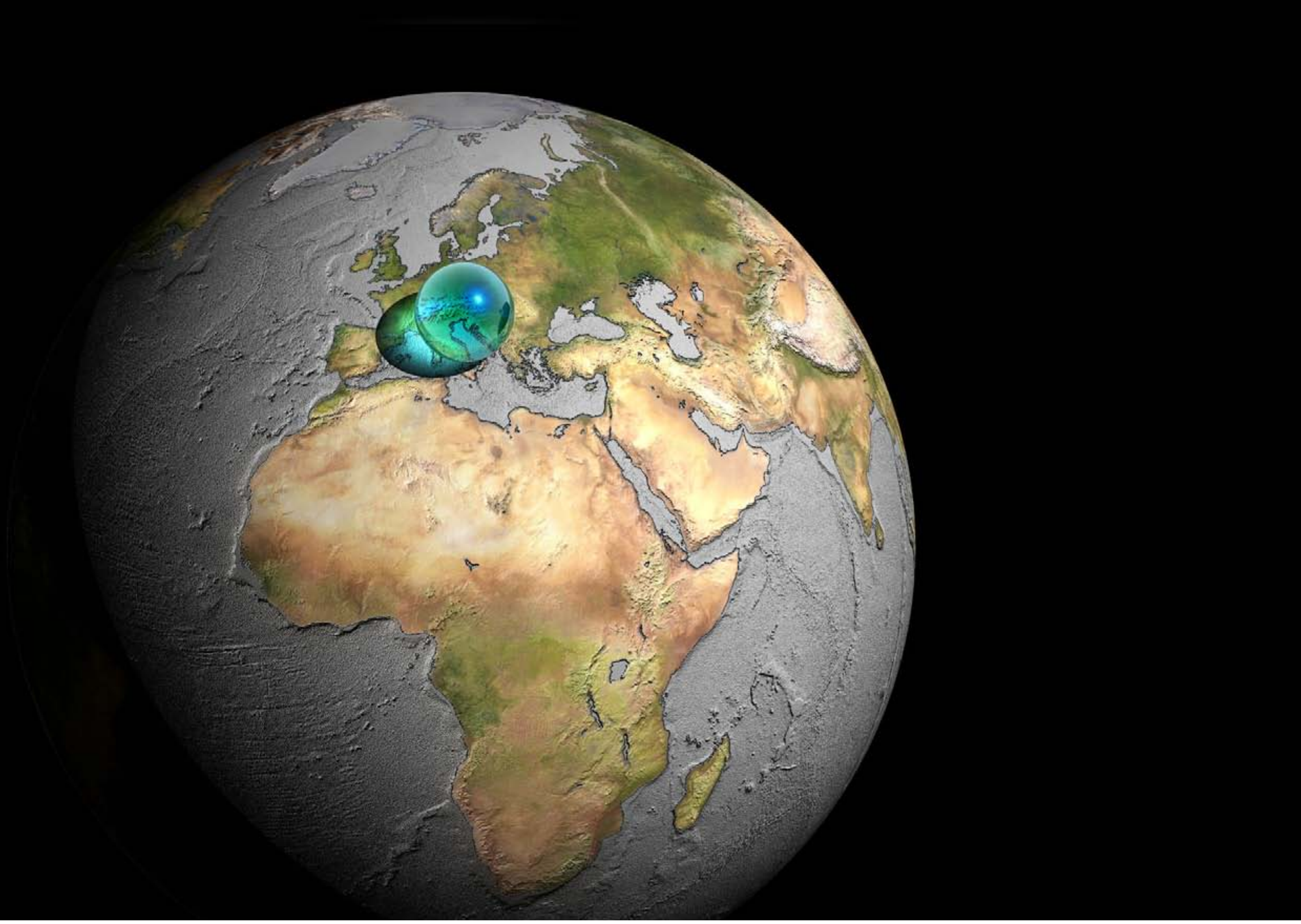

Making visible the invisible: Art, design and science in data visualisation

ADS-VIS 02011

International Advisory Board

Idea & Organisation
Michael Hohl

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All the water by Adam Nieman

All the water in the world (1.4087 billion cubic kilometres of it) including sea water, ice, lakes, rivers, ground water, clouds, etc. Shown on the same scale as the Earth.

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Tom Betts

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Making visible the invisible:
Art, design and science in data visualisation

ADS-VIS 02011

University of Huddersfield
School of Art, Design and Architecture


what are data?
ontology
beyond direct human perception
'inattentional blindness'
What does 'invisible' mean?
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How can aesthetics enrich a data visualization?
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Sarah Jane Pell, Undercurrent, 2002
www.andreapolli.com

Michael Hohl
Research Fellow in Design, University of Huddersfield, UK

Foreword

The two day *Making visible the invisible* conference was an experiment. It took place on 10–11 March 2011 at the University of Huddersfield, UK, and brought together 35 designers, artists and scientists from eight different countries. The purpose was to converse about the challenges of data visualisation, interdisciplinary collaboration and possible links to debates around climate change, sustainability and ecological literacy. A crucial aspect of this conference was its format which was based on conversations. Instead of listening to answers presented in the form of papers this event was about coming up with new questions through conversations in small groups. The papers presented in this volume were drafted before the event and made available for discussion among the authors via a dedicated online platform. After the event authors were given time to update their texts, using feedback received during the conference, before they were submitted for peer-review.

Why interdisciplinarity, sustainability and data visualisation?
How are interdisciplinarity, data visualisation and the debates around ecology connected? Let us begin with the 'data' in data visualisation. In August 2010 Eric Schmidt, CEO of Google, stated that every two days we create as much data as we have since the dawn of civilisation to the year 2003.[1] From 2003 on this rate increased dramatically, and it keeps accelerating. Much of this data needs to be processed to become useful information. The accessibility of some of this data is also supported by initiatives such as open-access, application programming interfaces (APIs) and open-standards which facilitate access.

As a result of this ease of access to data, in combination with other factors such as data visualisation being part of higher education curricula and the availability of software tools, data visualisation has received an increasing amount of publicity through popular blogs, book publications, workshops and presence in traditional media such as newspapers. Since 2007, for example, *The New York Times*, has its own 'Data-Visualization Research Lab',[2] which explores ways of visualising data and develops software tools for graphics, for both the online and printed version of the newspaper.

In our increasingly information-driven society, in which even biology has become an information science (Gleick, 2011), data visualisation techniques are becoming central tools for understanding, communicating and making informed decisions. In a sense H.G. Wells' 1904 prediction that 'Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write' (Huff, 1954) has not come true. Instead quite the opposite has taken place: rich and complex data is gathered by experts and transformed into formats that are easier to comprehend by the public. This is often pursued by interdisciplinary teams of researchers aided, for example, by software developers and graphic designers. How do these interdisciplinary teams communicate? How do members' skills complement each other? How constructive is disagreement?

Relevant to this context is that an increasing number of visualisations are created to inform the debates around climate change, sustainability or ecological literacy. This may include data on migration, economies, water cycles, consumption of resources, energy, environmental pollution or recycling. Often this requires input from experts from those disciplines, for example a scientist's assistance, to interpret and evaluate the data for an accurate visualisation and also to aid its analysis or interpretation. However, there are different approaches to visualising the data. Some may answer questions and elucidate, while other approaches intend to make us explore, reflect or ask questions. The data can be visualised within different conceptual frameworks and media. What is the role of technology in these developments?

In recent years there has been a silent revolution taking place in the sciences. This revolution is led by technology, especially sophisticated software and computers. Astronomers still look into telescopes, biologists still look into microscopes, however, crucial knowledge is gained by looking at computer monitors filled with graphs, charts and mappings rendered by software applications that visualise data. Before this data can be communicated to a non-expert audience it usually is analysed, scrutinised and modelled, forming part of the visual evidence of a larger theoretical framework, and a particular epistemology. We have become so accustomed to such aesthetic and convincing visualisations that some may not even consciously recognise them as such. The BBC's television series *Wonders of the Solar System* is full of such visualisations, for example of the Earth's 'Magnetosphere'[3] deflecting the solar wind. Scientists require visualisations such as these in order to have visual evidence of their abstract data, to support their theories or hypotheses, and to communicate their research to peers, the public, the media, and to funding bodies. As such, scientific data visualisations have become crucially relevant in recent years in terms of abstract knowledge becoming part of concrete visual evidence. This pertains to biology, the neurosciences, astronomy, economics, archaeology, just to name a few, which all transform into information sciences.

Making visible the invisible yet raises a number of questions. While the magnetosphere is a fact, what it looks like is not. No one has ever seen the Earth's magnetosphere and no one ever will, apart from the wonderful spectacle of the Aurora Borealis, the northern lights. However, everyone who has seen the vivid animation of the magnetosphere will have a distinct visual mental image of it, as of something being a clear fact, beyond doubt. This results in a number of fundamental questions. How do we visualise something that is invisible? Is the theory developed from research data accurate or is it contested? What is its correspondence with reality? Surely the scientists analysing the data did not create all animations themselves. In what way did they convey their interpretation of the magnetosphere to the designers that modelled and animated them? Are aesthetics given primacy over accuracy? How critical are we of impressions of natural phenomena that no one has seen before and which are based on theories which again result from interpreting measurements or experiments? How do we know that they are true to reality? Is an accepted hypothesis communicated as speculative or fact?

While scientists have to interpret, analyse and scrutinise data and draw their conclusions from it, it often requires designers or artists to transform these conclusions into communicable formats that capture the public's imagination. This also initiates debate. Roger Malina (Malina, 2009) speaks of our need for artists to make sciences intimate, sensual and intuitive, while Robert Kosara challenges the 'The Visualization Cargo Cult' (Kosara, 2010).

Two major London 2009 art exhibitions, 'Earth' (2009) at the Royal Academy of the Arts, and 'Radical Nature' (2009) at the Barbican, included 'visualisation art' exhibits. Another example is 'The Royal Society's Summer Science Exhibition 2010',[4] held at London's Southbank Centre. There aesth etic visualisations were complemented by over 40 scientific exhibition stalls which almost without exception used visualisations to communicate the relevance of their scientific findings in engaging and often tangible ways. The same data may be applied in order to tell the 'story' in different media and modes of practices. This results in fundamentally different experiences with the data.

It is worth noting that 'data visualisation' encompasses a vast range of practices. It reaches from clear and unambiguous mappings and elucidating, interactive animations of data, all the way to sonifications and more aesthetic physical installations.

This has resulted in an increased visibility of visualisations, both on the web and in other contexts, as devices to communicate complex information in a more tangible and evocative manner.

Such visualisations do not necessarily have to follow utilitarian principles, made to simply inform, but engage with the data or its theoretical implications with more explorative freedom, not giving answers but instead stimulating the spectator to reflect and perhaps ask questions.

Journalist Simon Rogers writes in the context of data-journalism:

> [T]he bigger task is to think about the data like a journalist, rather than an analyst. What's interesting about these numbers? What's new? What would happen if I mashed it up with something else? Answering those questions is more important than anything else. (Rogers, 2011)

From the overview above it becomes clear that data visualisation is often an interdisciplinary activity. Data emerges from one disciplinary background and requires an expert's interpretation while it is transformed, together with a visualisation expert, into a comprehensive – often visual – rendition. Every discipline contributes their unique skills in this process.

On the following pages we get an overview of the diverse approaches which engage in data visualisation and some of the methods used to facilitate and reflect upon the experience.

We would like to thank the authors for submitting their work, and the reviewers for their time and effort in providing constructive feedback. We hope that this publication will contribute to the advancement of knowledge around art, design and sciences in data visualisation. We would also like to express our gratitude to the American Society of Cybernetics for introducing us to the conversational conference and how to facilitate it.

Notes

1. Schmidt said: 'From the dawn of humanity to 2003 there were five exabyte of information created. An exabyte that is a lot. That is videos, movies and radio, books and things like that. You can measure roughly what those numbers are. In the last two days the same amount of information was created. Now that is a problem. If you plot this on a chart ... it goes straight up ... The rate of information generation is so overwhelming that we have never seen anything like it in humanity of this rate, and it keeps accelerating' (2 July 2010, Guardian Activate conference, http://www.guardian.co.uk/media/video/2010/jul/02/google-eric-schmidt-activate 11:50 min/16:08 accessed 10 August 2010).
2. The NYT data visualization lab can be found at http://open.blogs.nytimes.com/tag/data-viz/ (accessed May 2011).
3. A short video outtake of this visualisation of the Earth's magnetosphere can be viewed at http://www.youtube.com/watch?v=4QrYp8xGLhE (accessed 20 July 2011).
4. More information on the 2010 festival can be found at http://seefurtherfestival.org/ (accessed 9 May 2011).

References

Huff, Darrell (1954) *How to Lie with Statistics*. New York: W.W. Norton.

Gleick, James (2011) *The Information: A History, a Theory, a Flood*. New York: Pantheon Books.

Kosara, Robert, 2010, *The Visualization Cargo Cult*. Available at: http://eagereyes.org/criticism/the-visualization-cargo-cult [Accessed 28 July 2011].

Malina, Roger, 2009, *Rethinking art as intimate science: climate art as a hard humanity*. Available at: http://www.diatrope.com/rfm/docs/Art_Intimate_Science.pdf [Accessed 28 July 2011].

Rogers, Simon (2011) Data journalism at the Guardian: What is it and how do we do it?, *The Guardian* [online] 28 July. Available at: http://www.guardian.co.uk/news/datablog/2011/jul/28/data-journalism [Accessed 28 July 2011].

Huddersfield, May 2011

Keynote speakers

Ranulph Glanville
Independent Researcher
in Architecture,
Design, Cybernetics
Portsmouth, UK

Ranulph Glanville is a researcher in architecture, design, cybernetics and philosophy, and has published extensively in all four areas. He took early retirement and currently holds a post at University College, London, UK, and is professor and senior visiting research fellow at the Royal Melbourne Institute of Technology University, Melbourne, Australia. He currently is president of the American Society of Cybernetics.

Making invisible the visible
Sometimes you can learn most about a position by exploring its opposite or its complement.

I am interested in the notion that it may be as valuable to make the visible invisible, as it is to make the invisible visible.

As I write this, I am not clear on where this concept leads me. But I have in mind, for instance, the extraordinary way we lose ourselves – we become invisible – and in what I believe we gain from this: a truly shared experiencing. Or the way that not being in control may lead creativity (the value of unmanageability).

It is my intention to come to the conference prepared with ideas but with them insistently unformed. I will form them in the context of what goes on as we meet together. Who knows?

Mae-Wan Ho
Biophysicist, geneticist
The Institute of Science
in Society (ISIS)
London, UK

Dr Mae-Wan Ho is a world-renowned geneticist and biophysicist who has published extensively. She is Director of the Institute of Science in Society which raises awareness of unethical uses of biotechnology, and co-founder of the International Science Panel on Genetic Modification.

Beauty and truth in science and art
The quest for beauty is what motivates scientists, especially the greatest scientists. The beauty of a scientific theory can arouse such passion that some scientists are relatively unconcerned as to whether the theory happens to be true. Fortunately, really beautiful theories tend also to be true, in the sense that their predictions can be tested and confirmed empirically. That is what Indian-born American astrophysicist Subrahmanyan Chandrasekhar (1910–1995), recipient of the 1983 Nobel Prize for his work on the evolution of stars, argued convincingly in his book *Truth and Beauty, Aesthetics and Motivation in Science* published 1987.

