

THE NEW WELL-TEMPERED ENVIRONMENT: TUNING BUILDINGS AND CITIES

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Abstract: Our work has two main components - one part practical, the other theoretical - though both are related, and have developed in discussion. They both concern the measurement and feedback of energy usage in buildings, and then cities, in order to enable users to change their behaviour - to in effect, 'tune' their environment. The work is intended to raise important questions about the efficacy of such schemes, outline the potential of systems when stretched over urban and social networks, to speculate about the future of information as part of the fabric of buildings, and to make some practical considerations clear along the way.

1: Tuning 13 Fitzroy Street

The first part of the work concerns research and development work led by Arup's Dr. Duncan Wilson, deploying wireless sensor networks in the new Arup building at 13 Fitzroy Street, London.

This is predicated on the emerging understanding that occupation of a commercial building typically costs more than 200 times the initial capital cost of construction and that ~40% of final energy consumption in the European Community is in the buildings sector. In addition governments are pushing regulatory frameworks to reduce the energy impact of such running costs [1]. Within the UK, energy used in buildings accounts for some 50 per cent of the country's carbon dioxide emissions.

Thus the ability to moderate the use of energy in buildings can have a significant impact on the overall efficiency of the built stock. Changes to the design and construction of new buildings is leading to significant improvements in building efficiency but the majority of the built stock is comprised of older buildings with limited potential for passive energy saving. The Living Buildings initiative [2] at Arup is one example of our sustainability activities working towards the

consequences of the context above. At a macro level we are also working at a city scale on projects such as Dongtan eco-city in China [3]. But what are the opportunities for pervasive computing?

We have been exploring the use of ubiquitous or pervasive computing technology based around wireless sensor network (WSN) platforms to gain improved understanding of real-time operation of buildings and to allow greater environmental control of existing buildings that do not have the installed infrastructure to actively control energy consumption.

The first small steps have been to deploy WSN's in the office environment to investigate both energy consumption of the building and the comfort of the space [4]. Various quantitative and qualitative measures are being taken and fed back in real-time to occupants of the space (not just building / facility managers). At the newly built Fitzroy Street building, the two main sensor network development platforms used were Crossbow and Arduino. Motes have been deployed throughout the building (and in a related study at Central Saint Martins college in London), connecting over Bluetooth IEEE 802.15 and sensing occupancy levels (via Passive InfraRed sensors) combined with performance data from the building management system. The Bricks Framework is used to fuse data together, and provide the base for dynamic visualisations, sound installations and interactive devices.

We'll discuss various methods for conveying information back to users, and the many issues therein. As it stands, the system is producing data across all axes and various visualisation methods are being designed for a number of locations within the building.

Ultimately, this work at the level of buildings may provide an opportunity to start doing city wide monitoring of the pre- and post-occupancy performance of sustainable buildings. This pervasive data collection from very large sensor populations could be integrated to support control and optimisation at this scale. City information modelling systems are beginning to emerge, extrapolating from Arup's work with building informational modelling (BIM), and this provides a unique opportunity for post construction analysis and validation.

2: The Personal Well-Tempered Environment

Developed by Dan Hill, this section continues the themes covered thus far, extrapolating the potential for such schemes when stretched across urban and social networks. It's an imagined system at this point [5], a real-time dashboard for buildings, neighbourhoods, and the city, focused on conveying the energy flow in and out of spaces, centred around the behaviour of individuals and groups within buildings.

In this, it becomes a form of 'BIM 2.0' that gives users of buildings both the real-time and

longitudinal information they need to help change their behaviour and thus use buildings, and energy, more effectively. It would be an ongoing post-occupancy evaluation for the building, the neighbourhood and the city. Importantly, it proposes measuring contribution as well as consumption, through sensors embedded into localised wind and solar power, grey-water collection, and so on. Further, it explores the idea of measuring behaviour across wider circuits, such as an individual's movement through the city (scoring 'points' for public transport versus private transport, monitoring environmental usage in office environments, and so on.)

Suggested as a software service layer for connecting things together within and across buildings, it would take a 'plug-in' approach to connecting energy sources and resources, drawing from architectural theory of Archigram and Cedric Price amongst others. Multi-sensory feedback is a particular theme in the suggested interface, exploring different ways of conveying this information. The work is based on a survey of existing energy monitoring schemes and products in this area, collated and discussed online. Over and above this, it folds in some ideas from social software, particularly the reflexive mode produced by systems such as Last FM, Flickr, Dopplr, Nike+ and so on, and wraps these up with the aforementioned architectural theory as well as making connections to newer concepts like Bruce Sterling's spimes and everyday product design.

