Diverse Perceptions of Smart Spaces

Physical, Digital, Personal, Social, and Data aspects

Jeremy Frey, Colin Bird, and Cerys Willoughby

Chemistry, University of Southampton, University Road,
Southampton SO17 1BJ, UK

J.G.Frey@soton.ac.uk, colinl.bird@soton.ac.uk, Cerys.Willoughby@soton.ac.uk

Abstract

This is the era of smart technology and of 'smart' as a meme, so we have run three workshops to examine the 'smart' meme and the exploitation of smart environments. The literature relating to smart spaces focuses primarily on technologies and their capabilities. Our three workshops demonstrated that we require a stronger user focus if we are advantageously to exploit spaces ascribed as *smart*: we examined the concept of smartness from a variety of perspectives, in collaboration with a broad range of contributors. We have prepared this monograph mainly to report on the third workshop, held at Bournemouth University in April 2012, but do also consider the lessons learned from all three. We conclude with a roadmap for a fourth (and final) workshop, which is intended to emphasise the overarching importance of the humans using the space.

Keywords

smart spaces; meeting; user aspects; knowledge exchange; knowledge transfer; research management; data volume

1 Introduction

This is the era of smart technology and of 'smart' as a meme. However, the 'smartness' is pushed to us, in the form of "you can do this and that with your smart phone or other device." Less often do we pull the smartness and shape it to our needs and expectations, but in section 4.2 we see three examples of exploiting smart technology to meet specific user requirements.

We have run three workshops to examine the 'smart' meme and the exploitation of smart environments. This monograph considers the history of all of those workshops and their outcomes but concentrates primarily on the third workshop, held at Bournemouth University on 18th April 2012. This monograph brings all these aspects together and sets the scene for a planned fourth (and final) workshop, in which we intend to focus explicitly on users. Our theme will be the future for smart environments as utilities designed to provide what those users need.

At the outset, we based our investigation on smart *spaces*, but have since broadened its scope to smart *environments*. Similarly, our initial motivation was to improve knowledge exchange in learning and research, but we have come to appreciate the wider relevance of what we have learned.

2 Smart Spaces for Smart People - a history of the first two workshops

We embarked on the first workshop very much with an open mind, so invited participants with a range of interests, albeit constrained by individual availability at what was fairly short notice. We maintained the open agenda and the diversity of the contributions for the second and third workshops, held at the University of Southampton and Bournemouth University respectively. We presented a paper to the InnovationKT'12 conference, describing our experiences with the first two workshops [1]. This paper was the first in a series of three: we refer to the other two papers later in this monograph.

We ran the first workshop at the e-Science Institute, Edinburgh, in May 2011, with two broad objectives:

- To investigate the interaction between the use of Smart Spaces in the physical world and smart personal systems both technological and software;
- To explore and define best practice in enhancing the utility of the link between the physical and digital worlds.

Notwithstanding our initial intention, during the course of the workshop the emphasis clearly changed to the productive exploitation of spaces ascribed as *smart*, particularly meeting spaces. However, the underlying purpose remained as improving the exchange of information and knowledge. Later in this monograph we consider the relationship between information and knowledge and how we extended our findings to knowledge transfer in general. Knowledge exchange can occur in a range of settings, from the formal publication through e-mail and messaging to informal conversation. The exchange of research know-how commonly takes place in various forms of meeting.

The themes covered in the first workshop were focused on smart spaces as meeting places, in particular the issues around capturing and recording the activities that take place in the space and various methods for improving the effectiveness of, and collaboration during, in those activities. These discussions also highlighted the importance of calm technology and the importance of designing the space and associated technology taking into account the needs and behaviour of the people using them.

We ran Workshop 2 on the 21st of June at Southampton University. The workshop sessions took the sub-themes and considerations distilled from the first workshop as the basis for the discussions.

One issue that emerged from exploring those sub-themes was the meaning of the term *smart* and how we might distinguish a smart space from a 'dumb' space. The first workshop did not really tackle this issue, so we included it specifically in the plan for Workshop 2.

The following synopsis is intended to convey our basis for regarding smartness as *conferred capability*.

No space is, or can be, inherently smart. Indeed the term could be regarded as an example of jargon that is acceptable because everyone thinks they know what it means. A survey of the literature relating to smart spaces revealed that the overwhelming majority of the existing definitions are expressed in terms of technologies and the capabilities they confer: intelligence; assistance (to humans); and adaptivity (including mobility).

Mark Borkum gave a brief presentation during the second workshop, arguing that there is no such thing as a smart space; instead there are agents or smart objects that can be brought into the space. Intelligence comes from being able to plan and enact activities. To be smarter, we need agents, for example a mobile software platform that can control and coordinate the activities. Accordingly, the agent needs to understand objects and activities and have a way of assessing the space, aggregating the activities, and auditing the outcome of the activity. This cycle of activity has a strong parallel to organisational and quality control processes, for example the plan-do-check-act management method.

Although much of the focus was in both of these workshops on *smart meetings*, we remain aware of the continuing need to consider other environments, such as learning and research. The four sub-themes and three key considerations that we developed offer a basis for the successful planning and conduct of smart meetings. Many of the characteristics that we discussed are manifestly generic to most meetings, but our explorations of the quality of *smartness* led us to conclude that the role of hardware and software technologies is to *confer capability*. For a *system* to achieve smartness, we deem certain components to be essential, most notably people. We believe that smart spaces need to be designed and, in the process, must empower the users of those spaces.

2.1 Lessons learned from attempting to record the meetings

In our first InnovationKT'12 paper, we described the recording methods that we used during the first and second workshops [1]; we deployed the same approach for the third workshop. We will not repeat here the evaluation that appears in that paper, save to reiterate our intention for our range of recording methods, technological and traditional, to be complementary with each other. We consider this complementarity in the InnovationKT'12 paper.

We recognize the need for metadata to facilitate retrieval, and cross-reference links to enable exploration. To support continuous curation we need a *meeting log system*, a tool that we were very conscious of lacking during all three workshops. We are currently investigating the options for such a system; including specifying and developing bespoke software.

Recording is, of course, a vital component of research practice, thus linking back to our original motivation for arranging this series of workshops. We consider this aspect in section 4.2, from the perspective of research conducted "in the wild".

From the organisers' perspective, during the workshop evaluation sessions, we identified the following aspects as having been effective (in varying degrees) and therefore valuable for the conduct of meetings intended to be *smart*:

- The emphasis on discussion (over prepared presentations)
- The use of a facilitator, who maintains a visual record
- The use of an independent note-taker for preserving key points, ideas, and 'direction-changing' remarks (although the value is dependent on whether a log system is available)
- A contemporaneous Twitter feed, which, although undoubtedly beneficial, can be distracting
- Unobtrusive audio recording, which is an important form of data capture that can be complemented by video recording

During the evaluation sessions of the first and second workshops, the participants agreed that having an explicit facilitator (as well as a chairperson) was important for the successful running of the workshops. The facilitator was less important for the third workshop, owing mainly to its different style, with prepared presentations and no full-length discussion sessions. The evidence from our workshops is in accord with the relevant literature in regarding facilitation as vital for effective knowledge transfer, a point we explore more fully in the third paper we presented to the InnovationKT'12 conference, concerning smart meeting spaces for knowledge transfer [3 and references therein].