Are artists too, motivated by the quest for beauty and truth? What would 'truth' mean in art?

Or is the quest for beauty and truth in both science and art no longer relevant in the present day, having been overtaken by the profit imperative and the quest for wealth?

One commentator remarks:

> A century ago, beauty was almost unanimously considered the supreme purpose of art and even synonymous with artistic excellence. Yet today beauty has come to be viewed as an aesthetic crime. Artists are now chastised by critics if their works seem to aim at beauty. (Danto, 2003: 170)

But the pendulum is swinging back. Since the early 1990s there has been a rising chorus to bring beauty back to art, if not to science. I shall explore what it means to recover beauty and truth in science and art.

Luke Jerram
Artist
Bristol, UK

Luke Jerram's multidisciplinary practice involves the creation of sculptures, installations, live arts projects and gifts. Since his professional career as an artist began in 1997 Luke has created a number of extraordinary art projects which excite and inspire people around him. Currently working with a number of established arts institutions and organisations in the UK, new complex and ambitious arts projects are being developed in parallel with one another. Once born, these new projects will evolve and tour abroad. His celebrated street pianos installation 'Play Me, I'm Yours' is currently touring and being shown in different cities around the world.

At the edge of perception
At the heart of Jerram's ongoing research lies his interest in human perception. It is fuelled by the fact that he is colour blind. He studies the qualities of space and perception in extreme locations, from the freezing forests of Lapland to the sand dunes of the Sahara desert. New ways of seeing and new artworks emerge from these research field trips. Works such as 'Retinal Memory Volume', 'Sky Orchestra' and his glass virus sculptures have emerged from Jerram exploring the edges of perception. Published by The Watershed, *Art in Mind* is a new book tracking much of Jerram's perceptual research.

Jerram also works as a creative consultant where he feels confident in applying his creativity to any new situation. In 2007 his presentation in London to the DCSF helped secure £0.5 million of funding for interactive exhibits in Bideford school. His recent clients included the Polish Cultural Institute, London and the Royal Shakespeare Company, Stratford.

Fascinated with how the world works, Jerram consults and collaborates with scientists and engineers. Working in partnerships with individuals and institutions he builds teams of specialists to make each work come into being. Working with a team of specialist glassblowers, Jerram's microbiological glass sculptures are in numerous private collections around the globe and on permanent display at the Wellcome Collection, London, and in Bristol City Museum. In 2007 Jerram won an Institute for Medical Imaging Award for this work.

Jerram also creates unusual artwork gifts for his friends and family. In 2006 he made a Talking Engagement Ring for his girlfriend. The ring has his proposal etched onto the outside of it which can be played back using a miniature record player.

Andrea Polli
Mesa Del Sol Chair of Digital Media | Associate Professor, Fine Arts and Engineering, University of New Mexico, NM, USA

Andrea Polli is currently an Associate Professor in Fine Arts and Engineering in the area of Art & Ecology at The University of New Mexico, and Mesa Del Sol Chair of Digital Media at the University. Her work with art/science, technology has been presented in over 100 presentations, exhibitions and performances internationally, including the Whitney Museum of American Art, The New York Hall of Science and The Field Museum of Natural History, and has been recognised by numerous grants, residencies and awards including NYFA, Fullbright and UNESCO. Her work has been reviewed by the *Los Angeles Times*, *Art in America*, *Art News*, *NY Arts* and others. Her most recent book, *Far Field: Digital Technology, Climate Change and the Poles* is a collection of essays related to the contemporary Arctic and Antarctic by several scholars and artists, and will be available on Intellect Press later this year.

Who owns the air?

> Technological mediation supports and conditions the emergence of new cultural practices, not by creating a distinct sphere of practice but by opening up new forms of practice within the everyday world, reflecting and conditioning the emergence of new forms of environmental knowing. (Dourish, 2006: 304)

The accelerating crisis in climate change and the realisation that humans are the primary cause of this change has raised questions about ownership and responsibility. Who 'owns' the climate change crisis and who is responsible for mitigating and reversing it, if possible? One overwhelming response by governments on an international level has been to propose a market solution, in essence, to sell the atmosphere. Is the commercial marketplace the only answer? How can art, technology and media offer alternative cultural practices and open new forms of understanding the air?

Because the data space of atmospheric monitoring and modelling plays such a critical role in the prediction of climate change, increasing the public impact of the data space may be essential to the communication of that science. Contemporary art, technology and media projects that highlight the evolving role of public participation in climate change will be discussed along with the author's recent project, 'Particle Falls', a large scale public visualisation of particulate pollution in downtown San Jose (with collaborator Chuck Varga and project partners Metone, AirNow and the Bay Area Air Quality Management District).

References

Danto AC (2003) The abuse of beauty: Aesthetics and the concept of art. Paul Carus Lecture.

Dourish P (2006) Re-space-ing place: 'Place' and 'space' ten years on. In: *Proceedings of the ACM Conference, Computer-Supported Cooperative Work CSCW 2006* (Banff, Alberta), 299–308. Available at: http://www.dourish.com/publications.html

The Visual Communication of Ecological Literacy

Jody Joanna Boehnert - MPhil - School of Architecture and Design

Why? **Context**

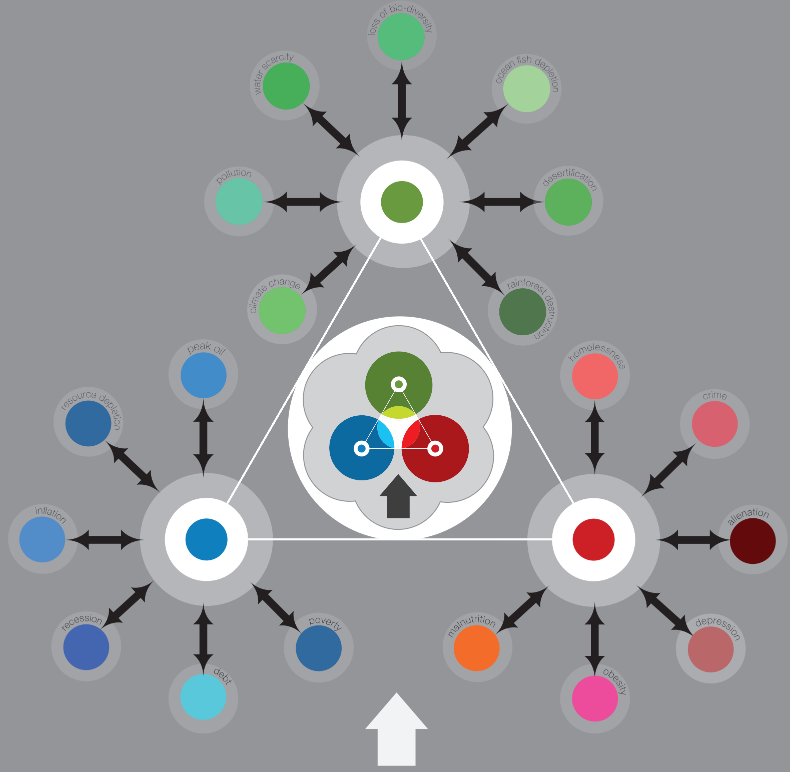
Presently humanity's ecological footprint exceeds its regenerative capacity by 30%. This global overshoot is growing and ecosystems are being run down as wastes (including greenhouse gases) accumulate in the air, land, and water. Climate change, resource depletion, pollution, loss of biodiversity, and other systemic environmental problems threaten to destroy the natural support systems on which we depend.

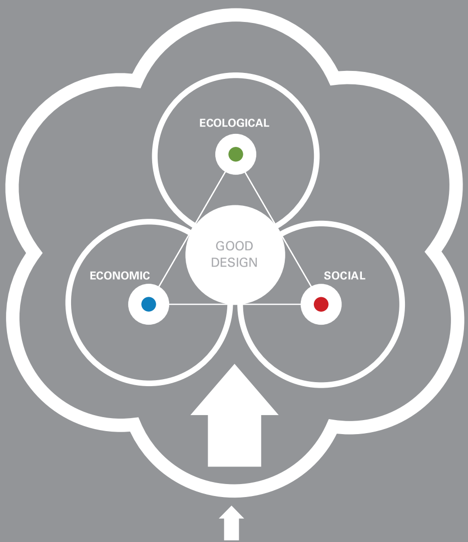
What? **Systems, Networks, Values**

Problems cannot be understood in isolation but must be seen as interconnected and interdependent. We must learn to engage with complexity and think in terms of systems to address current ecological, social and economic problems. Images can be useful tools to help with this learning process.

How? **Transformational Learning**

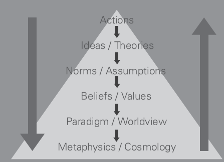
The value / action gap permeates education for sustainability and is obvious in environmental coverage in the media. The gap between our ideas about what we value and what we are actually doing to address the problem is the notorious value / action gap. This project uses transformational learning to move from values to action. This approach is integrated into cycles of action research and practice based design work.





Ecological literacy - the understanding of the principles of organization that ecosystems have evolved to sustain the web of life - is the first step on the road to sustainability. The second step is the move towards ecodesign. We need to apply our ecological knowledge to the fundamental redesign of our technologies and social institutions, so as to bridge the current gap between human design and the ecological sustainable systems of nature.

Fritjof Capra, 2003



Transformational Learning

Values, Knowledge, Skills

A: SEEING (**Perception**)
An expanded ethical sensibility or consciousness

B: KNOWING (**Conception**)
A critical understanding of pattern, consequence and connectivity

C: DOING (**Action**)
The ability to design and act relationally, integratively and wisely.

Stephen Sterling, 2009

Levels of Learning & Engagement

1st: Education ABOUT Sustainability

Content and/or skills emphasis. Easily accommodated into existing system. Learning ABOUT change. ACCOMMODATIVE RESPONSE - *maintenance.*

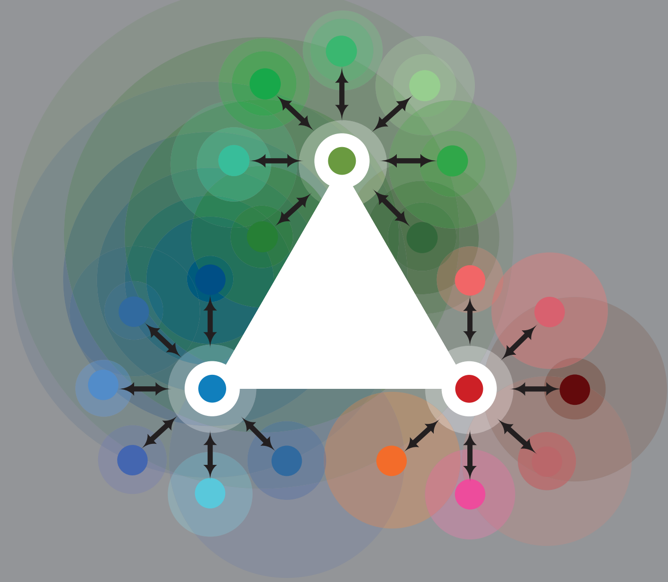
2nd: Education FOR Sustainability

Additional values emphasis. Greening of institutions. Deeper questioning and reform of purpose, policy and practice. Learning FOR change. REFORMATIVE RESPONSE - *adaptive.*

3rd: SUSTAINABLE Education

Capacity building and action emphasis. Experiential curriculum. Institutions as learning communities. Learning AS change. TRANSFORMATIVE RESPONSE - *enactment.*

Stephen Sterling, 2009



The world is a complex, interconnected, finite, ecological-social-psychological-economic system. We treat it as if it were not, as if it were divisible, separable, simple, and infinite. Our persistent, intractable, global problems arise directly from this mismatch.

Donella Meadows, 1982

References

Fritjof Capra. *The Hidden Connections*. London: Flamingo. 2003
Stephen Sterling. *Whole Systems Thinking as a Basis for Paradigm Change in Education*. University of Bath. 2003
Stephen Sterling. *Transformational Learning*. Researching Transformational Learning. University of Gloucestershire. 2009

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This poster can be downloaded on this website: **www.eco-labs.org**

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Visual communication, transformative learning and ecological literacy

Abstract
Communication design is uniquely placed at the intersection of disciplines to help facilitate learning processes for ecological literacy. Transformative learning offers a comprehensive toolkit and conceptual framework to inform design strategies to support sustainable practice. This paper describes the doctoral research project 'The Visual Communication of Ecological Literacy: Designing, Learning and Emergent Ecological Perception' and reflects on how graphic design can use transformative learning theory to enable an active engagement with complex ecological information.

Keywords
action research, critical pedagogy, design, education, ecological literacy, sustainability, transformative learning, visual communication

Introduction
Communication designers and educators have a unique role to play in the creation of sustainable futures due to our ability to help people imagine new realities, foster new cognitive skills for dealing with complexity and develop new social capacities. The challenges associated with sustainability communications and education demand more than mere dissemination of information. Communications for sustainability must transcend the transmissive approach to learning, what Paulo Freire refers to as 'banking education' (1970), because information alone does not necessarily lead to change. Sustainability educator Stephen Sterling explains that; 'not only does it not work, but too much environmental information (particularly relating to the various global crises) can be disempowering, without a deeper and broader learning process taking place' (2001: 19). Sustainability and ecological literacy require learning processes that create the social capacity to act on the basis of new knowledge.

Figure 1 (previous page) The Visual Communication of Ecological Literacy A1 poster

The practice-based doctoral research 'The Visual Communication of Ecological Literacy: Designing, Learning and Emergent Ecological Perception' uses visual communication design within transformative learning processes to not only communicate complex ecological ideas but help audiences start the work of creating sustainable futures. This paper will briefly introduce the research and describe how the theories of learning levels and transformative learning can inform the design of information visualisations and learning environments for ecological literacy. This research addresses the notorious gap that divides our awareness of environmental threats from our capacity to take action.

Transformative learning theory
Due to the fact that the problems with regard to sustainability are both complex and deeply entrenched within our culture, deep learning processes are essential for ecological literacy. Sustainability educator Stephen Sterling describes third order learning as learning that informs deep reflexivity, a realisation of 'context of contexts' and challenges epistemological assumptions (2003: 109). Epistemic learning is also known as transformative learning, a pedagogic practice influenced by Paulo Freire's concept of *conscientisation* and women's education in the 1970s. Beyond the mere dissemination of information, these pedagogies aim to engage participants in dialogic and experiential learning processes.

Central to better communications is a theoretical understanding of how communications and learning works towards creating change. Gregory Bateson described a framework of learning in *The Logical Categories of Learning and Communication* in 1964, further developed in 1971 (Bateson, 1972: 279). Bateson explains that both learning and communication occurs at different levels, distinguishing between various levels of abstraction. Stephen Sterling's interpretation of Bateson's work maps the four levels of learning in a trajectory from no learning to deep learning. Sterling describes learning levels in sustainability education:

> **Level A** – No change
> (no learning: ignorance, denial, tokenism)
> **Level B** – Accommodation
> (1st order learning – adaptation and maintenance)
> **Level C** – Reformation
> (2nd order learning – critically reflective adaptation)
> **Level D** – Transformation
> (3rd order learning – creative re-visioning)
> (Sterling, 2001: 78).