Drawing from this recent history of social software, the proposal describes various ways in which an 'open' approach to data, allied with social networks, may enable a socialising of the data, or even a 'gaming' element - in which individuals, suburbs, neighbourhoods and cities can compare their environmental performance. This latter aspect is an attempt to make the civic relationship between an individual and their environment clear, thus addressing a key issue in the emerging informational city. Taking the conceptual starting point of an API on a house, the idea suggests extending this to the API on the neighbourhood, even the city itself. Making the effects of informational behaviour visible on the street in turn asks further questions about how to perceive and communicate the emerging informational aspects of the contemporary city, a theme increasingly fundamental to urban planning.

Though initial investigations elsewhere suggest that feedback on energy use can help change behaviour [6], questions will be asked of the efficacy of such 'persuasive visualisation', as part of a critical assessment of whether such systems can truly have a beneficial effect in terms of 'tuning the environment', or whether the real problems lie elsewhere.

The connection to the aforementioned Arup projects will be made clear, seeing the Personal Well-Tempered Environment as an example of Arup's approach of 'total design' - a multidisciplinary framework for building - and discussing how information itself can increasingly be thought of a material within building. With a holistic approach, it makes sense to consider information as part of the built fabric, just as with glass, steel, ETFE etc. The Well-Tempered ideas will begin to inform Arup's work on the ground, and vice versa, thus creating a constructive relationship between imagined informational architectures and pragmatic, deployed engineering.

Motivation for participating in the workshop

This workshop provides an opportunity to extend the thinking around our projects so far, testing the ideas against related work and discussing with others working in this field, subsequently wrapping the findings back into practical work through our projects and research at Arup.

Biographies

As part of the Foresight Innovation and Incubation team at Arup, **Dr. Duncan Wilson (duncan.wilson@arup.com)** is responsible for researching medium and long term futures with a focus on social and technology factors. He develops foresight and innovation capability within Arup, co-created the Drivers of Change concept, and programme manages a series of workshops on the future of the built environment. He was Principal Investigator on a Euro 1.4 million two year research project (DTI technology programme) applying wireless sensor networks in the built environment, is a partner in the European Union SENSEI project looking at networks of wireless sensor networks and is leading an internal research project on the implications of ubiquitous computing for Arup. His research merges interests in sensing and monitoring and creating interactive, ambient displays that solicit and feedback information with the intent of influencing behaviour. Duncan is a Chartered Engineer (IET), has a PhD from University College London in Artificial Intelligence and Machine Vision and blogs at <http://www.driversofchange.com/emtech/>
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Dan Hill (cityofsound@gmail.com) has been working at the forefront of innovative information technology since the early '90s, and is responsible for many innovative, popular and critically acclaimed products and services. He was Head of Interactive Technology & Design at the BBC in London for 5 years, before launching the critically-acclaimed international magazine *Monocle* during 2007, responsible for its digital services. He recently joined Arup as a Senior Consultant in their planning group, working with urban informatics. During 2007, Hill co-organised the *Postopolis!* architecture and urbanism exhibition/conference in New York City, and has a background in academic research and teaching in urban regeneration and urban informatics. His weblog *City of Sound* (<http://www.cityofsound.com/>) is generally considered to be amongst the foremost architecture and urbanism sites, recently voted by Planetizen as one of the ten best planning, design, and development sites for 2008 (<http://www.planetizen.com/websites/2008>).

References:

[1] For example, the EU Energy Performance of Buildings Directive, <http://www.buildingsplatform.org/cms/>

[2] <http://www.arup.com/advancedtechnologyandresearch/feature.cfm?pageid=9887>

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[4] FANGER, P.O. Thermal Comfort. Analysis and applications in environmental engineering. McGraw Hill. <http://www.flickr.com/photos/pseudonomad/collections/72157603889824626/>

[5] <http://www.cityofsound.com/blog/2008/01/the-personal-we.html>, with video at <http://nextbutton.pureprofile.com/TVC/?id=4326>

[6] Pacific Northwest National Laboratory of the Energy Department, 2008

(<http://www.nytimes.com/2008/01/10/technology/10energy.html?scp=3&sq=department+of+energy>)