this a major problem, which is to be expected, and similarly 77% of Facebook users who would be unhappy about discussing coursework with a lecturer on the service said it was because they wanted to maintain separation between academia and social life. Most strikingly, however, on Facebook, 61% said it was not a suitable place for such discussions, but on BlackBoard this answer was given by 85%.

This could be because of the lack of discussion facilities available on Blackboard, or the fact that discussing things going on in a person's life is more natural on Facebook (and coursework is certainly a large part of a student's life, particularly close to deadlines). It could equally be due to the audience (i.e. the set of people who will read posts and comments) – on Facebook, the audience is generally friends and family, whereas on Blackboard, it is fellow course-mates. Generally, friends and family will be a less hostile audience than other people on the same course, which could make commenting on coursework in Facebook less intimidating than on Blackboard.

Further study is needed to determine the exact reason why more students discuss coursework on Facebook than they do in Blackboard, but irrespective of the reason, it is clear that Blackboard is not being used effectively as a two-way medium in which coursework discussions take place, and so may not represent the best learning environment for students.

Assessing Learning in Facebook and Blackboard

Another finding of note is that 31% of students said they had learned something from a Facebook post compared with 92% of Blackboard users. However, this should be understood in the context of each environment's primary purpose: Blackboard is purely designed as a VLE, and has no other purpose other than to foster learning.

In terms of a student's intent, only 15% use Facebook intentionally to learn, implying that most people use Facebook for other (more social) activities. However, perhaps more surprising is that only 49% of students use Blackboard intentionally to learn, implying that the remainder use it simply as a place from which to download course notes. The fact that 92% of people learn from Blackboard is not a surprise; it is surprising that so few people *choose* to discuss their coursework in Blackboard. This is backed up by the fact that 60% of students said they would not learn anything from Blackboard if there were no course lecture notes.

Assessing how students use Facebook and Blackboard, 22% use Facebook groups to discuss coursework, while 22% use it to share resources, compared with 17% of students who use Blackboard to share resources. 57% of students reported they had found people on Facebook who they would not normally speak to, compared with only 12% on Blackboard, which may contribute to the reported incidence of learning in Facebook.

Determining the most popular technologies of a PLE

Facebook, of course, is just one part of a student's PLE, and so we asked our students what other technologies they used as part of their learning environment. From their responses, email was the overwhelming tool of choice, with nearly 60% of respondents using it to discuss coursework. A similar number (54%) also used some form of Instant Messaging application, while nearly 4% used some form of Web-based Groups application (such as Yahoo Groups or Google Groups).

Organic vs. institutionally-driven environments

Our study has shown that the majority of students see Blackboard as an appropriate place in which to learn, while Facebook most definitely is not. Despite this, Facebook is the environment they choose to discuss coursework, with Blackboard only being used to download lecture notes.

As such, the key to an effective eLearning system is more about the environment than it is the features it offers. Facebook offers no features dedicated to learning, yet it is used more frequently for just this purpose than Blackboard, a dedicated VLE.

Looking at the two systems, there are several reasons for this:

- Facebook is used much more commonly than Blackboard, both in terms of reading content, and, crucially for learning, writing content. This difference in exposure is likely to contribute to users' skill in navigating the site, and therefore their ability to use it for whatever purposes they choose.
- The environment's audience is key: Blackboard provides a dry audience comprising solely of classmates and lecturers, thereby reflecting the rigidity of a lecture; in contrast, Facebook provides an audience of friends and family, free from the formal constraints that exist in a lecturing situation. By replicating the feel of a lecture, Blackboard has potentially alienated the students it was designed to help; conversely, by replicating the feel of a group of friends, Facebook has become a safe place in which difficulties with coursework can be discussed without fear of ridicule from either the lecturer or their fellow classmates.
- All communications on Blackboard can be monitored by staff, and students may tend to prefer to be able to control who can watch as they explore topics. Facebook provides the students with the control over who sees their information and comments, rather than Blackboard's approach, which gives control to the lecturer.

This shows a contrast between the two environments: the rigidly imposed framework of Blackboard, which creates a learning environment defined for students according to what the university thinks they need, and which attracts infrequent access; and the highly flexible, organic environment of Facebook, in which a learning environment is free to emerge based on what the students themselves actually need, and is focussed on frequent social interaction.

Clearly Facebook does not, at present, have enough tools to foster a complete learning environment, and there is some resistance to using a social tool in an educational context. However, there is also significant potential in using Facebook to support the education of students in a way that traditional learning environments such as Blackboard cannot. The following sections discuss some of the benefits and mechanisms at work that underlie learning within Facebook.

Social Connectivity

Facebook helps students connect with other students on the same course as them. For example, 60% of Facebook users found other people on their course through Facebook – 4.7 times as many as those who found other people through Blackboard. This, despite the fact that all UoR students who share a module are enrolled on the Blackboard site (over 24,000), whereas just over 12,000 are members of the Facebook Reading network, and some of those are alumni, hence it is estimated that around 60-70% of course mates will be on Facebook. These results are not dissimilar to the survey results for Durham, in which 81% of respondents are users.