However, it is necessary to qualify the lesson of facilitation, because it was apparent that either or both the facilitator and the chairperson can influence the discussion and the nature of the outputs. It is clear that these roles impose an editorial function, much like the explicit editor of the final outputs, but the influence of a facilitator can be much more subtle and less obvious.

2.2 The human aspects of smart spaces

A key foundation for our views about exploiting spaces ascribed as *smart* is that no space is, or can be, *inherently* smart. Our explorations of the quality of *smartness* (and how to distinguish a smart space from a 'dumb' space) led us to conclude that the role of hardware and software technologies is to *confer capability*. The resultant lesson was that people are essential for a *system* to achieve smartness, so smart spaces need to be designed and, in the process, must empower the users of those spaces.

Reviewing the published literature about smart spaces reveals a strong tendency to describe the enabling technology, so our focus on the human aspects was to some extent novel. Our view of smartness as *conferred capability* casts technology in a supportive rather than a controlling, or even mediating, role.

A related lesson was the recognition of the potential significance of the physical space and the manner in which humans configure that space; humans who run meetings can exploit the characteristics of the physical space to influence both the conduct of meetings and their outcomes. We explored this issue further in the second paper presented to the InnovationKT'12 conference, considering the human aspects of smart spaces [2]. In that paper we concluded that a space could be ascribed as *smart* only if it enables the users of that space to use the space for its intended purpose. Participants must be able to effectively collaborate, share, and engage in the intended activities; any technology employed should be unobtrusive.

2.3 Relationship between smart spaces and knowledge transfer

In our third InnovationKT'12 paper, we described how the ideas that emerged from the first and second workshops could be applied to influence strategies for exploiting smart meetings for knowledge transfer. Reviewing the knowledge sharing literature in 2003, Cummings examined a variety of factors affecting knowledge sharing [4]. Considering physical distance, he explained the evidence in favour of face-to-face meetings promoting more effective knowledge transfer in terms of the relationships between the parties. However, we must accept that some of the intended recipients of transferred knowledge will not be present in the meeting. It is therefore important to ensure that all contributions, however made, are effective, and that the record of knowledge transfer is accessible to people who were unable to be present but need to refer to that record subsequently. A potential issue for the fourth workshop to consider is the role of curation, particularly in preserving links between information sources in the record.

3 Smarter Research Management – the third workshop

The theme of the Bournemouth workshop was Smarter Research Management, reflecting a return to the original motivation. The invitation included the following description:

> "This workshop is the third in a series that examines the potential impact of technology on communication in spaces ascribed as smart. Well-designed spaces can enhance the quality and effectiveness of our communications, especially when those spaces are supported by smart systems."

We suggested the following topic areas:

- Using smart systems to improve information exchange
- Coping with increasing amounts of data as processes, disciplines, and communication methods change
- Managing research in the wild
- Improving the quality of our experiences in the spaces we are in
- Exploiting links in research management
- Adapting to individual needs in research meetings

The next section of this monograph contains synopses for the eight talks given, together with a summary of the facilitated discussion, evaluation, and review session with which the workshop concluded.

An examination of these synopses shows reasonably even coverage of the topic areas, but limited compliance with the overall theme. However, it was generally agreed to have been a most interesting day, owing particularly to the broad range of topics covered.

By offering an open agenda on this occasion, as we did for the first two workshops, we have obtained insights that we had not sought when initially planning the workshops. These insights have helped to inform our assessments of the series and so the remainder of this monograph will comprise an appraisal of the lessons learned and an examination of the fresh perspectives that we will take into account when planning the fourth workshop.

3.1 Bournemouth workshop presentations

Appendix A contains synopses of each of these eight talks.

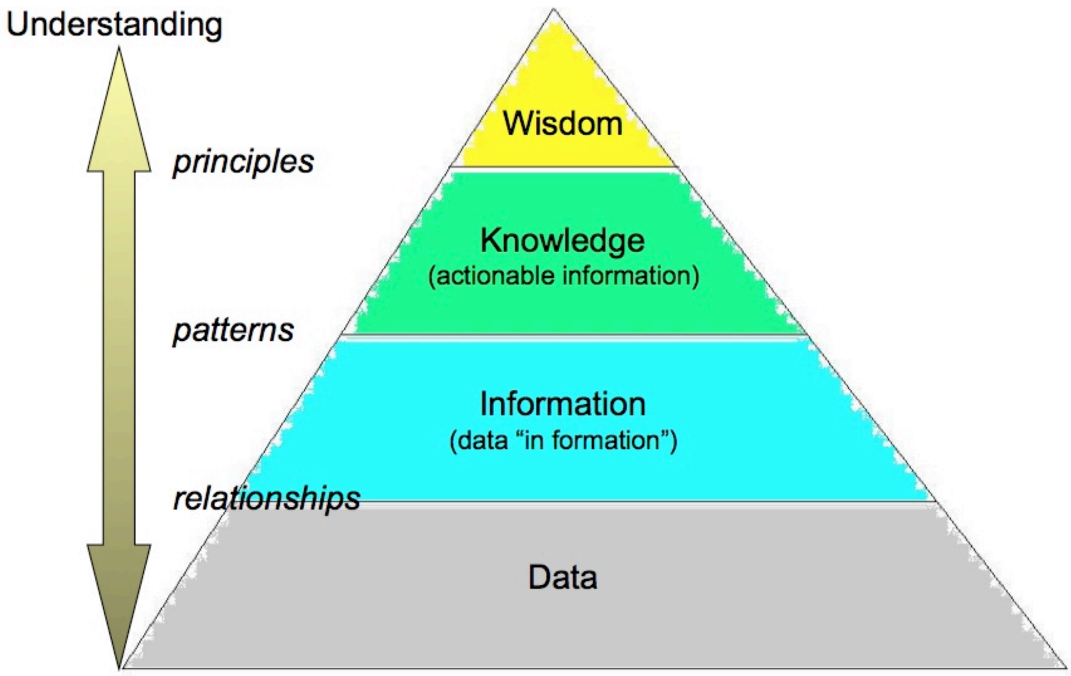
1. Bogdan Gabrys: Changing nature of research and business in view of the explosion of available data
2. Benjamin Parris: Mind reading and the proliferation of data and dependent variables
3. Ross Hill: The impact of remote sensing data on environmental science
4. Andy Stanford-Clark: A look behind the curtain in the house that tweets
5. Graeme Earl: The RCUK PATINA Project: Navigating Smarter Research Spaces
6. Alain Renaud: Musical interactions over distributed networked spaces: challenges and opportunities
7. m.c. schraefel: Are You Sitting Down? Towards Cognitive Performance Informed Design Spaces
8. Yonca Ersen: Convergence scenarios for seamless data flow in direct relation to space

3.2 Discussion, evaluation, and review session.

Following the talks, we held a discussion, evaluation, and review session. Three themes main themes emerged from the session:

- Some people regard data as the "new oil", although the metaphor relies heavily on what we do with the oil. We have to develop our techniques for handling the complexity, because the value resides in the knowledge, and in some cases the wisdom, that we extract from the data and the information derived from the data. The data itself, especially when in terabyte quantities, can be an encumbrance.
- The two main drivers for becoming smarter with data are to enhance creativity and to effect change. Wise use of space can improve creativity, as can the sharing of data, although it is more beneficial to share the processes of understanding the data. Mass demand is a major driver *for* change, but we can also use smart technologies to influence demand and therefore to effect change.
- Smart systems can help to close or tighten the control loop. By releasing knowledge, and by sharing the processes of understanding, we can give people greater control over the things that affect them, for example, their consumption of increasingly expensive energy. We can apply smarter controls at all levels, from the devices we deploy to the way we disseminate knowledge. Pertinent to the latter would be to make the publication of negative results more acceptable.