Transformative learning occurs in the higher orders of learning where review of basic premises occurs. This learning theory suggests that third order transformative learning is necessary for systemic understanding to become commonplace, thereby creating the capacity to embed ecologically positive practices into structurally unsustainable systems. Education for sustainability must transcend the traditional transmissive learning approach (1st order learning) because information alone does not necessarily lead to change (Sterling, 2001). Environmental communications and education require deeper processes than mere dissemination of information.

This research proposes that transformative learning is a process with the potential to transcend the notorious value/action gap that divides our awareness of environmental threats from our capacity to take appropriate action. Transformative learning engages an ecological view of education that is relational, holistic, participatory and practical. Jack Mezirow's transformative learning theory is based on extensive research in a 1975 American nationwide study of consciousness-raising in women's education. This study sought to explain the unprecedented new presence of women in higher education (Mezirow, Taylor and Associates, 2009: 19). Mezirow identified the 10 phases most often encountered during the learning processes women experienced as part of their empowerment process. These transformative learning experiences resulted in profound shifts in women's capacity to take action on the basis of their new beliefs. These sustained efforts for women's liberation resulted in remarkable changes in power relationships for women in the late twentieth century. Similar strategies can now be used to confront contemporary environmental challenges.

Over the past 35 years, transformative learning has been developed into a powerful pedagogic practice that helps learners develop the agency to act on the basis of new beliefs. Transformative learning is complete when an individual is able to act according to beliefs he or she has validated through critical reflection (Mezirow, Taylor and Associates, 2009). Mezirow describes transformative learning as a process of 'becoming critically aware of one's own tacit assumptions and expectations and those of others and assessing their relevance for making an interpretation' (Mezirow and Associates, 2000: 4). This process must be informed by a critical awareness of contextual, biographical, historical and cultural aspects of our collective beliefs and feelings with regard to the problems under examination. Through critical reflection we learn to 'act on our own purposes, values, feelings, and meanings rather than those we uncritically assimilated from others' (Mezirow, 2000: 8). Transformative learning involves three consecutive phases: 'critical reflection, reflective discourse, and action' (Merriam and Caffarella, 1999: 321) and through this process learners develop greater agency as they become more emotionally capable of change. This maturity is developed though encounters with deep emotion. The results are evidenced in reflective discourse and ultimately in action.

It is this deep learning that makes transformative learning both so potentially powerful and also so difficult to achieve. Transformative learning remains a severe challenge due to the fact that individuals are often intensely threatened by the prospect of re-examining accepted norms of beliefs and behaviour. Attempts to design processes of transformative learning might not always succeed, but there is evidence of progress in the more than 150 doctoral dissertations and hundreds of scholarly papers on transformative learning that map the territory (Kitchenham, 2008: 120). The journey to a place of agency is by no means an assured outcome, but as the consequences of not addressing basic premises become more severe and obvious (as the ecological crisis continues to deepen), perhaps the journey through transformative learning will start to appear like the more benign option.

Aims and objectives

One of the major premises of this doctoral research is that fragmentary thinking is an obstacle to sustainability, and that reductive attitudes towards knowledge cannot address problems associated with complex ecological systems. Responding to this dilemma, the project uses a whole systems approach facilitated by the visual communications of ecological literacy. Ecological literacy is a powerful concept developed by sustainability educators with the potential to create a holistic foundation for the understanding of environmental problems and solutions from a whole systems perspective. Unfortunately, ecological literacy has largely failed to spread across disciplinary boundaries in the two decades since the concept was first conceived. To address this problem the intensely trans-disciplinary practice-based research creates new visual displays and transformative learning processes within a series of iterative action research cycles.

This project contributes towards an integrated understanding of systemic problems by visually mapping new intellectual territory. Visual representations of ecological literacy help audiences build new metaphors to enable better understanding of complex information. Ideas associated with ecological literacy (such as ecosystem, climate change, carrying capacity, resilience, etc.) are often highly abstract and require new conceptual metaphors to help learning communities build new shared mental models. In the fast moving field of research in sustainability, the ability to communicate new understanding of ecological concepts is fundamentally important to help inform the design of new systems and decision-making processes for sustainable design.

Visual displays synthesise findings from transdisciplinary research, helping audiences reach a better, understanding of the complexity of ecological realities. By visualising complex webs of interdependence between elements of ecological systems (including human society and industrial systems as embedded within ecological systems), the work helps audiences understand some of our most serious environmental problems. Robert Horn claims that the current proliferation of visual communication indicates that we are witnessing the emergence of a new language, a visual language integrating words, shapes and images, with its own syntax and semantics (Horn, 1998). This research project attempts to use tools and capabilities from this new visual language towards creating accessible ‘big picture’ views of complex ecological realities.

Information visualisation has become a growing field of practice used by designers and visual journalists alike, in newspapers and also within interactive graphics online. While informational visualisations of quantifiable data are valuable tools in helping audiences analyse complex ideas, it would be a mistake to assume that this information on its own is sufficient to address the sustainability problem. As already described, ecological literacy requires deeper learning processes. Attractively presented data within information graphics, although useful, will not do the work of building agency and social capacities to address sustainability problems. My doctoral research creates graphics for use within transformative learning processes and designs learning environments in which the graphics will be used. These learning processes aim to create space for the investigation of personal values with regard to the environment and the agency to put new values and ideas into practice.

Conclusion

Design is uniquely placed at the intersection of disciplines to help facilitate transformative third order learning processes for ecological literacy. The research aims to harness all the tools, skills and processes within design and critical pedagogy to bridge the gap between rhetoric, values and action. Transformative learning has developed over the past 30 years and now offers a comprehensive toolkit and conceptual framework to inform design strategies to support learning processes for ecological literacy – as a foundation for sustainable practice.

The tradition of critical pedagogy suggests that there remains great distance between accepting something as an intellectual truth and perceiving, thinking and acting according to this position. Bridging the value/action gap is a challenge for sustainability communicators, designers and educators. As David Orr explains, 'The study of environmental problems is an exercise in despair unless regarded as only the preface to the study, design and implementation of solutions' (1992: 94). The pedagogic practice within this research is designed to reveal key concepts in ecological literacy in a participatory action-learning context. The work intends to enable learners not only to understand new information, but to build new social capacities in order to put new knowledge into practice.

References

Bateson G (1972) *Steps to an Ecology of Mind* (6th edn). London: The University of Chicago Press.

Freire P (1970) *Pedagogy of the Oppressed* (19th edn). London: Penguin.

Horn RE (1998) *Visual Language: Global Communication for the 21st Century*. Brainbridge Island: Macro VU Press.

Kitchenham AB (2008) The evolution of John Mezirow's transformative learning theory. *Journal of Transformative Education* 6(2): 104–123.

Merriam SB and Caffarella RS (1999) *Learning in Adulthood: A Comprehensive Guide*. San Francisco: Jossey-Bass.

Mezirow J (2000) *Learning to Think Like an Adult: Learning as Transformation.* San Francisco: Jossey-Bass.

Mezirow J and Associates (2000) *Learning as Transformation.* San Francisco: Jossey-Bass.

Mezirow J, Taylor E and Associates (2009) *Transformative Learning in Practice.* San Francisco: Jossey-Bass.

Orr D (1992) *Ecological Literacy* (13th edn). Albany: State of New York Press.

Sterling S (2001) *Sustainable Education: Re-visioning Learning and Change*, Schumacher Briefing no. 6 (4th edn). Dartington: Schumacher Society/Green Books.

Sterling S (2003) *Whole systems thinking as a basis for paradigm change in education*. PhD thesis, University of Bath, UK.

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An organising principle as a guide for collaborative thought and action

Abstract
This paper explores the concept of an organising principle as an approach to facilitate the interdisciplinary co-creation of a data visualisation tool. The concept is illustrated through the design and development process of *The Conversation Viewer*, a multi-modal data driven prototype software application. Designed to visually represent the evolution of a conversation through a dynamic touch-based graphical interface, *The Conversation Viewer* illustrates varied multi-modal elements of participants' email, text and voice messages as they seek to reach a mutual agreement on an appropriate meeting date.

This research demonstrates the value of an organising principle as a way to advance a project's collaborative development. To assist *The Conversation Viewer's* design and development various methods that visualise and express the project's central ideas were utilised to facilitate communication and understanding between diverse disciplines of knowing and working. This, in turn, transformed the nature of dialogue between participants and fostered the active development of project milestones and outcomes. This design case study draws on the theoretical framework for understanding system diagrams, developed by Jun et al. (2010). In doing so, it illustrates how different ways of thinking and working can be visualised in a variety of forms to communicate project knowledge that advances the collective actions and intentions of interdisciplinary teams.

Keywords
conversation and agreement, design, idea, interdisciplinary collaboration, organising principle

Introduction
An ongoing challenge for interdisciplinary collaboration is for individuals from different knowledge groups and levels of expertise to be able to communicate effectively and contribute to the development of a product or service. Literature (Harhoff et al., 2003; Saffer, 2007; Sanders, 1992, 2002) suggests that collaborative design practices can enhance the exploration of unknown design potentialities and the creation of innovative outcomes. However, the dynamic direction of interdisciplinary projects can present certain challenges that prevent participants from adequately: (1) understanding a project's direction; (2) grasping the manner in which different individuals communicate; or (3) discovering how they can mutually contribute to the co-creation of a desirable outcome (Ebenreuter, 2010). This is further impacted by uncertainty and interdependencies that can impede the capability for individuals to coordinate actions that lead to the realisation of shared goals (McEvily et al., 2003).

Despite these challenges, design as discipline is establishing itself as a significant field of intellectual development that utilises interdisciplinary knowledge from the arts and sciences as a basis for creativity and invention. Transdisciplinary in nature, design draws on and contributes to knowledge from computer, human and social sciences, psychology and usability engineering, among others. This is important because the integration of knowledge from a range of disciplines increases the potential for designed outcomes to have a greater impact on society. When understood in this light, design is central to the creation of effective systems of communication that not only rely on many forms of conventional practices to operate effectively, but also assist the collaborative discovery of new potentialities to take shape.

The goal of this paper is to highlight the value of an organising principle as a way to advance a project's collaborative development and make clear the ways in which this can be achieved. In the following sections, I discuss the function of an organising principle and give context to this research. By way of example I illustrate the significance of understanding how different systems of communication are organised. To achieve this I draw on a theoretical framework for understanding system diagrams (Jun et al., 2010) and show how important technical and design documents gave shape to the collaborative advancement of a data visualisation tool called *The Conversation Viewer*. Accordingly, the paper concludes with directions for further research.

Organising principles

An organising principle, known in classical literature, design and systems thinking, can be used as a central reference point to guide the ordering and structure of ideas for new products and services. When an idea and its active formulation, regardless of its foundation, becomes the organising principle behind the realisation of what is expressed (Burke, 1969), it gives shape to the overall process of bringing together different elements of a situation to foster the creation of a unified solution. According to Dewey (1910), orderly interaction may follow if an object or item is recognised and considered in relation to a key subject or theme. For that reason, the organisation of thought can be a result of organised action or a number of interrelated interactions surrounding a particular subject or idea. In the context of interdisciplinary collaboration, an organising principle provides a starting point for various processes and practices to develop that look at dynamic interrelationships between elements of a situation, rather than treating them as static isolated things.

McEvily et al. (2003: 92) tell us 'an organizing principle represents a heuristic for how actors interpret and represent information and how they select appropriate behaviors and routines for coordinating actions'. They (McEvily et al., 2003) illustrate this by way of an example where principles of authority, price and norms can align project objectives or incentives and orchestrate coordinated action. This functioning is based on particular elements that orient thought and action. Simon (1996), however, provides us with a slightly different example when he makes reference to an architectonics of music. He does this in order to provide an organising principle for the creation of alternatives or variations of a theme, which are guided by the underlying substructures of a larger system. This is where the invention of new structures, for example of a melody or of a rhythm, is calculated for their potential and the scope of what can be known technically. Where these examples differ is in their focus on the organisation of human actions or material components. This is an important distinction to make given that when working in interdisciplinary teams many issues can arise when conversations across diverse fields of knowing and doing are discussed from perspectives that are fundamentally different to one another.

While the above-mentioned principles hold significance to facilitating different types of actionable outcomes, I argue that it is perhaps more advantageous to understand how information can be designed to communicate specific intentions, purposes or functions (Jun et al., 2010). In this way designers or facilitators of collaborative action may not only better identify the manner in which different ideas may be communicated, but also understand how they interrelate to one another as an organised integrated whole. Before I do this, however, it is necessary to provide the context in which these ideas can be applied.

Visualising conversations

This research concerns the creation of a multi-modal data driven prototype application called

The Conversation Viewer. It seeks to address the complexity and mobility of advancing communication technologies by offering a way for us to deal with the fragmented experience of piecing together the disparate messages we receive from numerous telecommunication services existing today.

The prototype's collaborative development took place between researchers in France, India and the United States with expertise in computer engineering, semantics, social communication, hybrid communications and interaction design. Of particular significance to this interdisciplinary project was a workshop in which invited guest Paul Pangaro introduced researchers to the concept of an organising principle. This in turn led us to identify an organising principle for the conceptual development of *The Conversation Viewer* as one that centres upon agreement. Designed, as an iphone and ipad application (see Figure 1) the purpose of the tool is to visually represent the evolution of a conversation. This is achieved through a dynamic touch-based graphical interface where various elements of participants' email, text and voice messages illustrate the progressive development of their discussions, as they seek to find a mutual agreement.

Agreements can come in many forms. We recognise these as terms of reference for agreement in areas such as international policy, law, industrial negotiations and interpersonal communications, which are established to bring about cooperation between organisations, institutions, communities and partners. As a result of conversation, one may further extend the initial terms of agreement to perform certain acts, such as purchase new products or services, create new laws, travel abroad or enter into new working relationships (Dubberly and Pangaro, 2009).

In a first step toward facilitating mutual agreement we chose to focus on the confirmation of a meeting date as a driver of communication and to illustrate the evolution of a conversation based on agreement. This in turn provided us

Figure 1 *The Conversation Viewer*

with a starting point in which to shape a system of communication that would allow its end-users or participants to achieve a particular goal. The goal of *The Conversation Viewer* is to visualise information from a variety of data sources to inform participants engaged in conversation of the terms and conditions that enable them to reach a mutual agreement. This is achieved as a result of dynamic conversation, which is defined by a beginning, middle and end.

Drawing on cybernetic practices, it is important that in the course of interaction, understandings are not communicated (Glanville, 2004). They are, however, built collaboratively through conversation in which participants derive meaning from their interpretation of the discussion. This new-formed understanding is then offered to participants for further interpretation and comparison to the original, thereby building a mutual awareness around the circumstances in which participants are able to form an agreement around a suitable meeting date. The confirmation of a meeting date is by no means facilitated through a process of elimination made possible by the applications *Meet-O-Matic* (2011), *Meeting Wizard* (2001), *ScheduleOnce* (2010) or Doodle's *easy scheduling* (2009), to name a few. We envisaged that this first step approach would provide us with greater insight into the manner in which data driven conversations could be organised and visualised to facilitate more complex systems of ongoing mutual agreement. Even so, as Buchanan (2001) suggests this is fundamentally difficult because we ourselves are unable to fully experience or even see the extent to which a system exists, has existed, or will exist. At best, we have an awareness of the systems that play a part in our daily life, yet this is from our own individual experience of navigating through a part of a significant whole.