It appears that Facebook is filling a key role in learning, by facilitating the formation of social connections based around social groupings rather than an educational subject. Groups formed in this way are more likely to lead to students who are more motivated and engaged with the subject. Facebook is supporting “peer tutoring in *ad hoc* transient communities” (Kester et al 2007), which is a mode of learning that is not readily supported by the implementation of Blackboard at UoR. Furthermore, because any individual can easily set up a group on Facebook and control who joins it, they have control over the privacy of their discussions.

Research shows that talking with people who show an interest in your topic of conversation promotes your own interest in it (Thoman et al 2007), and it seems reasonable to infer that the same will hold true in computer mediated communication. This implies that Facebook’s focus on social connectivity not only lubricates social

interactions across disparate groups, it also offers the potential to facilitate learning to a better degree than that offered by existing learning environments.

Learning from posting

From our study, we find a strong correlation between those who learn through posting on Facebook, and how often they do so. However, no such correlation is seen with the results for the Blackboard users, where learning is almost universally reported. We would expect, if the software provides a suitable learning environment, for this correlation to exist – so that more time spent interacting with a learning environment leads to more learning. It seems likely that the lack of correlation for Blackboard users is due to a false positive result, but it may be that posting less than once a week really does lead to 67% learning from the experience. Some respondents indicated in follow up interviews that they felt they had learned from Blackboard because it is used as a repository for lecture notes, and not specifically for any other reason. In the second survey this was addressed, and 64% of students reported that they did not think they would still learn from Blackboard if it was not used as a repository for notes. It is notable that 32% of Facebook users report learning from things they have read on the service, despite the absence of content, and 36% felt that they would not learn from using Blackboard under the same circumstances.

Online forums are often taken over by dominant individuals who seek to reinforce their own sense of superiority by use of authoritative language, and by posting negatively or argumentatively, and this behaviour is more typical in males (Guiller and Durndell 2006). However, in this study there was no significant evidence that this was an effect, probably because the two environments have their own means of enforcing reasonable behaviour. Blackboard operates within the University's Acceptable Use policy, and Facebook can provide a safe forum, in which the only members are friends. The Facebook method allows for a way to explore issues without feeling 'watched', although without the quality control supervision can provide. It does not preclude members of the peer group from contacting tutors, or even inviting them to the group, and thus provides a good level of flexibility.

Intentional learning use of the tools

The survey asked whether students intentionally used Facebook and BlackBoard for learning. The results from this question were surprising in several ways. In both cases, approximately half as many intentionally use the systems as learning tools as actually learn from using them. Only 50.5% of students reported intentionally using BlackBoard as a learning tool. And 27.8% intentionally use Facebook to learn. More strikingly, however, is the fact that of those intentionally trying to learn from Blackboard, 1 in 6 categorise their frequency of learning using it as 'never'. Of those intentionally using Facebook to learn, *all of them* report learning at a higher frequency than this.

Comparison with Durham survey

The Durham study shows 25% of their students using Facebook for learning with either other students or lecturers. UoR reveals 50% reporting having learned from Facebook use. The difference in questions may be the main factor, in that any learning success will result in a positive result in the UoR study, whereas the Durham question gets closer to the conscious intent of the learners in deliberately using the system to help them learn. It is also possible that different practices in the use of Blackboard have a major effect here. Use of Blackboard at UoR does not tend, in general use, to encourage social or collaborative learning, whereas the Durham case study, at least, indicates that it has been used more fully there.

The Durham study was motivated by a noticeable decrease in discussion activity on Blackboard, and the observation that Facebook was being used. It seems reasonable to suggest that this could result in the difference in Facebook learning results between the two studies, as the students may be more conscious of learning on Blackboard, whilst considering Facebook activity as being purely leisure, even though discussions on academic matters still take place. This is an area both teams consider would benefit from further research.

It is also important to note that the Durham study shows students rate their implementation and use of Blackboard highly. Cameron points out (Cameron, private correspondence, 2007):

“Our report shows that at Durham, students also rate Blackboard very highly. The textual feedback from many students is that they want the focus of Blackboard to be learning. Facebook is their social space, where they may also learn as a side effect. This does not replace the need for Blackboard where formal learning is the main focus. It may affect what we think about using it for and what we can expect students to use.”

The Durham study used the opportunity afforded by the students granting lecturer access to their Facebook group to inform the development of interaction on Blackboard. This should be seen as an example of good practice, although it may not be a method available in other circumstances, where, for example, the students may be uncomfortable with a lecturer’s presence.

Supporting learning with Web 2.0 Technologies

Constructionism suggests that learners will learn better when involved in creating something that others will see, use and review. As such, given that users are more likely to write content to Facebook, it should be much easier to use Facebook as an educational tool than Blackboard. Currently, many posts to Facebook are probably of a trivial nature, but this helps build familiarity with the tool, a sense of ownership, and consequently is likely to increase the probability of learners using the medium to post academic material. The opposite is true of the VLE, where, due to policy, posting non-academic matters is frowned upon, if not banned. This reduces expertise with the system, segregates learning from ‘fun’, and means that even academic contributions are likely to be viewed as a chore rather than a constructive and enjoyable experience.