One feature of the discussion, evaluation, and review session was the need to add value, in the form of understanding, to the large volumes of data now available to us. The DIKW pyramid illustrates the value-adding process and, in a sense, captures the true meaning of being smart with data [5,6].



Adapted from: *Awad & Ghaziri* and *Bellinger, Castro, & Mills*

To give a simple illustration of ascending this pyramid, drawn from Andy Stanford-Clark's talk, his home sensors generate *data*, from which Andy extracts *information* that he publishes as tweets. He can then derive *knowledge* about what is happening in his house; whether he takes any actions as a consequence manifests his *wisdom* regarding the situation.

While the participants agreed that the workshop's relevance to smarter research management had been rather limited, the unanimous view of the meeting was that it had been unusually wide-ranging and therefore very interesting.

4 Bringing the workshops together

As noted earlier, the talks given at the third workshop complied in only a rather limited way with the overall theme of Smarter Research Management. Nevertheless, the presentations led us to consider the exploitation of smart environments from fresh perspectives.

The varied nature of the presentations in the third workshop does serve to emphasise the different interpretations of 'smart' in both industrial and academic communities. There are however common themes, suggesting that there are common problems to be solved and genuine innovations that can be achieved in the Smarter Research Management arena.

4.1 Large data volumes

The first three presentations in the third workshop had a strong focus on the benefits and associated issues of large amounts of data. The availability of more and more data enables the production of intelligent systems with smart capabilities such as event prediction, but also brings with it enormous challenges in terms of how to store, access, process and model this data. These discussions reflect many of the same desires and concerns that were expressed in the first workshop, where the ability to take existing data and both mine and model it effectively for presentation to the people who needed it, was viewed as an essential component of smart spaces. There is an abundance of data, but you need to be able to get at just the information you need at the time you want it. The data and information need to be kept: you might not need it now or might be unable to process it now, but that does not mean you will not do so in the future.

Bogdan Gabrys talked about predictive analytics and their use in a variety of contexts, such as travel patterns (to maximise revenue) and predicting the likelihood of account holders switching provider. Smart data analysis systems need to be adaptive and to recognise that the volume and complexity of data are not necessarily the same. Ben Parris, an experimental psychologist, discussed how humans read – and ignore – information, leading into suggestions for ways to influence how we process information. Ross Hill described the acquisition of atmospheric, ocean, and land data and explored issues associated with obtaining useful information from the large volumes of data available.

This modelling and mining of data could be considered a 'smart' activity within research and industrial environments that rely on this kind of transformation of data to knowledge. The need for smart spaces to be used for collaboration and cross-disciplinary sharing of knowledge was discussed in both the first two workshops. It could be argued that the interfaces for presenting the transformed data and models could be part of the definition for a smart environment. Given the real concerns about large volumes of data, and the associated 'information overload' that our participants faced, a smart environment is one that can help with this problem. At least one requirement of a smart environment is that its users can be presented with the right knowledge which requires that the technology in the smart space can both access and transform the raw data into something meaningful, potentially something different for each user in the environment.

The discussions about large data volumes are also reminiscent of the problems discussed in the first workshop in relation to the recording of meetings. Although there is exciting technology being developed for recording and transcribing meetings from audio tracks and speech to text, we are a long way from being able to process all this information in a useful way.

The perspective on the ‘smart’ meme thus created is essentially one of making intelligent use of the data: using smart processing to extract the significant information, then eliciting the patterns that contribute to knowledge. In approaching such tasks, we need also to ‘smarten’ our understanding of the interactions between humans and data. Smartness comes from being able to transform the data in such a way to make it useful to humans; on having knowledge about what individuals might need the data for or the technology to do; and on having effective and suitable presentation interfaces. The technology can only be called smart if it is actually doing what the humans need it to do – and smartness is certainly in the eye of the beholder. The processing and modelling of large volumes of data is certainly a value topic for smart research management, for those disciplines that generate and benefit from the collection of massive amounts of data.

4.2 The diversity of smart

The middle session of the workshop featured three applications: disparate examples, but illustrative both individually and collectively of the breadth of the ‘smart’ meme.

Andy Stanford-Clark entertained as well as informed when describing how his house tweets information derived from various sensors, such as those monitoring his energy consumption. In Andy’s smart environment he not only receives knowledge via the sensors that has configured in that environment, but he is able to control that environment directly or indirectly. Although in a sense a prototype application, Andy is adapting technology generally regarded as smart to his perceived need for greater and tighter control of what we can easily regard as *smart environment*.

Andy’s talk also reflected some of the topics that were discussed in the previous workshops. The sensors in his house could be considered examples of 'calm technology'. Once Andy has configured his sensors, messages are automatically sent to him as changes in the environment occur. For example, Andy doesn't need to check the environment directly or constantly query the technology to know what is going on. Going back to the discussions in the second workshop, the various sensors that Andy has set up could perhaps be considered agents – they are monitoring the environment for changes. The sensors have a particular purpose, and are therefore enabling the completion of an activity, and providing feedback on that activity. For example, the sensor for measuring water use was in effect used to determine that there was a leak, causing the leaking hose to be turned off, and the reduction of water use to be observed. Similar functions can be seen with the other sensors, for example, the mouse trap sensor – the mouse trap fulfils its purpose, the sensor provides feedback that the next activity needs to be completed by the next agent – in this case Andy’s son.

Graeme Earl uses smart systems to conduct archaeological research “in the wild”. There are two main environments for carrying out archaeological research, the lab environment that has much in common with the kinds of research environments discussed by participants in the previous two workshops, and the excavation environment. Excavation is a different kind of research environment and does not permit the sensor-based infrastructure that the published literature so often associates with research data gathering. Recording and analysing an archaeological environment does use technology and instrumentation, for example geophysics and surveying equipment, but traditionally much of the recording is done using paper-based methods.

Graeme’s group have been investigating how archaeologists work and record in order to determine the most effective, or ‘smart’, techniques and tools for facilitating recording in the field. Graeme's group currently makes effective use of iPads, relying on their long battery life, with Apps obtained "off the shelf". iPads are surprisingly robust and have many useful functions for recording in different mediums including audio, photos, videos, sketching, as well as notes.