With this in mind, it is fair to assume that the role of *The Conversation Viewer* is to make visible the abstract relations that exist between participants of a conversation that in a way they sense, because they are aware of them, but cannot see. Moreover, as Jun et al. (2010: 2) recommend 'we should not simplify a relationship as mere connectivity between numerous components, but rather take it as an idea or a thought that integrates different parts into a whole'. This brings us back to the importance of understanding how different interrelated elements of information can be designed to contribute to the organising principle or overarching idea of a system. This is because of a growing need for organisations to leverage different ways of knowing and thinking that can be integrated into concrete plans of action (Pfiffner, 2004).

The arrangement of thought

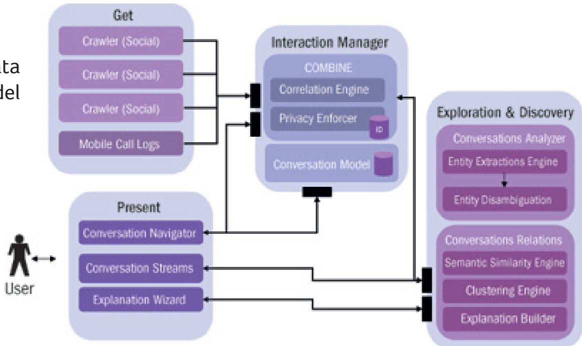
The term data visualisation itself can be suggestive of an early notion of systems design that deals with the relationships between things. This is where an entitative conception of reality provides a foundation for the visualisation of data or information in its smallest element. However, an expanded notion of systems design suggests that there exist richer more dynamic relationships between not only data or things as objects, but also human actions and thought. This accounts for the relationship between both abstract and concrete ideas as visible, invisible, tangible and intangible services or products that contribute to systems of thinking, working or making. Jun et al. (2010) provide designers with a powerful framework for understanding such relationships and their interconnections based on four modes of thought: '1) law that holds together individual components, 2) rule that guides decision making, 3) function that supports users' action possibility, 4) condition that facilitates participation in cultural ideals' (Jun et al., 2010: 3).

As a way to better communicate the structure, conventions, role and circumstances of different project goals, I suggest how the above modes of thought assisted the creation of project documents that were used to structure the collaborative development of *The Conversation Viewer*. This design case study begins from the tool's initial conception through to its implementation as prototype application.

Structure

Defining the fundamental structure of *The Conversation Viewer* was perhaps one of the most difficult goals of the project. This required a deep understanding of the system's technical components used to drive the visualisation of information that would enable end-users of the system to come to an agreement. This required designers and developers to work together to establish the components of individual data types. Information from email, text and voice messages needed to communicate different elements of a conversation and assist end-users to discuss their availability with respect to proposed meeting dates. The design of the data driven model (see Figure 2) provided the necessary laws and ordering of operations for correlation engines, semantic analysers and crawlers to construct a system of architecture that supports the visualisation of different media-types of information. Complementary to this, the user experience model (see Figure 3) shows

Figure 2 The data driven model

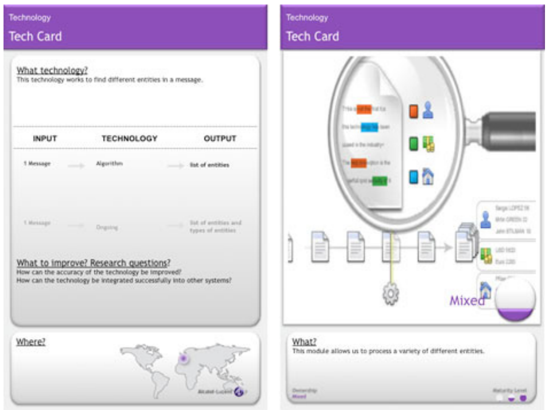


how a hierarchy of human relations concerning the communication between end-users, (1) the interactive tool, (2) other individuals, (3) the context of their situation, and (4) numerous participants are formed. The association between the two documents provided an understanding of how individual system elements and relations can be created to support and lead participants of a conversation to form a mutual agreement.

Conventions

Once the system's structural elements were clearly defined we focused on the design of

Figure 4 (right) Tech card



specific conventions or rules that enabled us to decide how we would assist end-users of the system to agree upon a suitable meeting date. The goal in establishing the treatment of technical and graphical conventions worked to clarify the manner in which certain data processing and rule based queries worked in concert with the display of visual graphic design elements in *The Conversation Viewer*'s interface. The documents served to connect the resulting system of interaction controlled by data driven processing techniques (see Figure 4) with specific graphical elements (see Figure 5) that indicate how precisely end-users of the system are moving towards a point of agreement.

Role

After the foundational elements and processing requirements of *The Conversation Viewer* were established our goal was to communicate the function and relationships between different visual elements of the interface to potential end-users of the system. Creating a holistic system of interaction that expresses these ideas is an important step towards enabling end-users of the system to experience different interactions and communication possibilities

Figure 3 (left) The user experience model

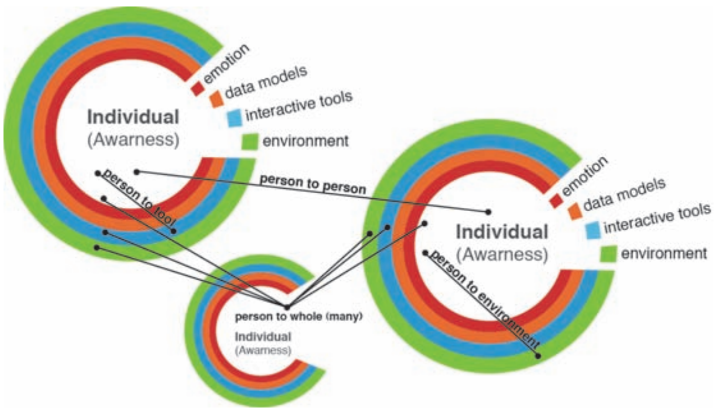
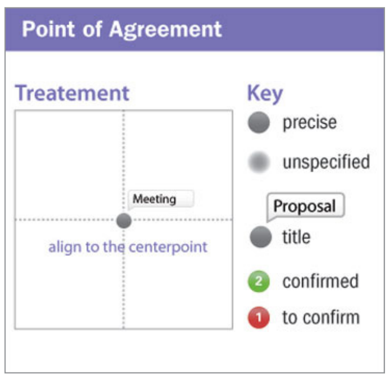


Figure 5 (right) Point of agreement



as they discuss potential meeting dates. The documents work to define the characteristics that visually represent an individual, their emotions and level of participation in a conversation (see Figure 6). This includes the role of distance that visually illustrates how close or far away each participant involved in a conversation is to reaching a mutual agreement (see Figure 7). We envisaged that the potential for a variety of actions would be made possible when different symbols that hold meaning for end-users are interrelated to one another. This is achieved through the dynamic interactions of participants that show different types of relations formed during conversation. Throughout the course of a conversation these interactions are analysed then represented as a function of the system that draws on the semantic content of participants' communications.

Circumstances
A final goal of the project was to illustrate the evolution of a conversation as participants reached a mutual agreement. Here it was necessary to introduce certain circumstances or conditions that enabled end-users of the system to understand and participate in the idea that gives unity to *The Conversation Viewer* as a system of communication. By adding information regarding the contextual positioning of participants (see Figure 8), a shared view is created of the circumstances surrounding the conversation that enable it to either carry on or cease to continue. This in turn provided a visual roadmap for designers and developers to further refine or develop new system components, rules and interactive functions that enhance the experience of communicating with and through *The Conversation Viewer*.

Discussion
This design case study focuses on how the notion of agreement as an organising principle can shape the collaborative development of a project from its conception to realisation. In this research I demonstrated the relationships that emerged between different types of knowing and working that facilitated *The Conversation Viewer's* development. A framework (Jun et al., 2010) for understanding these relationships and their interconnections assisted in identifying project goals and determining how the resulting outcomes of work produced could be integrated into the design of an interactive tool.

The production of various documents created throughout the project's development provided a common language in which individuals from varied backgrounds could understand and discuss the project's overall development. As a result, project participants were able to coordinate the advancement of different elements of the project, which led to the realisation of shared goals. This is important because the fragmentation in which collaborative projects can be developed, directly impacts the realisation of design outcomes as well-integrated products or services.

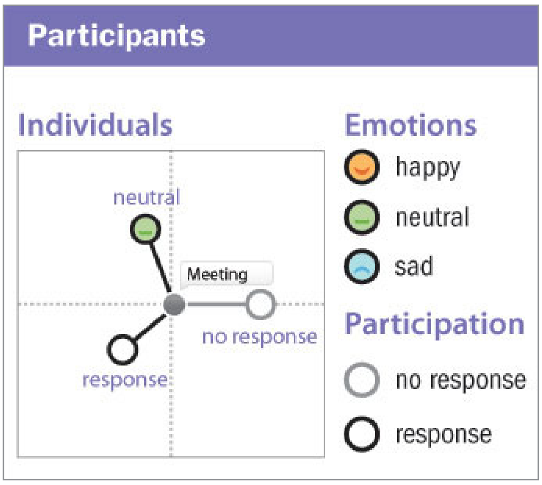


Figure 6
Participants

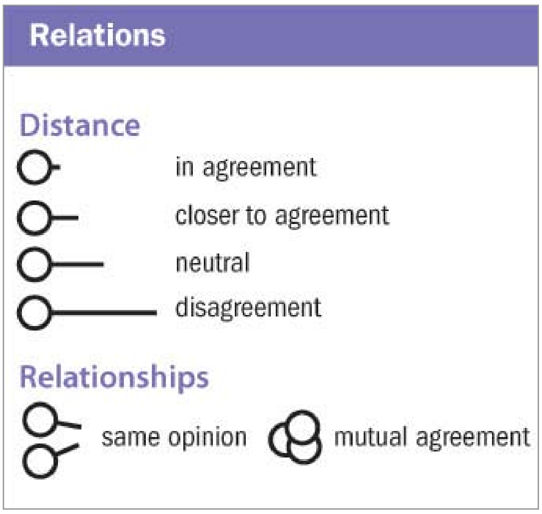
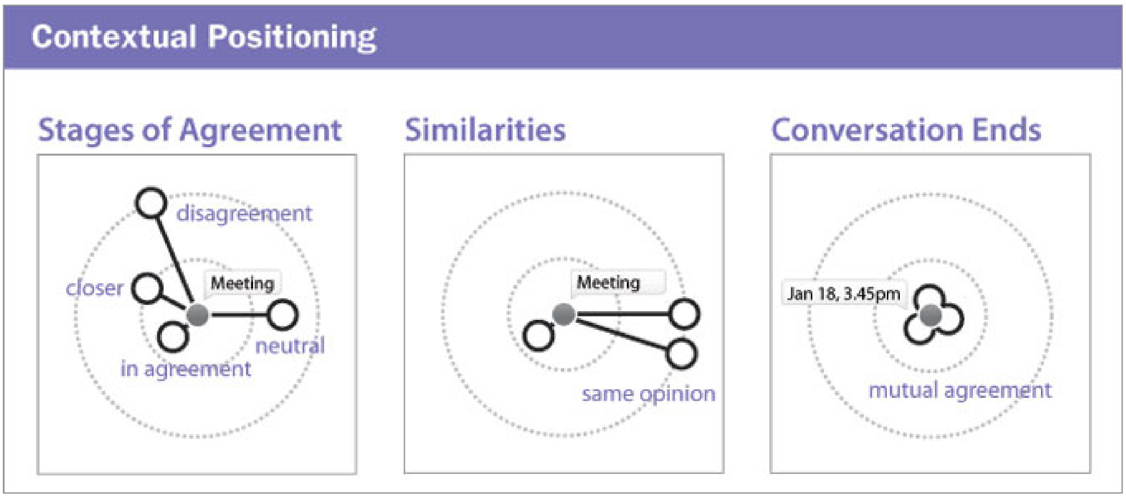


Figure 7
Relations

While an understanding of different ways of knowing, thinking and working is critical to the

Figure 8 Contextual positioning



role of designers in an interdisciplinary team, a valuable area of further research would be to introduce the framework offered by Jun et al. (2010) into the field of engineering. In this way computer scientists' understanding of the perspectives in which systems of communication can be created could enhance the potential directions in which collaborative projects are shaped to address complex problems.

Acknowledgements

I would especially like to thank Paul Pangaro for introducing researchers at Bell Labs France to the notion of an organising principle, and members of *The Conversation Viewer* project at Bell Labs, who contributed to this research.

References

Buchanan R (2001) Design research and the new learning. *Design Issues* 17(4): 3–23.

Burke K (1969) *A Rhetoric of Motives*. Berkeley: University of California Press.

Dewey J (1910) *How We Think*. Boston: D.C. Heath & Co.

Doodle (2009) Retrieved 6 February 2010 from: http://www.doodle.com/

Dubberly H and Pangaro P (2009) What is conversation? How can we design for effective conversation? *Interactions* xvi(4).

Ebenreuter N (2007) Dynamics of design. *Kybernetes: The International Journal of Systems & Cybernetics* 36(9/10):1318–1328.

Ebenreuter N (2010) Understanding the practical challenges of moving from closed to open source collaborative design. In: the Proceedings of DRS2010, Design Research Society International Conference: Design & Complexity, Montreal, Canada, July 7–9.

Glanville R (2004) The purpose of second-order cybernetics. *Kybernetes: The International Journal of Systems & Cybernetics* 33(9/10): 1379–1386.

Harhoff D, Henkel J and von Hippel E (2003) Profiting from voluntary information spillovers: How users benefit by freely revealing their innovations. *Research Policy* 32(10): 1753–1769.

Jun S, Miso K and Lee J (2010) *Rethinking system diagrams: From arranging components to organizing action, thought, and possibility*. In the Proceedings of DRS2010 Design Research Society International Conference: Design & Complexity, Montreal, Canada, July 7–9

McEvily B, Perrone V and Zaheer A (2003) Trust as an organizing principle. *Organization Science* 14(1): 91–103.

Meeting Wizard (2001) Retrieved 6 February 2010 from: http://www.meetingwizard.com/

Meet-O-Matic Version 3.6 (2011) Retrieved 6 February 2010 from: http://www.meetomatic.com/

Pfiffner M (2004) From workshop to syntegration: The genetic code of effective communication. *Malik on Management* letter (10).

Sanders EBN (1992) Converging perspectives: Product development for the 1990s. *Design Management Journal* 3(4): 49–54.

Sanders EBN (2002) From user-centered to participatory design approaches. In: Frascara J (ed.) *Design and the Social Sciences: Making Connections*. London: Taylor & Francis.

Saffer D (2007) *Designing for Interaction: Creating Smart Applications and Clever Devices*. Indianapolis, IN: New Riders.

ScheduleOnce (2010) Retrieved 6 February 2010 from: http://www.scheduleonce.com/

Simon HA (1996) *The Sciences of the Artificial* (3rd edn). Cambridge, MA: MIT Press.

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Mark Lombardi's visualisation discovery

Abstract
Mark Lombardi is known for his conceptual art, in particular for his diagrammatic drawing. Lombardi called his diagrams 'narrative structures' where he attempted to capture the global frauds by politicians and power brokers. His work been displayed in numerous international museums and galleries across the world. Many visualisation scholars (academics and professionals) discuss his work and see it as major influential contribution to the domain of visualisation. While the contribution of science and technology is well documented in the literature of visualisation, we raise the question of whether art can help us gain a new understanding of the subject of visualisation.
In order to address this question, we examined the data structure and classification inside Mark Lombardi's drawings. Our methodology, concept map analysis, is based on the measurements of frequency and classification of words/concepts found within his diagram drawings. We found that most of the terms found in his drawings are personal names that do not provide background information about their job title, their geographical locations, or their contribution to the frauds. As a result, we were unable to further analyse the statistical relationships we set up in our sample. We discovered that the terms 'Defense', 'Military' and 'Government' were the most frequent terms appearing in his drawings. Although we did not locate an empirical theme or classification scheme in his work, we found the need for an alternative methodology that would allow us to measure central themes and concepts found in the visualisation works. This epistemology will need to address not only quantitative and computer data but also the work of art and its contribution to the visualisation domain.