Taking a broadly connectivist view of eLearning, the key ingredients of successful learning in today’s connected, highly dynamic environment, where knowledge has a short half-life are about recognising:

- knowledge exists in a diversity of opinions. Discussion and dialogue are therefore key components in learning;
- learning is a process of connecting information sources, of recognising and abstracting patterns arising from those connections;
- nurturing and maintaining connections is necessary to facilitate continued learning.

Both the VLE and PLE approach are capable of supporting the discussion and dialogue necessary, with formal learning being supported by the VLE, and informal by the PLE.

The PLE is better able to deal with the nurturing and maintenance of social connections, which means it is better able to support continued learning. The VLE could be adapted to provide access to social networking site data to overcome this difference.

A recent JISC report (Conole et al 2006) identified eight key factors relating to the way students are currently supporting their own learning using ICT. These are worth re-iterating:

1. *Pervasive and integrated:* Students use ICT to support all aspects of their study. Utilizing technology in this way, they are providing themselves with ubiquitous support options.
2. *Personalized:* Students are mixing and matching component technologies pragmatically to produce the tool suite they require for their own needs.
3. *Social:* Students study as part of a learning network, and are members of a range of communities of practice.
4. *Interactive:* The perceived worth of ‘content’ is dynamic. Content is not ‘fixed’ and ‘valued’; it is a resource to be adapted and remixed.
5. *Changing skills set:* Students are developing new evaluation skills and strategies to enable them to make critical decisions about resources. They are developing skills in managing hybrid forms of information, from traditional, web and web2.0 sources.

6. *Transferability*: Students are used to using their PC for leisure and study, and expect to be able to have easy access via this medium for course materials.
7. *Time*: Expectations of information and results on demand mean that students are using technological tools, such as email, instant messenger solutions, and social networks, to manage their time, and remain connected with their peers.
8. *Changing working patterns*: The use of new tools is changing the way students find, gather, use and create knowledge.

Traditional VLEs can only go so far in supporting these changes to the way students work. Whilst they may continue to hold a privileged position because of institutional policy decisions, it is unlikely that students will regard them as much more than a "... just a repository for notes" (survey respondent) unless they provide access to some of the social networking facilities endemic in web2.0 at the very least.

Six Web 2.0 technologies are identified (Anderson 2007) as having implications for education:

1. Blogs : Usable in Blackboard, within the scope of a course. Not present in Facebook, but a similar functionality is available with the notes feature, and through plug-ins.
2. Wikis : Usable in Blackboard, within the scope of a course. Not directly present in Facebook, but available through plug-in modules.
3. Tagging and social bookmarking: Unavailable in Blackboard, and unavailable in Facebook, except for tagging of photographs.
4. Multimedia sharing : Unavailable in Blackboard, available in Facebook.
5. Audio blogging and podcasting : Unavailable in Blackboard, available in Facebook (via plug-in and using other podcasting services)
6. RSS and syndication : Incoming feeds available but not manageable by the user in Blackboard, available in Facebook

As can be seen, Facebook as a Web 2.0 application has more of these founding technologies than Blackboard. However, neither provides a full set, and both seem to be heading towards providing better provision of these sorts of services.

Dynamic technology environment

Social networking is set to become more flexible, with a move to providing platforms, rather than isolated services. Following on from the launch of Facebook Platform, Google has provided the Open Social API (Google 2007) which is already supported by a number of key social networking sites and other service providers, such as MySpace, Hi5, LinkedIn, Ning, and Plexo. The increased ease of interoperability is likely to spawn a range of new tools, some of which could radically alter the possibilities for e-Learning.

Is learning using Web2.0 technologies a revolutionary paradigm?

In the context of Facebook, a Web 2.0 application, and Blackboard, a computer supported collaborative learning (CSCL) tool, we can use these results to qualitatively examine whether Facebook is a revolutionary paradigm or whether it is in the CSCL family group.

Systems designed to support collaborative working, whether business or learning oriented, should support a number of key processes, summarised in (Kleanthous and Dimitrova 2006). These are:

- **Transactive Memory (TM)**– dealing with the way individual’s memories are maintained and communicated within the system.
- **Shared Mental Models (SMM)** – community members shared representations of knowledge about the relevant environment
- **Cognitive Consensus (CCs)** – dealing with shared concepts between members and the meanings they encapsulate, and how users come to agree on them.
- **Cognitive Centrality (CCen)** – managing how far from the consensus different members of the community are, and providing mechanisms to help the maintenance of community on this basis.

Blackboard and Facebook support, at least to some degree, each of these processes, even if only by enabling the community to manage them.

Transactive Memory is supported by allowing users to have their own content, in the form of notes and sharing content they have found elsewhere on the web. They can then set permissions, at a fairly coarse group level, allowing them some control over who can see what.

The other three elements are only supported in terms of allowing the users to discuss, reach consensus, and publish the conclusions. These would be better supported by a tool, or set of tools, which allow for the resulting properties to be captured and represented, perhaps in terms of a reification of the emergent folksonomy.