An interesting finding gleaned from Graeme's team is that although archaeologists may take extensive notes at an excavation, they rarely ever return to the notes once they have written them. Nevertheless, the act of writing the notes is thought to be an essential part of the interpretation process. In the previous workshops, when discussing the requirements for a logging system, there were discussions about taking notes, and whether people would actually read them after the event. This raises important questions about the development of technologies for recording, logging, and transcribing meetings. Is there any value in such a system, will people use it, what aspects will people use, and are there more or less effective ways of presenting the information to the people who want to use it? Is it the case that recording the whole meeting word for word is essential or even useful, or is it the case that the key points and decisions, or interpretations from the archaeologists point of view, are sufficient?

Finally in this middle section, Alain Renaud described the technology that he and his collaborators would use in the evening concert that concluded the workshop. The concert flyer began with the following invitation:

> "Immerse yourself in a unique networked space combining three auditoriums across the globe and distributed performers interacting over long distance."

The three locations taking part in this concert were: Bournemouth University; Queen's University, Belfast; and Stanford University.

A recurring subject in the previous workshops was about the nature of a smart space, whether this can only refer to a single physical space, or whether it can apply to distributed locations, virtual and online environments, or even temporally distributed locations. The network concert experience enabled performers in different locations not only to play and hear music at the same time, but also to interact. The pieces performed were reactive, so the musicians were either responding to an instrument played in a different location or to graphics generated by a remote program. This is quite different to the idea of musicians playing identical pieces of music in different locations, which would have involved only a minimum of interaction.

The boundaries of the space were not defined by the physical space. Although the rooms and audiences at each location were very different, for those of us in Bournemouth the way the sound was configured meant we could hear the different instruments at different locations in the same room. The experience of the concert was different depending which location you were in, and quite possibly where you were sat in the room!

Owing to its 'reactive' style, the concert had certain elements in common with distributed meetings as discussed in previous workshops. Although we couldn't see the other participants, there was effectively a 'conversation'. The musicians in the conversation had different voices (instruments) and different roles (leaders and followers), and because of the sound mixing, each participant also had a location within that space. In this way, although we were all in our own space, we were effectively sharing the same space. If you closed your eyes you would believe everyone was in the same place. We might easily consider this music space to be the nearest to being a smart space in its own right.

The perspective illustrated by these three applications reinforces our view of smartness as *conferred capability*: the environment, be it domestic, out in the open, or distributed becomes smart by virtue of how people instrument the space and how they deploy the smart systems. It is instructive that in all three instances the researchers have adapted the environment to match the environment to match the requirements of the people in the *smart* space.

4.3 Being in a space

The two talks comprising the third workshop session focused on how we can adapt *to* the space we are in and how we can design spaces. The messages clearly lent support to our earlier conclusion from the first two workshops that "people are essential for a *system* to achieve smartness, so smart spaces need to be designed and, in the process, must empower the users of those spaces." This clearly extends to the physical aspects of the space as well as the technological. Where the space is spatially or temporally distributed, consideration needs to be given to the interfaces between the spaces and the users, and how others not present in the space can be included in it.

The resulting perspective is arguably the most self-evident of all, in that we need always to give careful consideration to: how we intend to use space; how we might minimise our need to adapt to a space; and how we should design our spaces, especially if we want to ascribe them as *smart* spaces. An important point raised in the first workshop was the likelihood of failure borne by so-called smart spaces that were designed without an understanding of the needs and behaviours of the intended users of the workspaces.

We noted in section 2.3 that some of the intended recipients of transferred knowledge will be unable to be physically present. Although none of the workshops were run on a large scale, with participants in several, distributed, locations, we remain conscious of the need to ensure that all contributions, however made, are effective, and that the record of the knowledge transferred is accessible to people who were unable to be present but need to refer to that record subsequently.

5 Roadmap for the fourth (and final) workshop

The provisional title for the fourth workshop, **Smart Space as a Utility (SSaaU)** reflects our intention to focus explicitly on users by adopting as a theme the future for smart environments as utilities designed to provide what those users need.

The topic areas that we currently have under consideration are as listed below, but readers should be aware that until we announce the workshop our ideas are liable to change:

- While complementary recording methods can preserve the data and information generated within a space ascribed as smart, what are the roles for curation in adding value?
- To what extent should the space itself (be it open, closed, or distributed) be allowed to influence the activities taking place in the space?
- In what ways might it be feasible to build user focus into knowledge exchange processes? Could we establish a set of best practices in this area?
- What lessons might we be able to draw from the research context that we could then apply to the activities of ordinary citizens?
- What does the term 'smart' mean to people who are not technology-oriented?
- What might the adjectives "calm" and "non-intrusive" when applied to the technologies deployed in smart environments?
- How can users be smart about capturing their thoughts and how important is it for them to do so?

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6 Appendix A - Workshop presentations

The following provides synopses for each of the talks given in the workshop.

6.1 Changing nature of research and business in view of the explosion of available data

Bogdan Gabrys

Smart Technology Research Centre
Computational Intelligence Research Group
Bournemouth University
bgabrys@bournemouth.ac.uk

We are currently experiencing an incredible, explosive growth in digital content and information. According to the study conducted by IDC [11], there currently exists over 1.8 exabytes of data and it is estimated that the digital universe in 2020 will be 44 times as big as in 2009. Research conducted in many traditionally qualitative disciplines already has or is fundamentally changing due to availability of such huge amounts of data. In fact the data-intensive computing has been named as the fourth paradigm of scientific discovery [10] and is expected to be the key to unifying the theoretical, experimental and simulation based approaches to science. It is not only research but the commercial world has been transformed with a focus on BIG DATA. Companies are competing on analytics [12] and decisions are based on evidence as required in quickly changing and competitive environments. Data has become a commodity and in recent years has been frequently referred to as the new oil. We are entering a new era of predictive analytics.

There has been a lot of work done on the subject of intelligent data analysis, data mining and predictive modelling over the last 50 years with notable improvements which have been possible with both the advancements of the computing equipment as well as with the improvement of the algorithms [1]. However, even in the case of the static, non-changing over time data there are still many hard challenges to be solved which are related to the massive amounts, high dimensionality, sparseness or inhomogeneous nature of the data to name just a few.

What is also very challenging in today's applications is the non-stationarity of the data which often change very quickly posing a set of new problems related to the need for robust adaptation and learning over time. In scenarios like these, many of the existing, often very powerful, methods are completely inadequate as they are simply not adaptive and require a lot of maintenance attention from highly skilled experts, in turn reducing their areas of applicability.

In order to address these challenging issues and following various inspirations coming from biology coupled with current engineering practices, we propose a major departure from the standard ways of building adaptive, intelligent predictive systems and moving somewhat away from the engineering maxim of "simple is beautiful" to biological statement of "complexity is not a problem" by utilising the biological metaphors of redundant but complementary pathways, interconnected cyclic processes, models that can be created as well as destroyed in easy way, batteries of sensors in form of pools of complementary approaches, hierarchical organisation of constantly optimised and adaptable components.