Keywords
concept map analysis, Mark Lombardi, Mark Lombardi: Global Networks exhibition, narrative structures

Introduction
The communication paradigm of visualisation is often associated with capturing complex data structures found in computer systems, but the term is also affiliated with the domain of human cognition process that gives us accessibility and tracking of information and knowledge. The roots of the term 'visualisation' can be traced back into the history of map-makers, according to MacEachren (2004: 357). Since then, however, the term has been affiliated with computer science as a form of representation and exploration of data based on Rößling (2009: 234). Tufte (1990: 9–24) highlights the quantitative framework as by-product of statistical analysis, since most current statistical software provides visualisation presentations as an alternative to row numbers. Segel and Heer (2010) report that narrative visualisation has been emerged as a new reporting form within journalism industry. However, with all this progress and focus on technology and science, can art contribute to our understanding of visualisation analysis? And more specifically, can we examine leading artistic works of visualisation by using scientific and controlled methodology?

In order to address this question, we will look at the work of conceptual artist Mark Lombardi, to raise the following questions:

1. Can Mark Lombardi's work be examined under common data structure(s) and visual

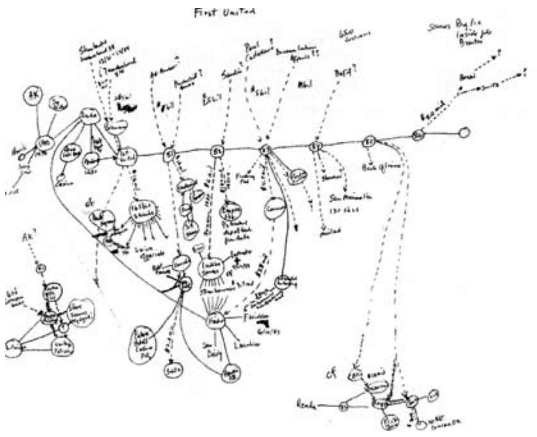

Figure 1 (left) Mark Lombardi, *George W. Bush, Harken Energy and Jackson Stevens, c. 1979–90* (2nd version). New York, The Museum of Modern Art collections: The Judith Rothschild Foundation Contemporary Drawings Collection Gift

classification often used in computer science and databases?

2. Can concept map analysis provide us with more insight into Mark Lombardi's work and framework?

Background

Mark Lombardi (1951–2000) was an American conceptual artist who specialised in line drawing diagrams. Lombardi's work has been exhibited in numerous international museums and gallery exhibitions, and his work has also been placed in the permanent collections of the Museum of Modern Art, the Whitney Museum and the Reina Sofia Museum, among others. The most successful exhibition of his work occurred after his death, when Robert Hobbes organised, curated and documented 'Mark Lombardi: Global Networks'. The subject of his work was political fraud committed by politicians and international brokers in the new global economy. Lombardi called his diagrams 'narrative structures', which held two connotations in his work, according to Hobbs (2003: 57–62): the content of a fraud and the visualisation form he selected to tell the story. Roberta Smith from *The New York Times* stated, 'He liked to say that his drawings were probably best understood by the newspaper reports who had covered the scandals he [Lombardi] diagrammed'.

Lombardi followed his narrative structure by employing a three-act procedure: conducting research; summarising the research findings by producing index cards; and drawing several sketches before the final release (Hobbs, 2003: 61–62). In the first stage, Lombardi conducted extensive research before starting to draw. He manually collected data from the mass media,

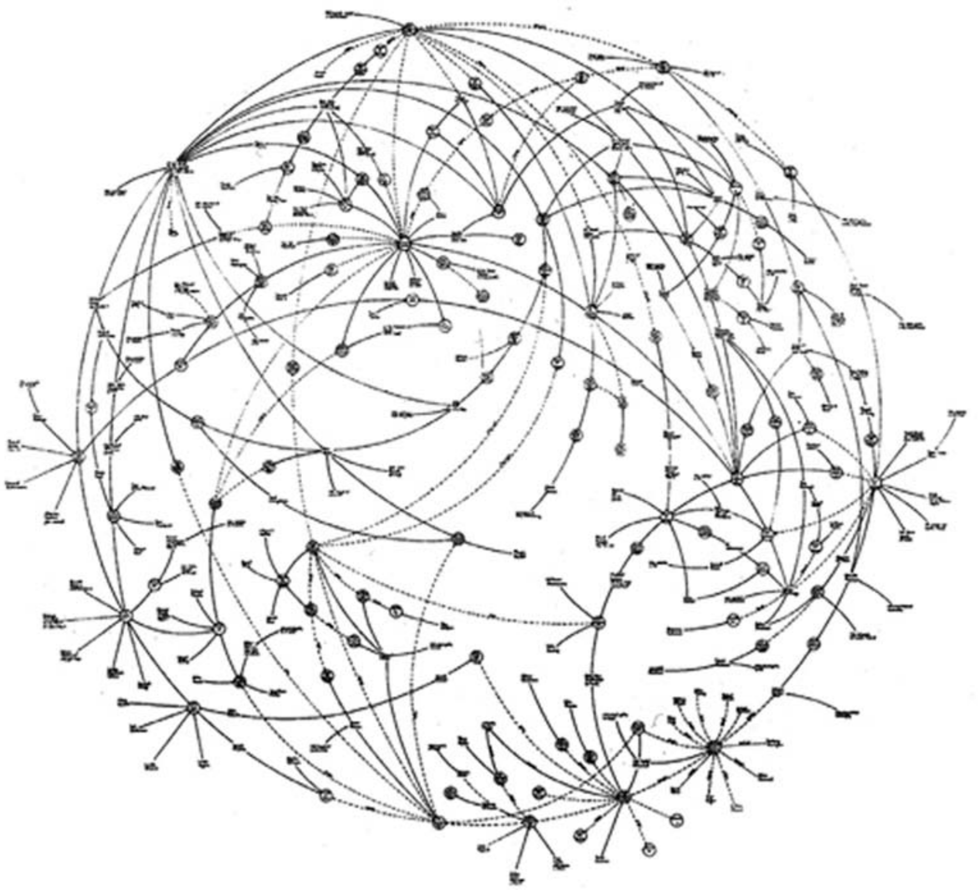

Figure 2 (right) Mark Lombardi, *Oliver North, Lake Resources of Panama and Iran-Contra Operation c. 1984–86* (4th version, 1999); Hobbs (2003: 79) Mark Lombardi: Global Networks

ranging from UPI Press to Spy magazines articles. In addition, he recorded a daily dairy on his findings where he gave precise citations for his references. In the second stage, he transferred the data to index cards, where he summarised the content of the articles on the subject of his investigation by listing the names, places and topics. He organised the cards in alphabetical order. Before moving to New York City, Lombardi had worked as a reference librarian for the Fine Arts Department in the Houston Public Library. During that time, public libraries across the US used a global framework for organising their collections based on index cards. The index card in the library holds the key concepts taken from every manuscript, with reference to the subject of the manuscript or its publisher. Lombardi transferred the library's procedure to his own work. In order to advance the organisation of his index cards, Lombardi used three different colour schemes to classify them: red, green and yellow. We did not find any in-depth analysis of the meaning of the three colour schemes in Lombardi's work. The last step of his work was drawing the narratives. This stage usually took Lombardi the longest time, and was the stage at which he updated his drawing based on latest news he heard on the subject. To illustrate the work flow in Lombardi's creative process, Figure 1 captures an early stage in his work *George W. Bush, Harken Energy and Jackson Stevens c. 1979–90* (2nd version). In this stage, Lombardi used harsh drawing lines that aimed to capture the main figures in his narrative whereas Figure 2 represents the final stage in his drawing.

The study of signs and their signification meaning found in cartography is often derived from philosophical speculations and language. According to MacEachren (2004: 228), signs provide the viewer with levels of meaning found in maps. Lombardi often used two levels of 'signs' to capture his narrative structures. The first level aimed to detain the narrative figures and their connection to the storyline, while the second level represents the road signs insight into his narratives. A closer examination of his work reveals that Lombardi used five graphic road sign elements to represent different types of data and their connections. These graphic elements repeat through his work and can provide us with a method of expression of communication. Figure 3 summarises Lombardi's road signs for his diagrams.

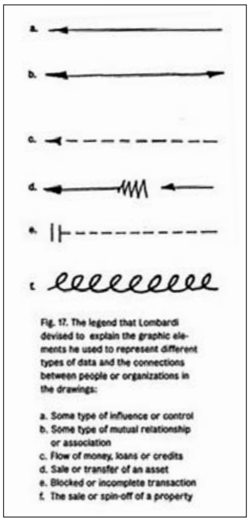

Figure 3 Road sign elements that Mark Lombardi used to represent different type of connection between the different fraud players; Hobbs (2003: 52), Mark Lombardi: Global Networks

The history of the term 'visualisation' can be traced to the history of map markers as a form of graphic communication, according to MacEachren (2004: 357). Card et al. define visualisation as 'The use of computer-supported, interactive, visual representations of data to amplify cognition' (1999: 6). Rößling reports the majority of researchers often discuss visualisation as a form of representation that is associated with the field of computer science and data structures (2009: 234). While Segal and Heer report that data visualisation is regularly promoted for its ability to reveal news stories, and yet these 'data stories' differ in important ways from traditional forms of storytelling in the mass media (2010: 21). Academic scholars often discuss Lombardi's work; Tufte (2003: 13–24) highlights Lombardi's influence on the exploration of large sets of data under quantitative frameworks and computer science. While most of the research in visualisation research can be classified under the quantitative paradigm, Fry (2008: 11–14) reports a lack of collaboration in visualisation analysis across different disciplines under the quantitative framework. Each field has produced its own methodology and framework. Furthermore, the term visualisation classification has been discussed by many researchers, with some applying visual classification by focusing on one preferred type of data structure (see Ankerst et al., 1999: 391–392). Our analysis discloses that many researchers that discuss their visualisation classification do not discuss the framework of their work. According to Bailey (1994: 4–11), classification is a very central process in all facets of our lives. It is ubiquitous even though we often fail to utilise it or even to recognise its very existence. Lombardi's work has never been examined in the context of data structure and visualisation classification methodology by visualisation scholars.

Methodology

Concept map analysis was the methodology chosen to discover whether classification relationships and data patterns can be found in Lombardi's body of work. The methodology is based on an advanced content analysis paradigm aiming to examine the content of visualisation diagrams. Friedman (2008, 2010) uses this methodology to analyse the content of researchers' diagrams found in the leading conference proceedings in the field of Knowledge Organisation. Kinchin et al. (2000: 43–57) employ concept map analysis to measure student achievement in the classroom. Our sample unit for this study was selected from the 'Mark Lombardi: Global Networks' exhibition collection, which contained his most documented work. The study progressed through four steps. First, we collected the terms found inside his diagrams. We then counted the term frequency found and then filtered them into groups. Finally, we performed statistical analysis to find the data structure and classification of the sample.

Results

An experimental study was undertaken in order to investigate Lombardi's data structure and the visual classification found in his diagrams. We drew our sample unit from 17 drawings presented at the 'Mark Lombardi: Global Networks' exhibition. The leading theme in this exhibition was international political fraud, and our sample unit reinforced this theme. As soon as we started collecting the concepts found in the diagrams and entering them as data entries, we found that the majority of these concepts did not share any common schemes or themes. The majority of the terms we collected from his diagrams were marked by personal names, usually with a short abbreviation. The list did not provide us with any information about personal job positions at that time, geographical locations, or the personal involvement in the frauds or background ideology. We used several methodologies to capture the terms collected under different classification schemes: mainly Dewey Decimal Classification (DDC), Bliss Bibliographic Classification (BC), a subject specific scheme and even Lombardi's road signs, but we were unable to organise or classify them in any logical and systematic way.

We conducted further analysis by counting all the terms and dividing them into two classes: central and sub-central terms. A central term was defined as a term that has two or more connections. A sub-central term was defined as a term with a single connection. Out of 270 terms, we counted 120 central terms and 150 sub-central terms. We did not find any relationships between the two groups with regard to their attributes, their semantic meaning, or degree of correlations between the two groups.

We also looked for the most frequent terms we found in our sample. The terms 'Defense', 'Military' and 'Government(s)' were the most frequent terms found. Table 1 summarises the frequency of the terms we found.

Table 1 Summary of the top 10 most used terms and concepts

Terms	# of times	Percent
1. Defense	4	3.1%
2. Military	4	3.1%
3. Government	4	3.1%
4. Joe Farnadez	1	0.45%
5. Allen Fiers	1	0.45%
6. Prescott Bush	1	0.45%
7. Lt Col Richard Gadd	1	0.45%
8. Aiv March	1	0.45%
9. M al-Kasser	1	0.45%
10. Robert B Anderson	1	0.45%

Without getting into the debate on the distinctions and commonalities between art and science, both paradigms require a mastery of skills, common methodologies, tools and technologies (Trochim, 1985: 575–604). We applied a scientific methodology that is used in the fields of information science and education. Our research procedure consisted of systematic observation, measurement and experiment, as well as the formulation, testing and modification of hypotheses. Our aim was to determine the presence of frequent concepts found within

Lombardi's diagrams. Our principle investigation was based on the idea that we would be able to find a common ground for Lombardi's work and the terminology he used to describe his line of narratives. Although we did not find any shared terminology or classification schemes in the work of Mark Lombardi, as we had expected, we did find additional evidence on why we need to investigate an alternative methodology in visualisation in the future to provide a better understanding of the work of art.

Furthermore, literature and his own writing suggest that Mark Lombardi was a follower of conspiracy theories. We recommend that future studies need to examine if conspiracy theories as a framework can be applied to data structure and visual classification under the paradigm of visualisation.

Summary

The field of visualisation is often associated with a quantitative paradigm as the preferred methodology and framework. Mark Lombardi was a conceptual artist who specialised in line drawings. His work methodology included a three-act procedure that entailed: conducting manual research on a subject; producing index cards based on the subject of his research; and drawing several sketches before the final release. His work was inspired by detailed diagrams that tell the story of the global frauds. In this study, we attempted to find out whether the terms found inside Lombardi's diagrams could provide us with more insight into his work structure. We employed concept mapping analysis methodology to determine the presence of association concepts in order tell us more about his terminology and visual classification. However, we failed to find common themes and classification schemes for those terms. Although we did not reveal new information about Lombardi's terminology, our study indicates a greater need for alternative methodology to analyse artistic work.

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References

Ankerst ME, Ester CM and Kriegel HP (1999) Visual classification: An interactive approach to decision tree construction. In: *Proceedings of the Fifth International Conference on Knowledge Discovery and Data Mining*, pp. 392–396.

Bailey KD (1994) *Typologies and Taxonomies: An Introduction to Classification Techniques*. London: Sage Publications.