The key difference, in relation to these four processes, is the level of control the user has over their own content management, and privacy. With this comparison, however, it is not so much a case of Facebook being revolutionary; rather it lives up to more of the ideals for systems supporting collaborative learning. Traditional VLE implementations, due to the hierarchical distribution of power and the lack of any method of storing information privately, or discussing material without oversight by instructors, does not support collaboration well.

However, a Web 2.0 approach does, in general, provide more flexibility in tool design. It allows for a suite of small tools to be developed by a range of authors, and chosen by the user on the basis of their needs and preferences. Because of this, the approach means that the technical environment of the user is more adaptive. This means, in turn, that the user is better able to adapt to changes in technology and to new sources of information, albeit at a cost of having to select appropriate tools, and learn how to use them. This cost, however, also has its own benefits as decision making reinforces learning, and choice of tools involves some degree of introspection and evaluation.

Thus, Web 2.0 provides better support for a connectivist way of learning. Learning using Web 2.0 is not revolutionary, but a partial fulfilment of CSCL. However, Web 2.0 provides support for connectivism, and that might just be an educational revolution.

Summary

The concept of eLearning has been discussed for many years now, and realised in the development of software solutions such as Blackboard that are provided by educational institutions. However, despite these solutions' widespread adoption, their ability to foster learning seems limited at best, precisely because they are provided by educational institutions and modelled around the traditional lecture.

In this paper, we have shown that although solutions such as these are widely regarded by students as an appropriate place to learn, it is in fact in other environments (specifically, global social networks) selected by the students themselves that they are more likely learn in the style that was hoped for by the institutionally-delivered VLEs.

In particular, the recent growth in social networks such as Facebook has seen new platforms emerge in which eLearning is taking place, even if that is not the intention of either the platform's design, or even of the learner. As such, the flexibility of social networks and Web 2.0 tools brings with it a new opportunity to provide eLearning tools that put the student very much at the heart of the environment, and gives them, rather than the lecturer, full control over both the environment's content and its audience.

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Appendix E

1 Perception, recognition and classification

Initial work on classification was done in the context of bio-acoustic species recognition. The underlying principles are common to the general cognitive case, and the specific application to analyse signals from flying insects and classify them according to which species they belong. Further research was done in the area of classifying human emotional state from vocalisations; in both cases the systems were designed as limited cognitive systems, able to recognise signals which were not readily classified by the existing learned recognizers and to train new ones to fill the perceived gap. The signals in these application areas are digitised audio, with an underlying periodicity. The general techniques can be applied similarly to other periodic digital signals, although other pre-processing methods may be more appropriate where there is a significant degree of divergence from the base frequency.

Bio-acoustics covers research into the sounds made by biological organisms. The original motivation of the work on species classification was related to monitoring populations of pest species, and the reason for focussing on bio-acoustic recognisers was because of the non-directional and relatively simple nature of the signals. Acoustic signals propagate in all directions from source, which makes using them advantageous over visual cues for the purposes of identification – vision is highly directional.

Acoustic signals of one type or another are produced by almost all animals (even if only as a side effect of movement) and are therefore a strong candidate for providing a general means of recognition. There are some issues, of course, including the range of frequencies produced by different animals, and the differences in volume of sound produced by different species. Also, a problem factor is noise – the corruption of the signal we are interested in analysing by other acoustic signals, or artefacts of the recording equipment.

There are many situations where it is desirable in terms of cost effectiveness or universal coverage, to be able to use automated recognition systems. Example areas of application include pest monitoring for agriculture, parasite detection for public health, stress detection for domestic and security systems. These can take a number of different forms including visual, behavioural and audio recognition systems.

Population studies of animals in the wild are time consuming and expensive. Experts are usually required to identify specimens, and samples must be collected using traps and, where possible, mark and recapture techniques. Whilst some domains, such as pest monitoring, are not deemed to have a concern about the welfare of the samples, non-invasive, non-damaging recognition methods which are potentially applicable to a range of target species are obviously desirable.

Acoustic signals produced by organisms can be intentional, or by-products of a process in which the organism engages. Humans, for instance, deliberately make vocal noises for communication, but usually do not deliberately make noise when walking (although they can optionally choose to do so) and involuntarily make breathing and other directly survival related noises.

Intentional sound signals also tend to have information content at levels below syntactic on the semiotic framework – the particular timbre and vocal fingerprint of a human, for instance, is imposed by the physical characteristics of the individual, imprinted on the intentional signal by the physical layer of the communication system.

1.1 Path of research

The initial work was based on the author's MSc project which described a method of classification of mosquito flight sounds by species.