In order to achieve such high level of adaptability we have proposed a novel flexible architecture [5-6] which encapsulates many of the principles and strategies observed in adaptable biological systems. The main idea of the proposed architecture revolves around a certain degree of redundancy present at each level of processing represented by the pools of methods, multiple competitive paths (individual predictors), their flexible combinations and meta learning managing general population and ensuring both efficiency and accuracy of delivered solution while maintaining diversity for improved robustness of the overall system.

The results of extensive testing for many different benchmark problems and various snapshots of interesting results covering the last decade of our research will be shown throughout the presentation and a number of challenging real world problems including pollution/toxicity prediction studies [8-9], building adaptable soft sensors in process industry in collaboration with Evonik Industries [6-7] or forecasting demand for airline tickets covering the results of one of our collaborative research projects with Lufthansa Systems [3-4] will be discussed.

Given our experiences in many different areas we see that truly multidisciplinary teams and a new set of robust, adaptive tools are needed to tackle complex problems with intelligent data analysis, predictive modelling and visualisation already indispensible. It is also clear that complex adaptive systems and complexity science supported and driven by huge amounts of multimodal, multisource data will become a major endeavour in the 21st century.

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6.2 Mind reading and the proliferation of data and dependent variables

Benjamin Parris

School of Design, Engineering & Computing
Bournemouth University (Talbot Campus)
bparris@bournemouth.ac.uk

For about 100 years Experimental Psychology survived as a discipline largely on the basis of one dependent variable: reaction time. The time elapsed between the presentation of a stimulus and a behavioural response was interpreted in manifold ways. The study of mental reaction times in humans, also known as mental chronometry, lead to the construction of complex theories of the mind and how it works. Differences as small as a few thousandths of a second might reveal something about the mind and how it functions. Using this method allowed psychologists to uncover mental processes that cannot be observed overtly. Inferences were made as to the content, duration and sequencing of cognitive operations. An example found in the Science Museum is known as the Stroop task. The Stroop task requires participants to identify the colour of the font in which a word is presented, whilst ignoring the word itself. Performance in the task is indexed by measures of interference and facilitation. For example, when the written word is incongruent with the font colour (e.g. *green* written in red), the time it takes to identify the colour is increased relative to a baseline control condition (e.g. *flower* written in red), a difference known as Stroop interference. This suggests that processing a word to a semantic level is effortless and automatic.

With the development of new technology, Experimental Psychology was able to move beyond reaction time. Machines that allowed researchers to track where the eyes were looking, added a new dimension to the study of the mind. With this new technology came a new set of dependent variables. It was no longer only possible to measure how long it took for participants to reach a decision. Psychologists were now able to record where in a picture participants we looking prior to making a decision, and where they were looking afterwards. Psychologists could literally see what participants were thinking. It is now possible to sample eye movements 1000 times a second giving incredibly precise data. Psychologists can measure where participants are looking, for how long and the size of the eye movements made; even eye movements so small that we would not notice them if we were looking someone in the eye. With the still advancing technology of eye tracking, data sets have increased in size from 1 or 2 values per participant to 1000s. Eyetrackers bring us, as a discipline, closer to Neuroscience because neuroscientists have long studied the neural underpinnings of eye movement control in non-human primates. Eyetrackers permit us to measure changes in pupil dilation; a mechanism that now has strong theoretical links to the neurotransmitter norepinephrine. Many researchers with a background in Experimental Psychology would now define themselves as Cognitive Neuroscientists because the mind has become the brain.

Technology continues to change Experimental Psychology as a discipline with the advent of neuroimaging techniques. It is now not only the increase in dependent variables that one has to contend with but also the explosion of data points for some dependent variables. Functional Magnetic Resonance Imaging (fMRI) permits the recording of activity in increasingly smaller collections of neurons. Sampled in volumetric elements or voxels, fMRI records the activity of the brain at a rate of one whole brain volume every few seconds. Given voxels typically measure $3mm^3$, recording activity in the whole brain results in tens of thousands of data points every few seconds. Compounding the problem is the advent of the equivalent of more 'megapixeled' brain scanners that enable resolutions of voxels at $0.2mm^3$.

Where once complex theories were built around a single dependent variable, theories now have to catch up. Researchers have to deal with more dependent variables and much, much larger datasets. Storing, sharing and dealing with data becomes cumbersome; as does analysis. Theories built around one dependent variable have to learn to interact with those built around another. Analyses have to move from the univariate to the multivariate. Disciplines have to help each other out.

An oft-quoted comment about the potential folly of trying to understand the mind and brain suggests that if our brains were simple enough for us to understand, we would be too simple to understand them. Improvements in technology help us understand the mind; they change disciplines and change minds (to brains). Reacting to improvements in technology requires smarter more interactive and collaborative research networks and smarter treatment of data.

6.3 The impact of remote sensing data on environmental science

Ross Hill

School of Applied Sciences
Bournemouth University (Talbot Campus)
rhill@bournemouth.ac.uk

This presentation introduced remote sensing and Earth Observation, outlining why environmental scientists use remote sensing for environmental assessment and giving a series of examples. Advantages and disadvantages of remote sensing for environmental assessment were addressed, which led to discussion points including data size issues.

Earth observation (EO) is the study of the Earth's surface and atmosphere by remote techniques. In general, this involves the use of sensors on board aircraft or satellites to measure reflected or emitted electromagnetic radiation. The spatial scale of focus can be anywhere between local and global. EO systems can be passive, recording reflected or emitted solar radiation, or active, recording backscattered radiation supplied by the sensor. The focus of EO can be on the atmosphere, land, oceans, or cryosphere, and the global teleconnections between them. This can be critical information for global environmental modelling.

Remote sensing and EO is used for environmental science for many reasons: (i) it is a rich source of spatial and temporal information on Earth surface components and processes, which can therefore be used to monitor and develop an understanding of the environment; (ii) the information provided can be accurate, timely, consistent, and provide remote access to areas that are inaccessible, dangerous, out-of-bounds; (iii) there are archive historical data (air photos since the 1940s and satellite imagery since the 1970s); EO data facilitates a move to quantitative applications (i.e. measurement and modelling); (iv) EO is a low cost per unit area means of data collection; and (v) EO is the only feasible approach to collecting data at regional to global scales

Examples of where EO data have been used in real world environmental applications are numerous and include the monitoring of: deforestation, flooding, forest fires, ice cap retreat, volcanic ash, severe weather, air pollution, and global vegetation productivity. Landscape-scale mapping and assessment has included: land cover, carbon, geology, soils, agriculture, forests, urban expansion, landscape and habitats.

In spite of the above advantages and numerous applications, remote sensing is a highly technical and rapidly evolving discipline. This provides many opportunities to explore new areas and acquire new physical or geochemical measures relating to Earth surface properties. However, this also lead to difficulties, for example in calibrating data and validating derived measures, in software that meets ever increasing user requirements, and in data storage, transfer and processing. EO data file sizes have increased exponentially over the past 20 years, with software and hardware not keeping pace with the development of data generating EO systems.