Bigge R (2005) Making the invisible visible: The no-conceptual tentacles of Mark Lombardi. *Left History* 10(2): 127–134

Card SK, Mackinlay JD and Schneiderman B (1999) *Readings in Information Visualization: Using Vision to Think*. San Francisco: Morgan-Kaufmann.

Friedman A (2008) Concept mapping in Knowledge Organization through a semiotics lens. *3rd International Conference on Concept Mapping (CMC)* Conference in Helsinki, Finland, pp. 230–239

Friedman A (2010) The use of concept maps in knowledge organization: An analysis of conference papers. *Knowledge Organization Journal* 37(1): 43–50.

Fry B (2008) *Visualizing Data: Exploring and Explaining Data with the Processing Environment*. Sebastopol,CA: O'Reilly Media Inc.

Fry B (2011) Learning from Lombardi. Available at: http://benfry.com/exd09 (accessed 1 February 2011).

Hobbs R (2003) *Mark Lombardi Global Networks*. New York: Independent Curators International (ICI).

Kinchin IM, Hay DB and Adams A (2000) How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research* 42(1): 43–57.

Lombardi M (1987) *George W. Bush, Harken Energy, and Jackson Stevens c. 1979–90* (2nd version). New York, The Museum of Modern Art collections: The Judith Rothschild Foundation Contemporary Drawings Collection Gift.

MacEachren AM (2004) *How Maps Works, Representation, Visualization and Design*. New York: The Guilford Press.

Rößling G (2009) A Visualization-Based Computer Science Hypertextbook Prototype. *ACM Transactions on Computing Education (TOCE)* – Special Issue on the 5th Program Visualization Workshop (PVW'08) archive 9(2).

Segel E and Heer J (2010) Narrative visualization: Telling stories with data. IEEE Trans. *Visualization & Comp. Graphics* (Proc. InfoVis).

Smith R (2000) Mark Lombardi, 48, an artist who was inspired by scandals. *The New York Times* 25 March.

Tufte E (1990) *Envisioning Information*. Cheshire, CT: Graphics Press.

Tufte E (2003) *The Cognitive Style of PowerPoint*. Cheshire, CT: Graphics Press.

Trochim W (1985) Pattern matching, validity, and conceptualization in program evaluation. *Evaluation Review* 9: 575–604.

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Buzzaar

An environment and tool to map your web

Abstract
As web users, we visit pages and our navigation history is often locally stored in our browser logs, thus creating a data set that contains a lot of valuable information, not only for ourselves but also for peer users that we might be willing to share this information with. How can we exploit this information? How can we give it a meaning and transform it into knowledge that can be shared with others? Buzzaar[1] is a web application that intends to help answer such questions. Buzzaar's long-term goal is to provide a free environment available to all who want to interact with their browsing history and transform it into visual representations of their interests and navigation habits. The key idea behind the buzzaar approach is the notion of *webmap*, a graphical representation of web pages visited by a user that should be intuitive and easily understandable and could be tailored to specific user needs. Furthermore, as knowledge building is also a social and collaborative act, it is crucial that the knowledge represented in the form of personal webmaps can be shared, merged and compared. Therefore, the overall purpose of buzzaar is to create a tool that will help users to better interpret their webmaps, create new (individual and/or common) knowledge out of them and help them to better exploit (individually and/or collectively) the information these webmaps contain.

Keywords
collaboration, data visualisation, knowledge sharing, mapping, network, user, web

Introduction
The development of digital technologies has brought fundamental changes into our lives, cultures and societies. Social networking media (e.g. Twitter, Facebook), user generated sites (e.g. blogs, Wikis, YouTube, Flickr, delicious, etc.) and peer-to peer networks have contributed to the development of a new participative culture where users have access to tools to create and share contents with peers.

As web users, we spend significant time online, searching for contents and visiting numerous web pages. These actions leave traces that can be collected, typically within web server logs. These data represent potential sources of valuable information for various private and public purposes.

Commercial companies (e.g. search sites such as Google, Yahoo!, e-commerce sites such as Amazon[2] or specific purpose sites such as Compare.com) have well understood how useful the above mentioned data can be if properly analysed and transformed into exploitable information for their targeted audiences. Meaningful analysis, representation and comparison of actions, and the habits and navigation history of web users can help them to better understand and exploit the knowledge that these data contain.

However, in most cases, users cannot access the generated information that is kept private, even though the original data have been created by the users themselves.

A lot of personal navigation data is also locally stored in users' browser logs (navigation history) that contain visit frequencies and, if specific browser plug-ins are used (e.g. Voyage[3] and buzzaar), visit co-frequencies. However, there are currently no popular and easy to use tools to exploit these data and they remain quite difficult to share in an efficient way.[4]

We strongly believe that data created by users should be made available to them so that they can interact with them and share them with others, in order to build a culture of commons,[5] a participative and distributed knowledge, part of our digital culture. Therefore, there clearly is a need for web activity analysis tools providing new graphical representations which give more sense to navigation data and show relations that are otherwise difficult to perceive. Such tools should allow users to create dynamic interactive displays where they can see, explore and manipulate contents. By fostering contextualisation and conscientiousness, such tools could also contribute to users' awareness and lead to their empowerment.

In this perspective, the goal of the buzzaar project is to build a free and publicly accessible environment (*the buzzaar environment*) providing:

- a tool (a firefox plug-in – *the buzzaar toolbar*) allowing users to gather their site visit frequencies and co-frequencies and to store them in a private space on a web server (*the buzzaar server*);
- a tool (a java applet running on the server – *the webmap manager*) allowing registered users to: (1) visualise their navigation data in the form of interactive graphical webmaps that intuitively represent their interests and navigation habits; and (2) share their webmaps and collaboratively build common webmaps representing various communities; the common webmaps (as any other shared webmaps) can then be used by all registered users to be merged or projected into their private webmaps in order to identify commonalities or differences, thus allowing them to better understand and exploit the knowledge they contain.

The long-term goal of the buzzaar project is to contribute to the development of a widely exploitable set of web data management techniques and tools allowing reliable collaborative creation of publicly shared information, while providing efficient ways to protect users' privacy by keeping their identity and contributions anonymous.

The rest of this paper will present: (1) the main concepts (webmaps and webmap manipulation mechanisms) developed in the project; (2) the existing experimental buzzaar prototype; (3) some related works; and (4) a set of general conclusions.

Concepts

1. Interactive visualisation through user-centred webmaps

As previously mentioned, our intention was to create a web infrastructure for creating and manipulating webmaps that correspond to visual representations of raw visit frequencies and co-frequencies sent by buzzaar members and stored on the buzzaar server.

Webmapping as a concept is not new. Several existing tools (e.g. the ones developed in projects such as TouchGraph,[6] or Voyage) allow users to visualise relations between web pages they visit, and to translate a huge amount of data into graphical representations. Webmaps can be fully interactive, multimedia, collaborative and

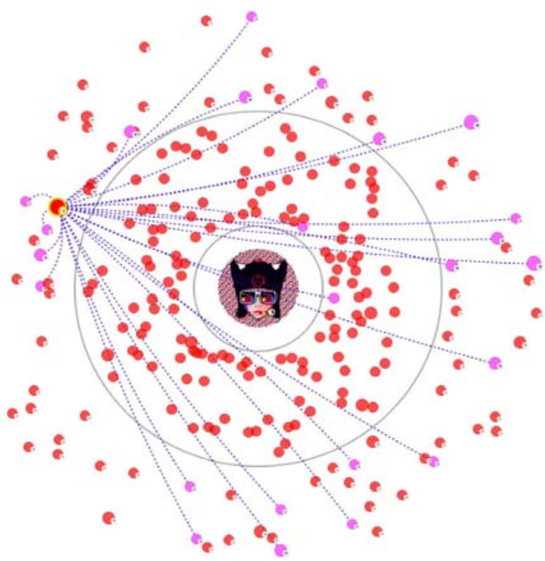
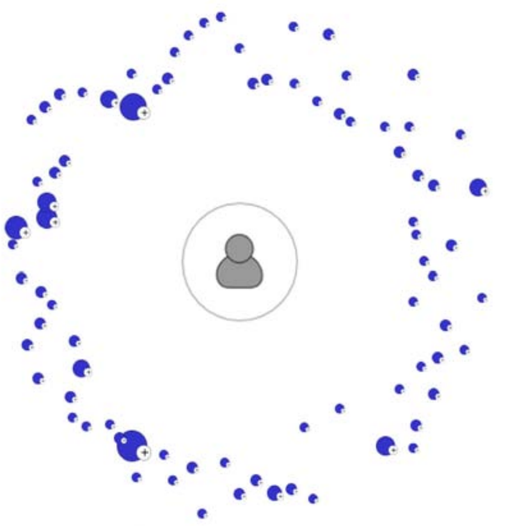


Figure 1
Buzzaar webmap

sharable, thus enabling users to experiment with their own ways (emotional and intellectual) to build knowledge.

Our goal was to create dynamic and interactive webmaps that users can edit, customise, manipulate and share. Thus we have provided our users with webmap manipulation operat-ions (see section 2. below) that allow them to display, manipulate and analyse various types of information, including page popularity (number of visits), associations (number of times two distinct pages have been both visited in a given interval of time), categorisation (tagging and filtering), and display with different visual markers (size, position, colours and alpha transparency).



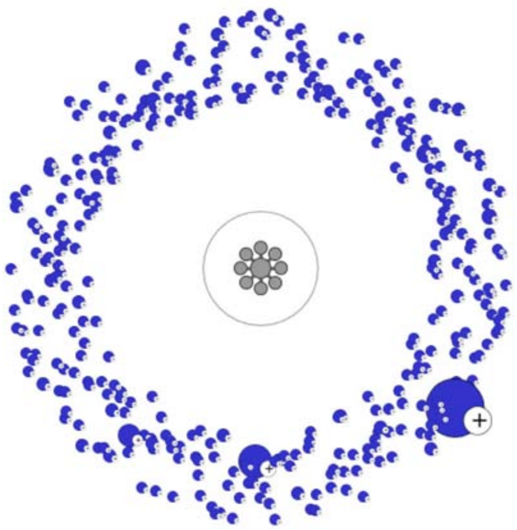


Figure 2 (left) User webmap customisation by default

Figure 3 (right) Common buzzaar webmap

By manipulating their webmaps, users can associate meanings and better position themselves in the global informational context of their navigation history. For privacy purposes, user webmaps are private access only. Members can access their own maps as well as the buzzaar public webmap. However, the buzzaar infrastructure also allows them to share their webmaps with peers (typically by sending webmap files over email).

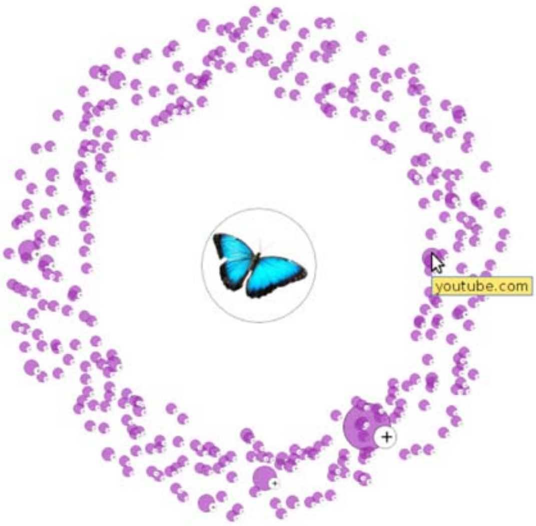
Websites are made of web pages and one of the main challenges was how to display such a huge amount of data in an organised and easy-to-understand representation. We should be able to display information at different levels, while organising and representing their complex nature and relationships with familiar visual metaphors.

Individual user's webmaps are representations of their personal navigational interests; there-fore, buzzaar webmaps are designed to be user-centred, with a user's navigation history being displayed around a centre that represents the user him/herself (Figures 2 and 3).

The buzzaar interface is made up of two parts: (1) a textual part – a conventional list of visited web pages (URLs); and (2) a graphical part – the user-centred webmap representing the same URLs. Following standard interface design principles, simultaneity and synchronisation are systematically enforced: any change in the URL list echoes that of the webmap and vice versa.

Information is displayed at two different levels of granularity: the URL granularity where the units correspond to individual URLs and the domain granularity where units correspond to URL domains aggregating all associated URLs. Users can easily switch between the two levels of granularity, either by expanding/collapsing an entry in the displayed list or by directly operating on the webmap (Figures 4a and b).

In the webmap, URLs and URL domains are represented by differentiated visual metaphors



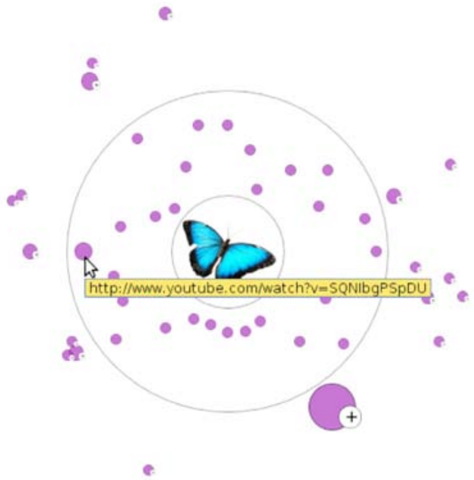


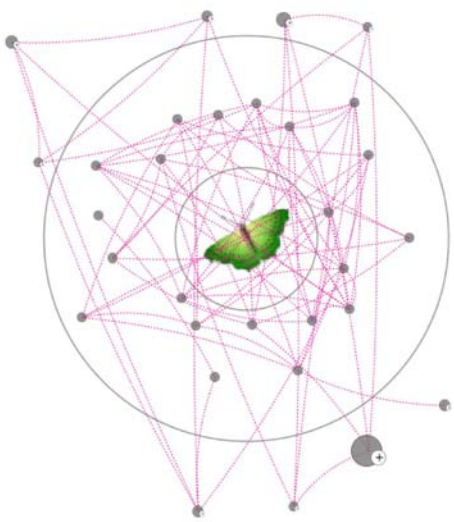
Figure 4a (left)
Domain mode

Figure 4b (right)
Domain mode: URL domain – expanded

(two distinct types if circles hereafter called nodes). The size of the circle representing a URL (URL domain) is proportional to the popularity (cumulated popularity) of the associated URL (set of URLs). Circles are commonly used in many other graphical visualisations to represent URLs and URL domains and should thus be intuitive and easily understandable to users.

Webmaps can also visualise association between URLs in the form of undirected links. Links are defined as follows: there is an undirected link between URL A and URL B, if the user has visited URL A and URL B (URL A before URL B) frequently enough in a given interval of time. In addition, users can also choose to visualize, either all links (Figure 5) or only those related to a selected subset of URLs and can switch between undirected and directed links (Figure 6). The notion of co-occurring URLs is an important feature of the buzzaar webmaps and the visualization of links can help users to contextualize their web navigation.