Reviewing the method, some shortcomings were found and identified as research issues, along with some further research areas:

- Original MSc work was based on a small sample size, and so a proposal for a larger scale study was drafted, to try to obtain funding for field work. This included the aim of a cognitive recognition system designed to adapt to new signals and new sources of noise to minimise the amount of lab-based configuration needed for field studies.
- In the original MSc work, the method of codebook generation was not sufficiently well defined to be directly represented as an algorithm. The main issue here was that the data was such that any of the proposed partitioning methods produced similarly good codebooks. Further work was identified as needing to be done around selecting the partitions and using the best, or a combination of them, to produce a suitable codebook for the recognition mechanism.
- The method was tested, in passing, on human voice (multiple samples, single subject), during the MSc project, and appeared capable of classifying speech by mood of the subject. This was seen as having potential for security applications and for HCI, which was pursued in a small scale research project as outlined below.
- The original method was subject to low frequency noise. Some work was done on designing and testing a band pass filter to overcome the twin problem of mains noise and high frequency noise, but not satisfactorily – testing against original mosquito recordings showed the filtered signals were less classifiable by the recognition system.
- The original method assumed that specimens retained relatively consistent flight tones. This assumption was demonstrated as inaccurate by a study on flight tone convergence (Russell & Gibson, 2006). Additionally, some mosquito specimens were found to be significantly harder to record in flight than the original samples.

1.1.1 Extension of original method to human voice samples

1.1.1.1 Experimental design

The experiment was designed to use the existing algorithms (from MSc project) and apply them to human speech to evaluate their application to mood classification across multiple subjects. The full study was to record audio samples of 48 individuals, with the subjects sampled from the population such that:

8 Subjects who were native English speakers (4 male, 4 female)

8 Subjects who were natively oriental (4 male, 4 female)

8 subjects from other national backgrounds (4 male, 4 female)

and such that there was a range of ages represented.

The subjects would be asked to practice a standardised script, in a variety of different moods. The text was deliberately somewhat bland, comprising of the seven different combinations of single word stresses in the sentence “I did not say you were stupid”. Subjects would be asked to deliver the lines in three simulated moods – emotionless, angry and frightened.¹

Although acted moods were recognised as probably not being as immediately differentiable as samples representing genuine emotion, it was deemed as being a valid first step in the evaluation process. If the acted samples could be distinguished, it was thought likely that real sample would follow the same pattern, and this would be investigated in a subsequent experiment.

1.1.1.2 Method

1.1.1.2.1 Data collection

¹ These choices were based on a potential application area, and were markedly different from the originally observed differentiable moods. This is now regarded as having been an error in design.

Recordings were taken in a relatively quiet, but not entirely noise free, environment, using a hand held recorder, at 44KHz, with 16 bit sampling². Subjects were encouraged to practice beforehand and to work in pairs if they found it helpful. They were also encouraged to re-record samples if they felt that they were able to inject more passion in to the performance. Due to the potential size of the collected data set, an initial prototype study was performed using only 4 subjects. These were not representative of the overall intended sample, but comprised a less diverse collection for feasibility testing purposes. The sample comprised 4 white native British male speakers.

1.1.1.2.2 Data pre-processing

Each sample was sub-sampled, and categorised according to whether the sample came from the emphasised word in the sentence, along with gender, nationality, stressed word and mood. The sub-samples were then pre-processed by normalizing, finding zero crossings, recording the duration of each wavelet, and the sum of the normalized readings in the first and second thirds of the wavelet, as per the method used for mosquito recordings in the previous work. The sums of readings for the first two thirds of the wavelet were represented as percentages of the total sum for the wavelet.

This technique is a variation of the Time Domain Signal Coding (TDSC) method used by Chesmore (Chesmore, 2004) adapted to remove problems of high frequency noise. It is also a simple to implement algorithm suitable for inclusion in cheap sensing equipment for field studies.

² This sample size and rate was chosen to allow for artificial downgrading in the lab, rather than having to potentially scale up the sampling regime later in the experiment.

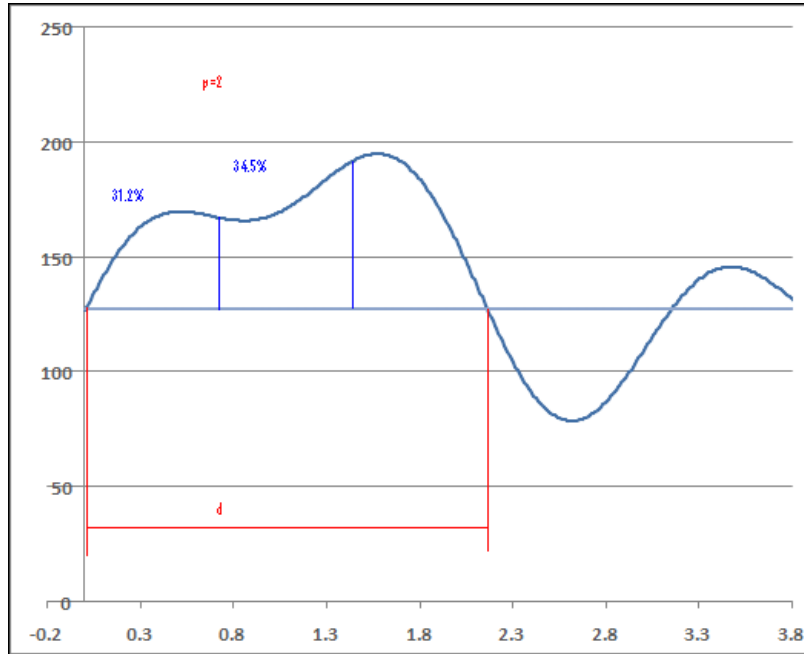


Figure 3 Illustration of sum-sum-duration coding

1.1.1.2.3 Data processing

The 3-tuples produced by the previous step were then used in state transition matrices to produce a bitmap image. These were produced at a two different resolutions; with durations collected into buckets as appropriate. The resolutions of bitmap produced were 10x10 and 100x100, and pattern recognition was performed using a multi-layer perceptron³, as per the original work. This was done for each of the 9 possible transition matrices (sum1 v. sum1, sum1 v. duration, etc.)