6.4 A look behind the curtain in the house that tweets

Andy Stanford-Clark

Distinguished Engineer
Chief Technology Officer, Smarter Energy
IBM Global Business Services
ANDYSC@uk.ibm.com

Andy Stanford-Clark's house is full of gadgets. Primarily based on ways to give him and his family information about the energy use of their home, but also a range of other experimental home monitoring and home automation devices to help further Andy's understanding of energy use in the home, and the application of IBM's MQTT messaging middleware (http://mqtt.org) for interconnecting sensor systems within the home.

Andy has been monitoring the electricity usage of his home since 2007, and has amassed a large corpus of data for data mining investigations. Initially using a home-brew power monitor, he now uses off-the-shelf equipment from UK company CurrentCost.

The devices in Andy's house are interconnected using IBM's MQTT lightweight messaging software, which supports a publish/subscribe messaging pattern using a central message broker. Brokers can be interconnected into a defined topology, so in the case of home energy monitoring, a local broker has a "bridge" connection to a public broker on the internet which enables some of the data from the house to be made publicly available. The MQTT message broker of choice is either "Really Small Message Broker" (RSMB) (http://www.ibm.com/developerworks/community/alphaworks/tech/rsmb), or the open source "MosQuiTTo" (http://mosquitto.org). The home message broker runs on a low powered embedded Linux server, of which a number of models are available, but the Viglen MPC-L was chosen for Andy's system, costing less that £100, and most importantly for a server that's running continuously: only uses 10 Watts of power, so costs only £10 in electricity each year to run.

The range of sensors that Andy has deployed include sub-metering of different areas of his house, using additional CurrentCost power sensors (CT clamps) and "IAMs" - Individual Appliance Monitors - which record the power use of specific appliances such as dishwasher and TV. Other sensors give additional dimensions of data: whether windows are open or closed, an indication of "occupancy" of a room, and environmental data such as temperature. Water usage is tracked using a magnetic sensor on the water meter and published over a wireless connection to the home message broker. Andy also monitors the readiness of mouse traps in the loft, with the system sending out a "mouse event" message when a trap is triggered. This is sent to Andy's mobile phone as an SMS message or a tweet.

As well as monitoring, devices in the home can be controlled. Andy has used the X10 power-line carrier system for controlling electrical appliances. He can control outside lights, the fish-pond fountain, and arranged an SMS interface to control Christmas lights in the garden.

IBM talks of a "Smarter Planet", which is based on the 3 "I"s - Instrumented, Interconnected, Intelligent - which is the basis for the architecture that Andy has applied to his home automation system. Making sense of the sea of data that is generated from sensors systems is a problem that is gaining greatly increased traction, in the areas of data mining, optimisation and analytics.

The Big Challenge of the 3rd I - "intelligent" - is to turn Data into Information, Information into Knowledge, and Knowledge into Wisdom or Insight about the world "out there". Turning insight into timely, actionable events, is what makes Smarter Planet such a compelling philosophy.

TweetJects are objects that twitter - compare BlogJects, objects that blog, covered by others. Using Twitter as the communications platform for objects has several advantages - the "timeline" of the object gives an audit trail of its activities; the Direct Message capability of twitter gives real-time alerts as SMS messages to mobile phones to alert someone of something important happening; and finally the configurability of Twitter enables different users to configure their own notification preferences for their interaction with any given TweetJect.

Andy's house tweets about various aspects of its activities, including energy use (e.g. every £5 of electricity used during the month is tweeted); regular electricity and water meter readings; unusual "water events" such as a burst pipe or a dripping tap; doors and windows opening and closing; the identity of phone callers to the house (from the callerID). The "house that twitters" has been on television (http://www.youtube.com/watch?v=dSScLMMmkMk), and provides a useful test-bed for Andy to explore aspects of home automation, energy-related behaviour change, privacy, security and interaction with Social Media.

6.5 The RCUK PATINA Project: Navigating Smarter Research Spaces

Graeme Earl

Faculty of Humanities
University of Southampton
graeme.earl@soton.ac.uk

The RCUK PATINA Project (http://www.patina.ac.uk) is funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Arts and Humanities Research Council (AHRC) through the RCUK Digital Economy programme. It began in October 2010 and will last for three years. The project developed from a funding sandpit focused on the technical and epistemological aspects to designing and using research spaces for the next 50 years. The PATINA project that emerged from it is particularly concerned with the blending of digital and physical research practices, and creating and evaluating hybrid research spaces with novel properties. In part the project is examining the theoretical implications of what could be described as smart spaces, particular in terms of wearable, portable, subtle technologies where no fixed instrumentation of the research environment is undertaken. Modes of use of such technology include the recording of research practice, and in playing it back, and the ability through this metaphorically and practically (both digitally and physically) to walk in the footsteps of researchers. This paper introduces some of the core themes that have emerged and identifies some work relevant to just one of the many domains implicit in it: namely archaeology.

Given the breadth of research spaces of relevance the PATINA project has a tight focus on three types of research space:

1. The field, characterised by limitations on resources, need for robust and intuitive tools, and a focus on matching novel approaches to extant, ingrained physical and perceptual research approaches;

2. The library or archive, characterised by existing rigid structures of knowledge management and retrieval, and stable modes of engagement with research materials;
3. The home, characterised by informal, personalised patterns of research practice, and significant emotional ties to space and activity.

Digital and theoretical approaches to bridging the digital/ physical divide are being employed in an environment structured around semantic representations of knowledge, particularly in terms of provenance – the interrelatedness and contingency of research ideas and information. Through this combined interaction design, engineering and data architecture the project team have been able to address core theoretical issues concerning the nature of research objects and processes. For example, creating, understanding and representing narratives of research practice are fundamental – whether by capturing research events and interactions or by building novel architectures of information. These narratives can be seen to create what Yates (1966) described as “memory palaces” – mechanisms for spatialising memory. It has been the vision of the project therefore to consider means by which interaction methods and data structures can build intangible, hybrid equivalents to such internal models.

Alongside differences resulting from the varied research backgrounds of the participants the PATINA project has also revealed shared core issues such as the need to personalise, and at times to make private our research spaces. One pervasive analogy has been the need to distil the affordances of the ever-productive train journey in which the researcher seems able to function particularly well, and to artificially create its balance of dislocation, concentration, temporal structure, and alterity.

From my perspective as an archaeologist I would summarise where PATINA sits in terms of smart spaces by comparing a research meeting mediated by Skype and shared desktops, and research undertaken in a dusty, complex field site. The former is a common research engagement characterised by both physical and technological mediation. The Skype discussion provides communication and enables note taking, merging synchronous and asynchronous modes. The excavation in contrast is reminiscent both of the means by which PATINA was funded – a sandpit where strangers meet to brainstorm research – and the location for much of my work. For me what emerged from both of these ‘sandpits’ was an understanding of research as being contextual, complex, interactive, personal and patinated. The research Skype chat evidences much of this but PATINA is exploring how much better this hybrid space could be when understood in terms of performance of situated research.