Finally, in terms of layout, a user-centred webmap is divided into four concentric zones, each devoted to a specific type of information: (1) a central zone containing the visual identity of the user (typically, an icon that can be customised); (2) an expansion zone, where aggregating nodes (URLs domains) can be expanded and nodes associated with a given tag can be displayed (see the description of the domain/tag modes below); (3) a default zone, dedicated to the visualisation of URL domains (aggregating nodes), or, when a tag or a domain is expanded in the expansion zone, URLs and URL domains linked to the expanded content; and



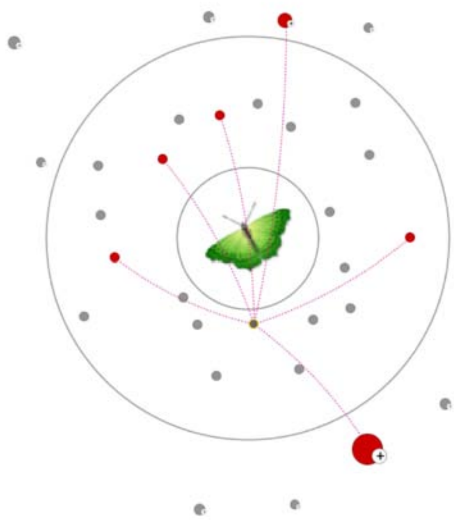


Figure 5 (left)
Co-occurrence: show all

Figure 6 (right)
Co-occurrence: from selected node

(4) a peripheral zone containing external URLs linked to the user's content (see the notion of projection in the next section).

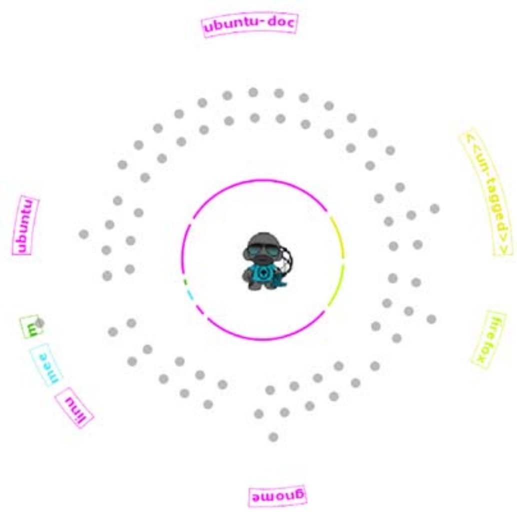


Figure 7a (top, right) Tag mode

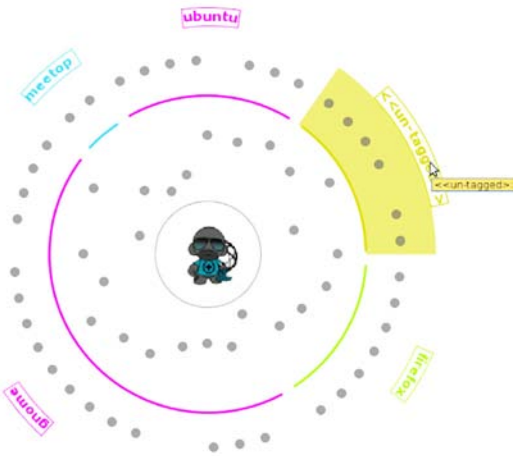


Figure 7b (bottom, right) Tag expanded

2. Webmap manipulations

Besides the representational aspects previously described, another important feature of webmaps is that they can be manipulated by various operations that can be used to better understand and exploit their content. These operations can be classified into two main categories: those operating on a single webmap (filtering, tagging and customising), and those operating on two distinct webmaps (merge and projection). The merge and projection operation are usually performed with one of the webmaps being the webmap of a given user and the other corresponding to a webmap that this user has received from some peers (or a public webmap).

Filtering

Filtering enables users to filter their webmaps by name patterns in order to focus on specific information. Filtering can be either temporary (typically when exploring a given webmap), or persistent if the user saves the filtered result as a new webmap.

Tagging

When surfing on the web, users often want to categorise information they collect and find important (in order to return to it later or to share it). In this perspective, each web browser provides the possibility to tag favourite links. Social networks such as delicious also offer the possibility to share tags. Tagging is nowadays considered a popular and useful functionality which also allows users to give a personal meaning to the collected information. The buzzaar webmap manager therefore also provides a tag mode so that users can visualise and categorise URLs into topics of interests described by tags and differentiated by colours (Figures 7a and b).

Customising

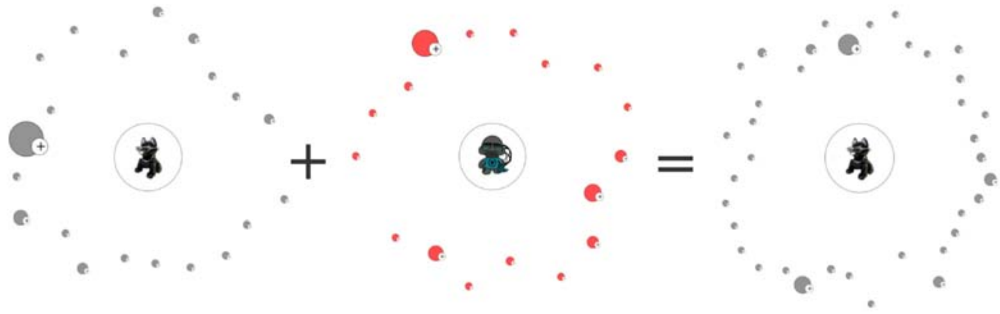
Users can personalise their webmaps. They can change colours of nodes, colours of links, and they can personalise the central icon. Such customisation is commonly used in numerous social web platforms and has become familiar to web users. It makes webmaps more playful and personal.

Merge

The merge operation allows buzzaar users to add other webmaps (typically the ones received from other users) into their own webmaps. In the resulting webmaps, URLs, URL frequencies/co-frequencies and tags are cumulated. The merge operation can therefore be used when a group of friends, peers or colleagues want to put their information into a single webmap representing their community as a whole (Figure 8).

Projection

The projection operation allows users to compare and differentiate information present in two webmaps. In particular, it allows users to easily search for information present in



$$x \in X = A \cup B \Leftrightarrow \{x \in A \text{ or } x \in B\}$$

Figure 8 Merge operation

the projected webmap that is relevant to the information present in the webmap into which they are projecting.

More precisely, the projection is a non-symmetric operation that can be described as follows: the result of the projection of a webmap B into a webmap A is a webmap C: the central zone of C is the central zone of A (i.e. the visual identity of the user performing the projection is preserved); the default zone of C contains all the URL/URL domains common to A and B (thus allowing commonalities to be easily spotted); and the peripheral zone of C contains all the URL/URL domains of B that are linked to some of the nodes in the default zone of C (thus allowing the easy identification of the information in B not present in A that is potentially the most relevant to A) (Figure 9).

The projection operation can be interpreted as a simple (graphical) equivalent of the recommendation techniques used by many e-commerce companies such as Amazon to inform their customers about other customers' choices close to theirs.

Furthermore, in order to allow users to exploit more efficiently the potentially relevant information identified by a projection, the following visual hints are also provided:

- The external co-occurring nodes are displayed in a specific *colour* (that can be customised by the user) in order to be easily distinguished from the nodes present in the original webmap;

- The *alpha-transparency value* of all the displayed nodes is proportional to their popularity in the projected webmap. This graphical feature provides users with an intuitive way to simultaneously assess the importance of displayed nodes in the original webmap (through their size) and in the projected webmap (through their alpha-transparency).

Therefore, the buzzaar projection operation does not restrict itself to simply identifying which of the URLs in the projected webmap are new with respect to the original webmap, but rather focuses on the new URLs that are potentially relevant (because they are co-occurring with some URLs present in the original webmap) and indicates (through their transparency) how much these URLs are potentially relevant. Similarly, the projection operation does not simply identify commonalities between two processed webmaps, but also indicates how much each of

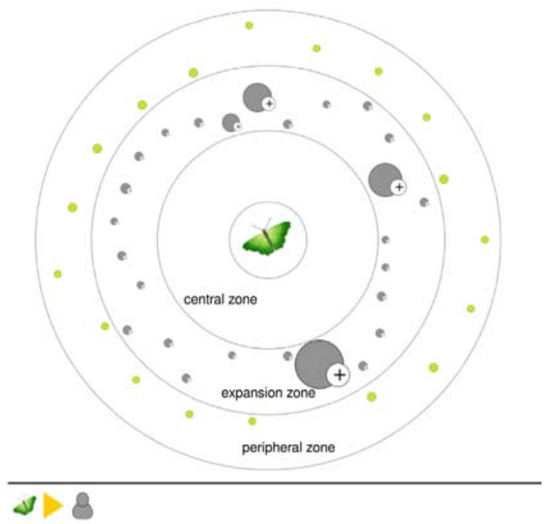


Figure 9 (left) Projection operation

the common URLs displayed in the default zone is important: (1) in the original webmap (through its size); and (2) in the projected webmap (through its transparency). As such, we believe that the projection operation represents a useful tool for users to efficiently process the information generated by the projection (Figures 10a and b).

Experimental prototype

The buzzaar project is currently being implemented in the form of an experimental prototype consisting of: (1) the buzzaar server and applet (running on a server hosted at EPFL);[7] (2) the buzzaar toolbar (a Firefox plug-in allowing users to generate raw visit frequencies and co-frequencies required for them to build their own webmaps); and (3) the buzzaar website (www.buzzaar.net), maintained by the meetopia community and providing information on the project (up-to-date news, charter, FAQ, tutorials, forum, webmap gallery, etc.).

The buzzaar toolbar and applet are under the GPL license and the content of the buzzaar website is under a creative commons license in order to contribute to the development of a common culture on the web.

The buzzaar prototype is freely accessible for anyone, either as guest user or as registered user (member). Guest users can access and explore common webmaps present in the public space of the server. Registered users benefit from an additional private space where they can store and process private webmaps they can produce with the data generated by the buzzaar toolbar, if installed in their browser.

To prevent the misuse of storage space on the buzzaar server, registered users can only produce and exploit webmaps generated from website visit frequency and co-frequency data transmitted to the server by the buzzaar toolbar (Firefox plug-in). The toolbar also provides users with possibilities to filter the data to be transmitted (thus allowing them to prevent the transmission of possibly sensitive information) and the possibility to suspend/resume data transmission at any time.

Finally, the data sent to the server by registered users is also cumulated within a global webmap, thus allowing every registered user to contribute to the progressive setup of a collaborative knowledge base about the general use of the web.

Related works

Although buzzaar is a unique tool and environment to map your web use, there are other projects that have already developed similar operations and different tools, graphical and dynamic environments for web users to play with and share their data, bookmarks, history files, etc.

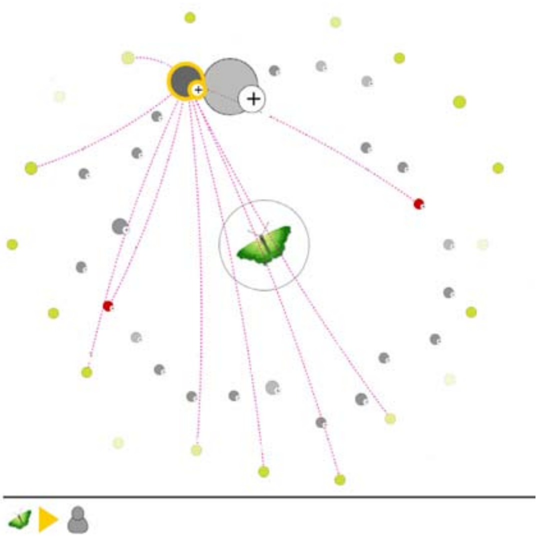


Figure 10a (left) Projection in domain mode

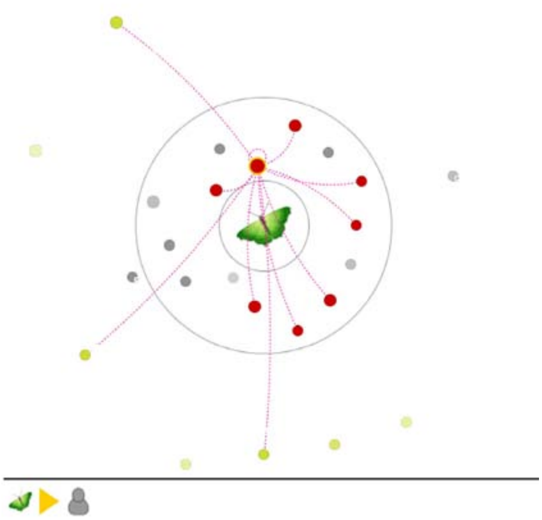


Figure 10b (right) URL domain expanded in projection

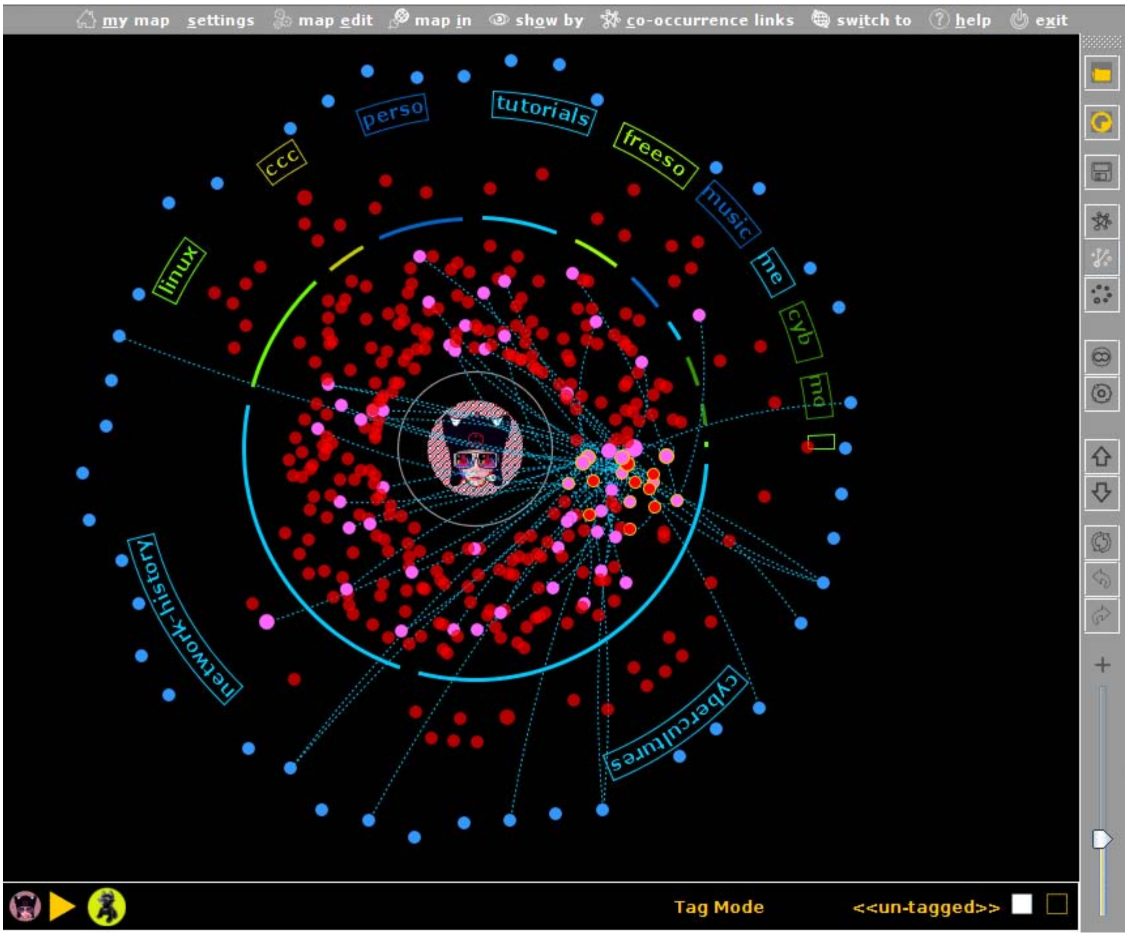


Figure 11
buzzaar webmap

One of the first of such projects is the *Internet Cartographer*[8] from Inventix Software (available for older Windows operating systems and unfortunately not maintained anymore). This software was designed to manage users' navigation history, bookmarks and co-occurring links, and had tools like research by keywords or tags. However, Internet Cartographer did not address the issue of information sharing between peers.