1.1.1.3 Results

The initial prototype results were disappointing. The ability of the trained network to classify between any given pairing of attributes was no better than 60% accurate, in comparison to the 95% and better accuracies in mosquito trials. However, it was observed

³ The configuration used had no momentum or other variations – it was a ‘pure’ MLP. However, the problems encountered with the accuracy of classification were not related to being unable to train to a satisfactory level of classification due to time constraints, or even as far as could be told, from getting caught in local minima, but due to a lack of adequate features to discriminate by.

that the nature of the audio data is, of course, more varied than with the mosquitoes. The best transition pairing, albeit by a small margin, was the duration-sum1 transition, which is an approximation to a measurement of frequency and the attack of the sound envelope.

1.1.1.4 Modification to method

The number of partitions for each wavelet was increased to determine whether better results could be obtained by a finer resolution. This, in retrospect, was an ill-considered change to the method, as it increases the minor problems with short duration wavelets (the coding of a wavelet with fewer readings than partitions) and increases the number of possible transition matrices to evaluate (noting that the total number is $(n+1)^2$ where n is the number of partitions and the $+1$ is due to the duration component).

However, after a period of extreme number crunching, it was determined that there was a slight improvement in the best transition pairing performance, and the potential for further improvements with different combinations of attributes. These remain to be examined in more detail.

1.1.1.5 Conclusion

The prototype showed up a problem with the method for human voice recordings. This looks like it might be rectified by using either combinations of higher resolution attributes, or alternative coding methods. The processing overhead of multiple attributes is time consuming, and an automated method of coding is desirable anyway, so methods of clustering wavelet data suitably were considered as further research topics.

1.1.2 Investigations of Self Organising Maps for coding

The wavelet data to be coded comprises 3 metrics presented as a vector. One value is a count of sampled readings within a wavelet, and the other two are fractions of the sum of the readings within the wavelet, across the first and second thirds (in terms of duration) of the wavelet. Similar wavelets should be grouped together, and the coding mechanism should, ideally, produce an extensible code which has version compatibility.

Existing work in the area of species classification (Chesmore, 2004) does not make use of any form of automated codebook generation. Self Organising Maps, such as the Kohonen network, provide clustering without supervised training, and also reduce the dimensionality of the data. These features make the SOM an obvious choice for codebook automation.

1.1.2.1 Initial results

Whilst the clustering of wavelet data using a standard SOM provided a small number of clusters, using a randomly initialised, bounded square grid produced some ‘clumping’ of the clusters near the corners of the output grid. The system of coding was tested on a subset of both the original mosquito and the voice samples, and showed a tendency to confuse samples which clustered near the corners of the SOM produced codebook.

1.1.2.2 Refinement

The edges of the square grid were connected, so that the output map was topologically toroidal. A range of learning parameters were tested, including zero or random initialisation of the weights, and different distance metrics (Euclidean, Manhattan and ‘dot product’ rules).

Good clustering performance was achieved, but the results have not yet been tested on the audio samples. The observation was made that some clusters were much more heavily populated than others, and that these also had a fairly high variation of data within them. It was decided to develop a dynamic hierarchical SOM which could better represent the heavily populated clusters (effectively re-clustering and increasing the resolution in the high population centres).

The technique designed is similar to DASH (Hung & Wermter, 2003), and further investigation of the benefits of independent development remains to be done. This especially includes examining the possibilities for processing skewed vectors, such as can be generated in natural language analysis (Georgakis & Li, A SOM Variant for Heavily Skewed Vectors, 2005) and using an ensemble, which is in keeping with the agent based

architecture proposed (Georgakis & Li, An Ensemble of SOM Networks for Document Organization and Retrieval, 2005).

1.1.3 Alternative Coding - Investigating 2nd order model fitting.

Reflecting on the differences in the wave forms of the mosquito data and the human voice data led to considering an alternative method of coding the individual wavelets. An example of each waveform is included here for reference (Figures 3 and 4). Although there are significant differences in the form of the signals, it was noted that they could both be approximated, for short durations, by the output of a second order feedback model.

Samples of 2nd order systems were generated for comparative purposes, (Figure 5) and initial work on an algorithm for automatically generating the parameters for the 2nd order model based on an audio sample was done. The mechanism being developed was a genetic algorithm, but this was being reconsidered in favour of a more analytical approach.