The patina of a research space refers to the sense in which locations of research have biographies, trajectories in time, and which indicate gaps in knowledge as much as the knowledge itself. Patina implies transformation of, in the case of archaeology, the physical research object through use, and analogically of the digital surrogates that commonly build up around modern research practice. Patina thus also implies travelling through time – reflecting on research processes as they unfold and providing a trail to follow. Research is also contextual as research spaces afford different behaviours, including in archaeological terms the material of the object of study. Data objects can thus be considered to encapsulate context, and this is often personal to the researcher and mutable. Inevitably our research spaces are therefore also complex, requiring increasingly sophisticated methods to visualise and explore. PATINA is therefore also examining the potentials of alternative visualisation, haptic and other mechanisms. Research spaces can finally be defined in terms of potentials and forms of interaction and personalisation. In an archaeological context one might define collaborative vs. solitary practices, and various social, political and cultural influences on these. Clearly technology has much to offer the re-routing of behaviours around these influences.

The PATINA team have engaged in a broad range of research activities to explore these issues. In the area of note taking we have examined behaviour of archaeologists in archives and lab spaces and in particular the way in which they associate objects of study (e.g. ceramic fragments) with interpretative information such as weight and type. This has led on to development of a data structure for representing the gradual accumulation and modification of such contextual, collaborative notes that is based on capture of digital provenance. We have also examined research processes on fieldwork sites such as Çatalhöyük, Pompeii and Portus and considered issues such as hierarchies of information, and the relationship between space and the formal and informal development and documentation of interpretations. We have created mobile solutions for capturing, prompting and expanding research collaboration in the field, including work on automated analysis of text notes, visualisation of research data, gestural interaction tools, scanning and wearable life-logging approaches. Finally, we have created hardware probes that consider how the morass of such digital research information can best be expressed and interacted with. One example of this has been the Chronotape. As PATINA continues so I envisage a greater sense in which the embodied nature of archaeological and other research practice permeates wholly digitally analogues, and the hybrid smart spaces of the future.

6.6 Musical interactions over distributed networked spaces: challenges and opportunities

Alain Renaud

School Of Design, Engineering And Computing
Bournemouth University (Talbot Campus)
arenaud@bournemouth.ac.uk

Interacting musically across a multitude of networked spaces is a good example of smart interconnected spaces. It requires the combination of several disciplines ranging from network engineering, the configuration of spaces, multichannel sound and smart agents to make a performance as interactive as possible and rewarding for the performers and the audience alike.

The case of music

Music is a good example for understanding the interplay between participants scattered across a multitude of locations.

A- Music has stringent timing requirements. Indeed performing across several spaces require the development of strategies to keep latency or the delay to a minimum.

B– Music is a natural process. The fact that the “language” used to interact is unspoken, allows the development of natural interactions that become meaningful and elaborate as a piece of music progresses in time.

C- Because the audio quality is so important in this context, the network can be tested to its limits in terms of bandwidth and reliability.

D- Once musical interactions are achieved over the network, the same models of interplay can be implemented to other disciplines with the aim to develop interconnected physical spaces over the network for a variety of other applications;

thus leading to the development of spaces which couldn't exist outside of a networked situation.

What is a networked space?

The traditional configuration of a network space is to connect a multitude of nodes (physical or virtual) to a central focus point, traditionally a server, to manage the interactions between nodes and agents communicating over the network. Another approach, which is the one used for musical interactions over the network is close to a mesh network configuration, in which each node is connected to all other nodes, creating a real physical spaces combining several individual environments.

Challenges

The mesh network configuration poses several challenges that are all part of a research question and being solved through various practice based research initiatives in the field of networked music.

A: Latency

Latency is indeed an issue. If two nodes are connected through a reliable and over provisioned network, the latency value will be stable. Therefore interconnecting two nodes with a latency of say 50ms will not be an issue. However, once a third node is added, the latency ratio between the mesh-connected nodes will lead to unequal latency ratios. The challenge in this case is to find ways to creatively manage latency.

B: Sharing environments

Connecting several nodes leads to the combination of physical spaces into one. However, each space will retain its acoustic features and need to be cautiously combined with the other nodes to create a physically connected environment that makes sense to both the performers and the audience. The sharing of these environments also leads to the combination of the acoustic particularities of the network itself. Indeed the network distance generates latency, which once rendered as an audio signal leads to echoes or reverberation depending on how high the latency values are.

C: Listening experience

A particularity of combining real spaces through a network connection is the fact that even though meaningful interactions can be achieved, the perception of the sound and the environment will be different depending on where the subjects are located as such individual spaces will have different reverberation times and the latency values will be perceived differently depending on the location. Strategies to overcome such issues are therefore needed.

<u>How does this apply to the development of smart spaces?</u>
The lessons learnt with network music interactions are very relevant to the building of smart interconnected spaces in two ways:

- The features inherent to musical interactions over the network can be ported to the development of distributed meetings with an experience that goes way beyond the traditional teleconferencing model.
- Interacting musically over a network requires the building of very immersive environments sonically and visually. Such an immersive experience can be implemented in the development of interconnected smart meeting spaces.

6.7 Are You Sitting Down? Towards Cognitive Performance Informed Design Spaces

How smart can an environment be, if we're not "smart" in them?

m.c. schraefel

Electronics and Computer Science
University of Southampton
mc@ecs.soton.ac.uk

In our work to support creativity, innovation and discovery, we have been looking at simple factors that affect cognitive performance. For instance, we know from related research such as the 2005 Whitehall prospective study (Singh-Manoux 05) that people who are sedentary over time effectively become more stupid. The inverse is true of active colleagues. We also have numerous studies now that show school children who start active and remain active continue to outperform more sedentary colleagues throughout school and university. Studies have shown across a range of populations that even a short burst of physical activity improves cognitive performance: twenty minutes of stationary bike pedalling at a mildly elevated heart rate resulted in improved cognitive task performance. A pilot study we carried out seems to indicate sometimes that even muscular work as small as moving eyes back and forth to find a target on the left the one on the right back and forth can have performance improvements. A smart environment, it seems, will be one that considers how to incorporate regular movement. Kind of movement may not be obvious.

More recently, work has also shown that remaining sedentary throughout the work day has a negative impact on a number of lifestyle disease factors, like insulin resistance that can lead to onset of type II diabetes: that working out a couple of times a week does not seem to offset what happens during the day without movement. A solution proposed has been the walking desk: where folks have a slow treadmill beneath a standing desk to keep their bodies moving while they work. Interestingly, one study that looked at a few cognitive performance tests showed that while many tasks did not degrade while using the walking desk, first, none improved cognitive performance (like the pedalling before similar tests did) and second some got worse, especially math type tasks. We do know that sitting has other physiological harms associated with it, not just cognitive. Standing desks have become increasingly popular to address these seated effects (see schraefel 11 for a survey of these papers). We looked, therefore, at a range of what are known as cognitive executive functioning tasks to compare sitting with simply standing - not walking. Our results were similar to the walking desk study: with some tasks there was no significant difference; with one, there was, and it was a surprise: if multitasking, better sit down.

With respect to smart environments it seems that blending standing and sitting is a good idea for physical health; learning how to coordinate those movements for optimal cognitive performance benefit is an opportunity for smart environment design (schraefel and Andersen, 12). And lest we forget, the ubiquitous ON of email, colleagues recently looked at performance and stress markers when they asked participants only to look at email once a day rather than ad libidum. It's easy to imagine how over a week, performance seemed to improve and stress levels were perceived to go down.

Research from Japan has shown that for workers contemplating returning from work after stress leave, Heart Rate Variability is a better measure of readiness than the standard questionnaires to assess fitness to return (Takada 09) - and that participants usually think they're ready sooner than they are. A smart environment may also therefore consider better balance around just how much multitasking is enabled or expected or how much work is past an effective dose for optimal performance.

What each of these studies has in common are efforts by scientists to consider cognitive functioning related to physiological markers, from heart rate variability to brain wave ratios when combining interaction of a brain within a physical body, and that body within a physical and social context. The opportunities for grounding smart environment design in such quantifiable baselines of our Selves as we develop them is an exciting prospect for truly smart, responsive environments of the future.

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6.8 Convergence scenarios for seamless data flow in direct relation to space

Yonca Ersen

Freelance Architect / Product Designer / Interior Designer
Lecturer in Architecture at the University of Westminster
ye_class@hotmail.com

Smart(er) cities topics is high on urban planning agenda. The city represents a "total institution" and a strategic space for application of all types of new technologies. The general expectation is that by weaving technology into the built environment in a robust way; networking, functionality and prosperity can be brought up to the individualist expectations of modern day society. The aim is to not only upgrade the capital infrastructural assets but also increase the availability and quality of knowledge, communication and social infrastructure. This concept is a means by which technological innovation can be encouraged to strengthen economy and further democratise the society through more evenly distributed urban infrastructure.

The "total institution" archetype of western cities dates back to 800BC Greece. It stretches the field of urban planning and architecture beyond design, construction and management of manmade surroundings. The Greek agora -an early prototype of city as an institution concept- was a result of “peoples politics”, democracy. It delivered a physical space that converged public services and the market place. It made knowledge more accessible to the people in a central space and created a meeting point with those who had the latest news. Around 1000AD, the Medieval Europe centred on market economy and emphasised the importance of adequate information exchange for efficient trading. As a result, the marketplace became a location of urban status; the midpoint of the urban layout that cultivated power and wealth. During the Renaissance period the concept of individualism was added to the medieval concept of city. Later, lack of its availability to the masses ultimately led to the French Revolution.

Across the ocean, the settlers of North America had the opportunity to experiment with the earlier Greek concept of urban democracy; producing landscapes without central space, in search of social equality by rejection of spatial hierarch. Only, such idealist inspirations were not enough to prevent the American society from producing a new type of centre. Yet again, centres were naturally formed to support the liberal economy and these unintentionally formed hubs represented both spatial and social hierarchy.

The idea of urban democracy that eliminates spatial hierarchy remains only as a vision. Technology is seen as a means by which we can re-configure the concept of centre through a re-definition of the concept of agora. At present, our understanding of centrality is completely different. People are distinctly individual, space is not necessarily relevant to accessibility of information and communication with others. All this is possible because today, the potential for information sharing is unmatched in history. As well, our understanding of the market place is shifting, rapidly; workspaces, meeting spaces are mobile and money can be made or spent without geographic boundaries.

Yet, in this post-industrial, post modern era, we still live in cities with infrastructural problems, poor air quality, poor hygiene, luck of access to green space, luck of affordable housing, luck of social justice. It can be argued that, available technologies are not successfully deployed in urban environments, in order to address the necessities for long-term wellbeing in dense urban settlements. The interrelated discipline of urban living draws upon economics, law, public policy, management, design, sustainability and technology as well as social scales –from micro to macro- that is included in all such elements. In designing smart cities, the combination of these factors will have to be reconfigured harmoniously to maximise application of smart technologies to city infrastructures, in a shorter timeframe.

The internet is fast becoming the "new agora". Professionals commenting on IT trends and producing new technologies all suggest that majority of people are interested in information being presented in a dynamic and usable form. This should allow different users to view different aspects of the available information. However, currently the value of online user contributions is limited to their being collected into community sites.

The key technical challenge is generating an ecosystem of participation aimed to capture structured data on its way into the internet. Subsequently creating interlinked structure fields with class hierarchies (collective knowledge systems). This can help add specificity to data content for improved analytics through automated leverage of metadata tags based on publishing classifications; reduce ambiguity and increase reliance of sources. Collective knowledge systems would require, convergence, planning and implementation of resource infrastructure in a multifaceted way and it will play a significant role in the formation of "Future Internet".

If we aim to build smart cities for social and environmental benefits by mapping out the built environment as a very dense ecosystem that requires internet and smart technologies for a more harmonious organization, we must address interoperability.

Cloud infrastructure: software architectural framework to solve confluence, privacy, governance and other relevant issues that will compliment;

Services infrastructure: hardware and services for capturing, effectively distributing as well as cataloguing relevant data to encourage innovation in IoS and IoT.

Furthermore, possible effects of future internet - governs, economic models and policy making- must be viewed as an overall package and should include feedback from society. This requires developing a new type of dialog and collaboration between academics, open source communities, public/private sector service providers as well as end-users. The outcome is likely to not only advance the research based on feedback but also open up channels for exploiting links in research. It may encourage creation and analysis of progressive relationships and new economic dimensions. Consequently, the online activities may become more robust/error free, user friendly and created in shorter timeframe.

History shows that, mass demand is the biggest drive for change. Therefore, the internet is still potentially “untapped”, until critical mass demands more accessibility and utility which can be driven by collaboration for the benefit of all stakeholders.

7 Appendix B - Analysis of recording methods

We have given careful consideration to how far we should go with analysing the records captured during the three workshops, especially those for the Bournemouth workshop, as we have a 3D audio recording of all the sessions. We have collated in a time-stamped Excel spreadsheet the *#smartspaces* tweets from that workshop with the logs made by the note-takers; it would be straightforward to insert in the appropriate places the contents of the facilitator's flipcharts.

Previously, we have experimented with creating transcripts of the audio recordings from the first workshop, but thus far have not needed to examine those transcripts, mainly because the note-takers' chronicles were more than adequate for our needs when reporting the outcomes of the first workshop. We continue to be aware of the observation made in section 4.1:

> Although there is exciting technology being developed for recording and transcribing meetings from audio tracks and speech to text, we are a long way from being able to process all this information in a useful way.

In section 4.2, when discussing the use by archaeologists of recording technologies, we pose the following questions:

> Is there any value in such a system, will people use it, what aspects will people use, and are there more or less effective ways of presenting the information to the people who want to use it? Is it the case that recording the whole meeting word for word is essential or even useful, or is it the case that the key points and decisions, or interpretations from the archaeologists point of view, are sufficient?

We are also conscious of another observation made in section 4.1:

> The data and information need to be kept: you might not need it now or might be unable to process it now, but that does not mean you will not do so in the future.

Our conclusion with regard to further analysis of recording methods *at this stage of our investigations* is that we should not proceed with any deeper analysis, but we should nevertheless retain all the recorded data and information in case we need to pursue particular issues at some time in the future.