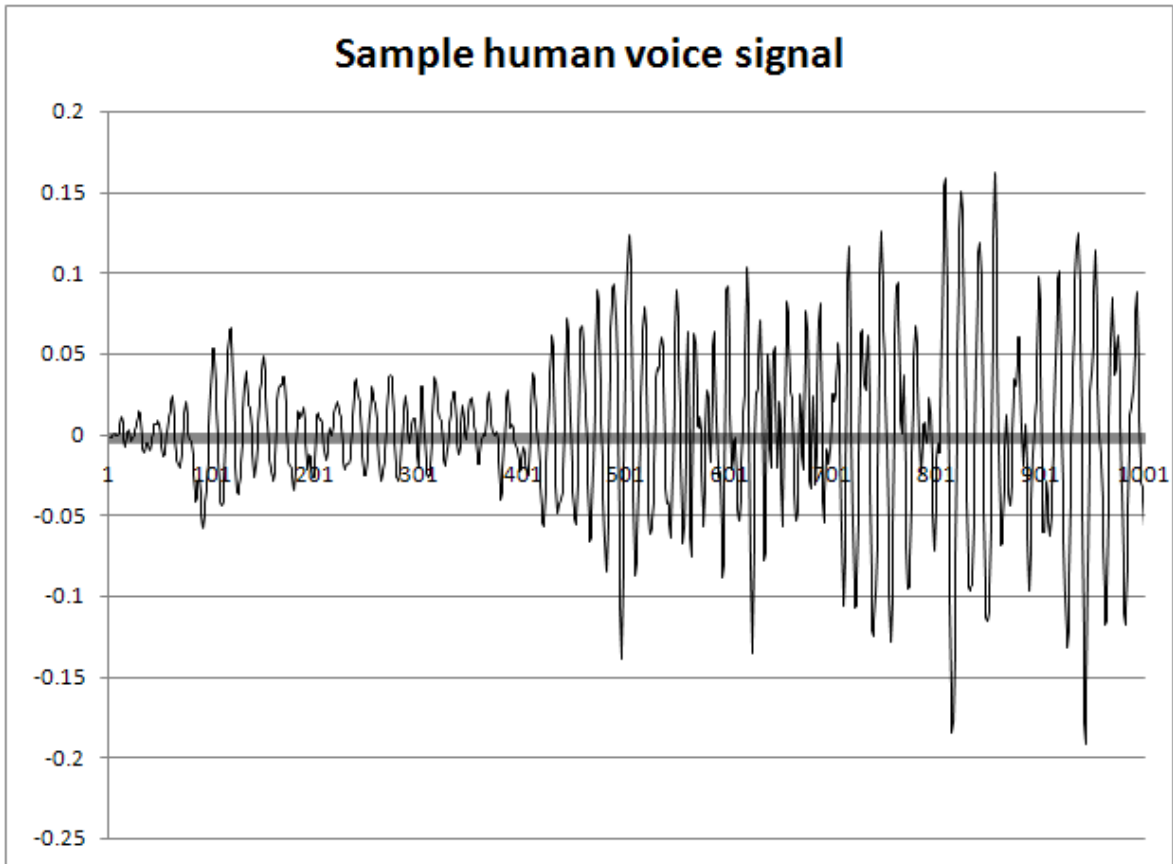


Figure 4 Sample human voice signal

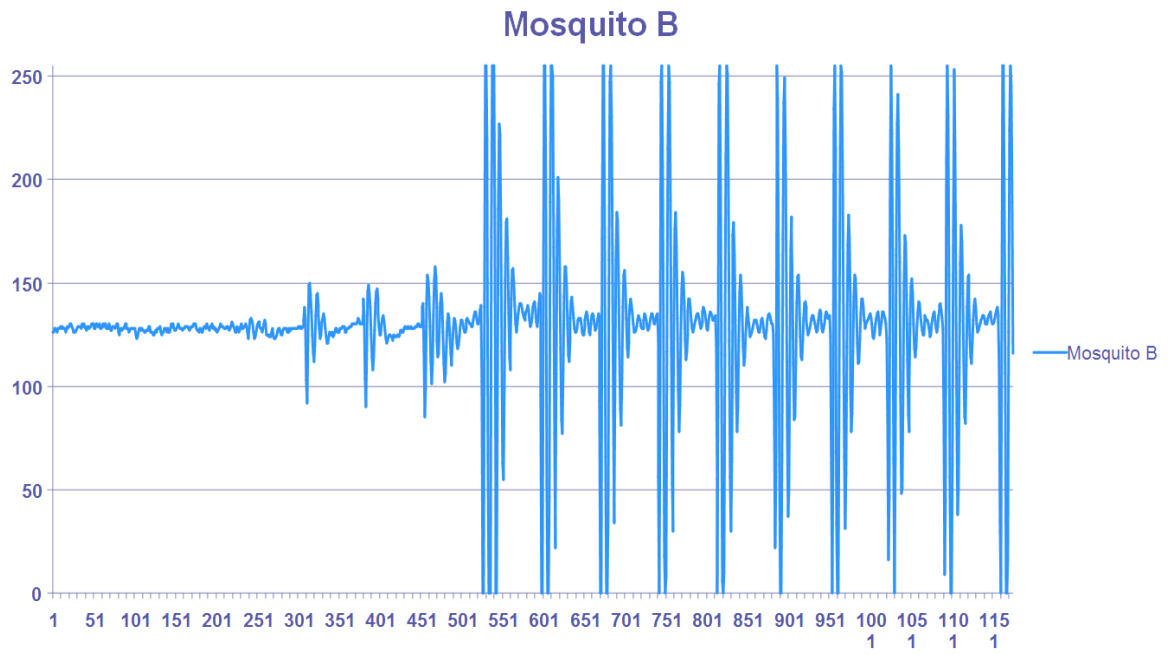


Figure 5 Sample mosquito flight audio

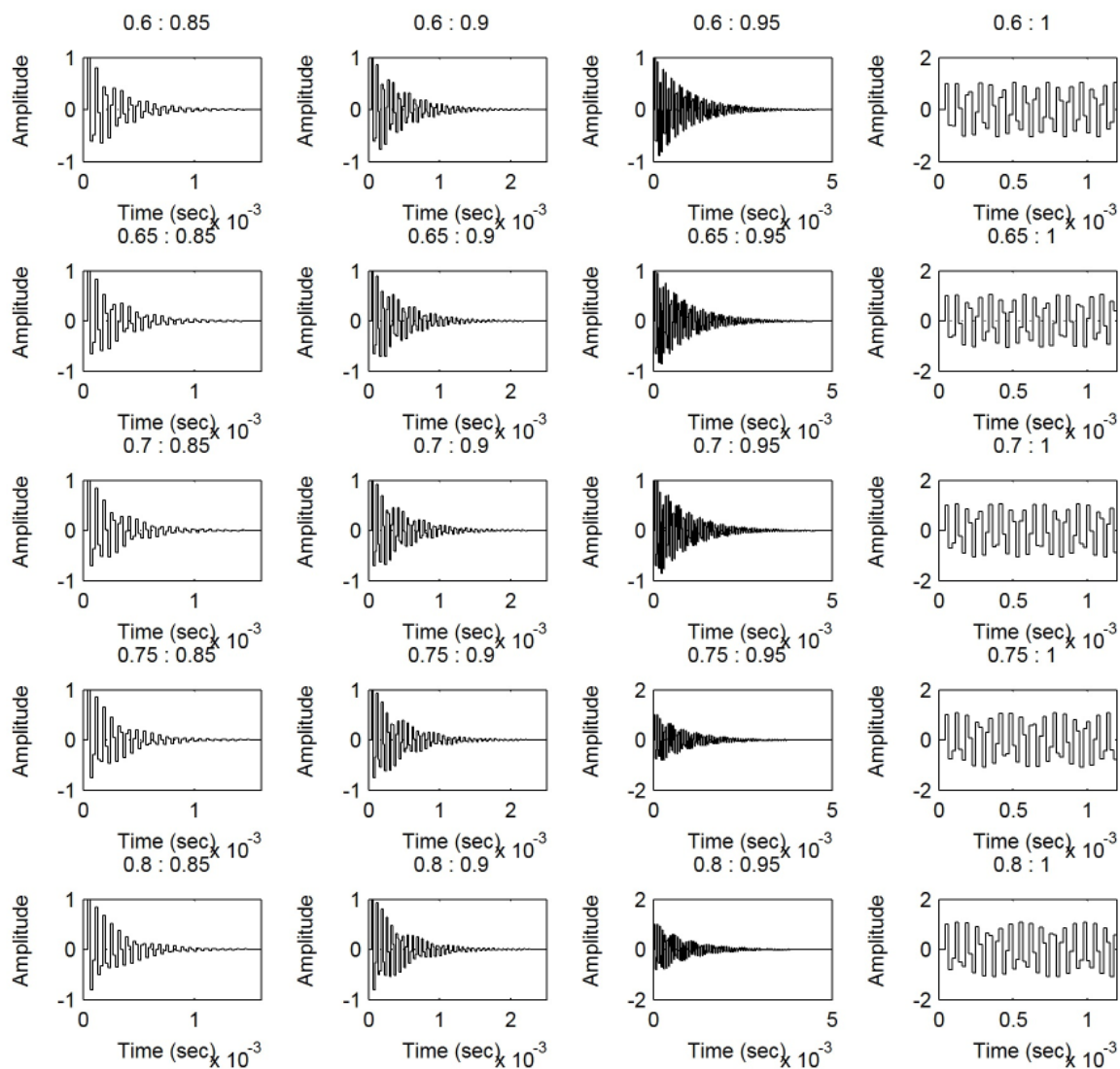


Figure 6 Example impulse responses from 2nd order models

1.2 Future work

For audio work, continuation of the 2nd order modelling system seems to have benefit. In terms of other work, the dynamic hierarchical SOM approach appears to have the benefit of scalability, and coupled with a suitable method of historical offsetting, it should provide an adequate means of tracking clusters of vectored data over a changing problem space.

Further work also needs to be done on comparing the relative merits of different pattern recognition techniques, particularly with regard to temporal data. Additionally, this investigation failed to consider the wavelet-wavelet peak ratio, which may have made the crucial difference in facilitating recognition.