Also, since 2009, Firefox users can install *Voyage*, a plug-in developed by Hsiao-Ting Yu. Voyage was designed to map and visualise navigation history, to provide users with an interactive tool to search into their history files. Voyage's users can 'travel' within a visual web history navigation map organised along a timetable. They can select a specific date, see visit frequencies and co-frequencies and display visited multimedia files on a Media Wall. They can also integrate their twitter feeds. However, generated data can be neither shared, nor edited.

Delicious is another social bookmarking website for storing, sharing and discovering web bookmarks. It offers the possibility to its members to share their bookmarks using a non-hierarchical classification system of tagged bookmarks with freely chosen index terms (thus generating a kind of folksonomy). Delicious allows its users to compare bookmarks and share their interests, but it does not provide any visual environment to explore the available data.

TouchGraph Navigator 2[9] available since 2001, provides its users with the possibility to visualise and interact with information. With the TouchGraph Navigator Desktop users can perform the analysis and create a network-like visualisation of their personal data, either on their local computer or on a local server. It displays relations between information units, translates raw data into intuitive visualisations, and allows to share information and export images. However, unlike buzzaar, it is a commercial tool that requires a license and it does not provide support for collaborative knowledge building.

Finally, it is important to mention that the buzzaar project is also coupled with the *SPADS project*, a collaboration between EPFL and the University of Neuchâtel, aiming at the design of distributed, peer-to-peer techniques allowing privacy preserving transmission of data to aggregating servers. In this perspective, the long term goal of the buzzaar project is to integrate the techniques developed in SPADS into the buzzaar toolbar in order to strengthen privacy protection.

Conclusion

As web users we spend significant time on-line, browsing for different types of information, leaving digital traces and generating data about our information gathering and knowledge building habits that could potentially be interesting and useful if gathered, visualized, analysed, made easily understandable and exploitable. The resulting information could also potentially represent an interesting knowledge to be shared and collaboratively explored with peers.

The buzzaar webmap manager translates users' web navigation history into webmaps. It allows users to visualize their web site visit frequency and co-frequency data in the form of an interactive, intuitive and easy to use graphical representation. It also provides users with the necessary operations (e.g. filtering, tagging, merge and projection) to easily manipulate, understand and exploit their webmaps and their informational content. The buzzaar prototype also provides all web users with a common public webmap representing the culmulated data from the buzzaar's members, and thus could be a potential valuable source of public information based on web navigation data.

We believe that the buzzaar initiative, if accepted by users, could be an interesting step towards the emergence of a new web-based, participative culture, where interactions of individual users with the web can be progressively and collaboratively transformed into a meaningful and exploitable knowledge available for any web user.

At this moment we are in the promotional phase, trying to present this tool and environment to a wider web community. Future buzzaar usage will show if its long term goals can achieved or not.

Notes

1. Buzzaar, 2011: *buzzaar project*. Available at: http://www.buzzaar.net (accessed 8 June 2011). The team of the buzzaar project is composed of researchers from the EPFL Artificial Intelligence Laboratory and the netartists from the meetopia community.
   Meetopia is a collective of European web net artists. Most projects developed on the platform focus on elements of the net culture as part of a new culture; hybridity, replication, sharing and reformulated identities. According to the meetopia website, 'Internet is understood as a virtual public place for production, broadcasting and sharing'. Available at: http://meetopia.net/ (accessed 8 June 2011).
   The Laboratory of Artificial Intelligence of the EPFL (École Polytechnique Fédérale de Lausanne) is part of the Institute of Core Computing Science in the School of Computer and Communication Sciences at EPFL and its work focuses on algorithms for distributed problem-solving, and methods for recommendation and reputation systems (LIA – Ai Lab of the EPFL). Available at: http://liawww.epfl.ch (accessed 8 June 2011).
   The project is supported by the Swiss Office of Culture, sitemapping project, and the EPFL.
2. Amazon, 1996. Available at:http://www.amazon.com (accessed 8 June 2011).
3. Hsiao-Ting Yu, 2009. Voyage – Firefox add-ons. Available at: https://addons.mozilla.org/en-US/firefox/addon/voyage/ (accessed16 February 2011).
4. Sites such as Delicious do allow users to share bookmarks but do not provide any intuitive graphical visualisation nor do they provide mechanisms for users' data aggregation. Delicious. Available at: http://www.delicious.com (16 February 2011).
5. 'The commons is terminology referring to resources that are collectively owned or shared between or among populations' (Wikipedia contributors, 2010, updated 31 May 2011). Available at: http://en.wikipedia.org/wiki/Commons (accessed 8 June 2011).
   'Culture of the commons is a concept frequently used by the Creative commons initiative to underline this idea of a public and shared culture belonging to the whole, such as a common good' (Dylan, 2008).

6. TouchGraph, LLC, 2001. TouchGraph Google Browser. Available at: http://www.touchgraph.com/navigator (accessed 16 February 2011)
7. EPFL (École polytechnique fédérale de Lausanne).
8. Inventix Software, 1999. Cartographer. Available at: http://www.inventixsoftware.com (accessed16 February 2011).
9. TouchGraph, LLC, 2001. TouchGraph Google Browser. Available at: http://www.touchgraph.com/navigator (accessed16 February 2011).

References

Bauwens M (2005a) *Peer to Peer and Human Evolution: On 'the P2P Relational Dynamic' as the Premise of the Next Civilizational Stage*. Available at: http://economia.unipv.it/novita/seminario/P2PandHumanEvolV2.pdf (accessed10 June 2011).

Bauwens M (2005b) *The Political Economy of Peer Production*. Available at: http://www.ctheory.net/articles.aspx?id=499 (accessed16 February 2011).

Burke J (2006) *Network Collaboration: Peer To Peer As A New Way Of Living – Video Interview with Michel Bauwens* (video online). Available at: http://www.masternewmedia.org/news/2006/09/29/network_collaboration_peer_to_peer.htm (accessed 16 February 2011).

Dylan J (2008) *A Shared Culture* (video online). Available at: http://creativecommons.org/videos/a-shared-culture (accessed 16 February 2011).

Felber P, Rajman M, Riviere E, Schiavoni V and Valerio J (2010) SPADS: Publisher anonymization for DHT storage. In: *P2P 2010, 10th IEEE International Conference on Peer-to-Peer Computing*. Delft, The Netherlands.

Klanten R, Bourquin SEN and Tissot T (2010) *Data Flow: Design graphique et visualisation d'information*. Berlin: Gestalten.

Lau A and Moere AV (2007) Towards a Model of Information Aesthetics in Information Visualization. In: *IV '07, IEEE International Conference on Information Visualisation*. Zurich, Switzerland. Available at: http://web.arch.usyd.edu.au/~andrew/publications/iv07.pdf (accessed16 February 2011).

Manovich L (2002). *The Anti-Sublime Ideal in Data Art*. Available at: http://www.manovich.net/DOCS/data_art.doc (accessed16 February 2011).

Manovich L (2010) *What is Visualization?*. Available at: http://manovich.net/2010/10/25/new-article-what-is-visualization/ (accessed16 February 2011).

Wallis JC (2005) *Databases & Data Visualization: The State of the Art*. Center for Embedded Networked Sensing. UCLA: Center for Embedded Networked Sensing, Data Management Team. Available at: http://www.moebiustrip.org/CENS/DataVisTechRep.doc (accessed 16 February 2011).

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Collaboration metrics through semiotic narrative

Abstract
Today we are witnessing first-hand a global revolution in collaboration and innovation that is enabling creative minds to come together across vast expanses of space and time. People now have access to the tools and channels necessary to communicate and collaborate in nearly every mode of value creation imaginable. They are profoundly changing the world as we know it.

The project presented in this paper constitutes a synthesis of evaluation and design. The purpose of the research is to analyse and track several core characteristics of effective collaboration as exhibited by interdisciplinary design teams over the course of a 10-week project. Data composites representing these core characteristics were then encoded into a visual narrative for each team, revealing a new, holistic perspective of multivariate data, evolving throughout the project life cycle. This technique not only offers a diagnostic window into the collaborative dynamics of a team in flight, but also moves the complexly nonlinear issue into a visual dimension, which is better suited for reasoning with problems that are systemic in nature. This technique is not meant to captain the ship. Rather it provides a new layer of information to aid in the interpretation and negotiation of the journey.

Keywords
collaborative mechanics, data visualisation, design, evaluation, interdisciplinary, semiotics

Background
The project presented in this paper constitutes a synthesis of evaluation and design. The purpose of the research was to identify, analyse, and monitor several core characteristics of effective collaboration as exhibited by interdisciplinary design teams over the course of a 10-week project. Data composites representing these core characteristics were then encoded into a visual narrative for each team, revealing a new, holistic perspective of multivariate data, evolving throughout the project life cycle. This technique not only offers a diagnostic window into the collaborative dynamics of a team 'in flight', but also moves the complexly nonlinear issue into a visual dimension, which is better suited for reasoning with problems that are systemic in nature. This technique is not meant to captain the ship. Rather it provides a new layer of information to aid in the interpretation and negotiation of the journey.

The work presented here documents observations and analyses of three sets of design teams, two of which were graduate course projects that were in process. The third student group was completing global virtual team (GVT) projects that were started in the previous quarter (Fall 2009).[1] Consequently, while the two classes provided an opportunity to focus on collaboration in real-time observation and analysis of processes within co-located teams, the final group provided a unique opportunity to capture the reflections of graduate design students after their participation with teams of computer and information science graduate students from the University of Cologne and Aalto University, Helsinki. Since these interviews were conducted with members of interdisciplinary virtual teams, they provided background and a contrast to the study of co-located design teams that are the focus of this paper.

The methods employed in this study were informed by the works of academics and practitioners (Cultural Connections, Inc., n.d.; Gluesing and Riopelle, 2009; Gluesing et al., 2003; Sawyer, 2007) and readings in organizational and design management theory, in particular, *Communities of Practice* (Wenger, 1998) which introduced the 'social theory of learning' and provided a conceptual framework for understanding the intricacies of social engagement that constitute 'collaboration'. The four components of Wenger's theory – community, identity, practice and meaning – operationalised collaboration and informed observation of activities and development of multiple research methods to better understand the indicators of successful collaboration. Additionally, Sawyer's identification of seven characteristics of effective creative teams (2007: 14–17) provided a structure from which to articulate and 'write' heuristics and dynamics of collaboration which constituted the survey instrument.

Establishing a framework for research

Five primary research questions guided this study of collaboration in design teams:

1. What is collaboration?

2. How can collaboration be operationalised and identified?

3. What are the mechanics of collaboration? What are the activities that facilitate or inhibit collaborative practice?

4. Can a successful collaboration be observed and measured?

5. How might the output of a study of collaboration be visualised to enable rapid assessment of the performance of a design team?

Methodology

Multiple data collections methods were used which included:

- *Observation*: The study began with passive observation of group interaction, work processes, and overall functionality (Figure 1). This method provided familiarity with group formations, individual team members, their interactions, and group routines. Observation of client presentations documented formal group interactions. This proved very helpful when reviewing survey data to relate occurrences of conflict and group flow.

Figure 1 Passive observation of design teams

- *'Confessional' interviews*: single students from each team were recorded weekly to capture roughly two minutes of personal interpretation regarding group progress, possible obstacles, and perceived trajectory of the team. This revealed the individual's doubts, concerns, and hesitations about team functionality that could not have been documented through passive observation and ultimately correlated to the data captured in the written survey (Figure 2).

Figure 2 Subjects of weekly 'confessional' interviews

- *Individual survey*: comprised of 25 questions, each calibrated to quantify personal and group dynamics of: mission and objectives, coordination, participation, communication, benefit to client, personal commitment, personal satisfaction and team formation. As the observation sessions and confessional interviews were taking place this 25-item survey was developed to collect quantifiable data. The need for a survey instrument emerged as a response to Research Question 4, which was to devise a means of quantifying the characteristics of collaborative practice and team performance. Two major factors shaped the formation of the survey. The first from Sawyer's (2007: 43) 'ten conditions for group flow.' The second source that influenced the development of the survey was the Self-Assessment Instrument for Global Virtual Team (Cultural Connections, Inc.) which provided a conceptual framework on which to base the survey. The questions were carefully developed to solicit answers that could capture evidence that translated into Sawyer's 'ten conditions for group flow' (2007: 43). The specific categories articulated in the self-assessment survey were crucial to graphing and mapping the results which proved to be strikingly accurate in assessing the levels of collaboration for each of the teams that were studied (Figure 3).

Figure 3 Survey instrument

DMGT 745 Collaborative Culture in Design Organizations

Team Name: ______________________________ **Number of courses you are taking:** _______

Rate these statements as they describe your project today: (1) "Not at all", (5) "Very Much", (DK) "Don't Know"

1.	Mission and objectives are well-defined	1	2	3	4	5	DK
2.	Mission and objectives are well-understood by all team members	1	2	3	4	5	DK
3.	Mission and objectives are supported by all team members	1	2	3	4	5	DK
4.	Mission and objectives are achievable	1	2	3	4	5	DK
5.	This project is critical to your client's success	1	2	3	4	5	DK
6.	This project is relevant to your own educational/career aspirations	1	2	3	4	5	DK
7.	Your team makes plans and executes them on time	1	2	3	4	5	DK
8.	Your team is internally cooperative	1	2	3	4	5	DK
9.	Your team is externally cooperative	1	2	3	4	5	DK
10.	Your team was formed based on skills and knowledge	1	2	3	4	5	DK
11.	Your team was formed based on friendships	1	2	3	4	5	DK
12.	This project takes priority over other coursework	1	2	3	4	5	DK
13.	Your team is on schedule	1	2	3	4	5	DK
14.	Everyone contributes equally	1	2	3	4	5	DK
15.	A few members dominate team discussions	1	2	3	4	5	DK
16.	Successes and failures are shared by the team	1	2	3	4	5	DK
17.	Work is fairly distributed among members	1	2	3	4	5	DK
18.	Your contributions and opinions are well-received and appreciated	1	2	3	4	5	DK
19.	Team members are flexible and willing to compromise	1	2	3	4	5	DK
20.	Your team effectively negotiates conflict	1	2	3	4	5	DK
21.	Your team members understand and value your expertise	1	2	3	4	5	DK
22.	Your team coordinates strengths to accomplish new challenges	1	2	3	4	5	DK
23.	Your team communicates adequately to stay on schedule	1	2	3	4	5	DK
24.	Your team members fulfill their commitments to the team	1	2	3	4	5	DK
25.	Your team communicates and shares ideas with other teams	1	2	3	4	5	DK

Rate the following methods of communication by level of significance to your team's work

Email	1	2	3	4	5	NA
Phone	1	2	3	4	5	NA
Txt Msg	1	2	3	4	5	NA
IM/Chat	1	2	3	4	5	NA
Face-to-face	1	2	3	4	5	NA

Your team's mission (in your own words):

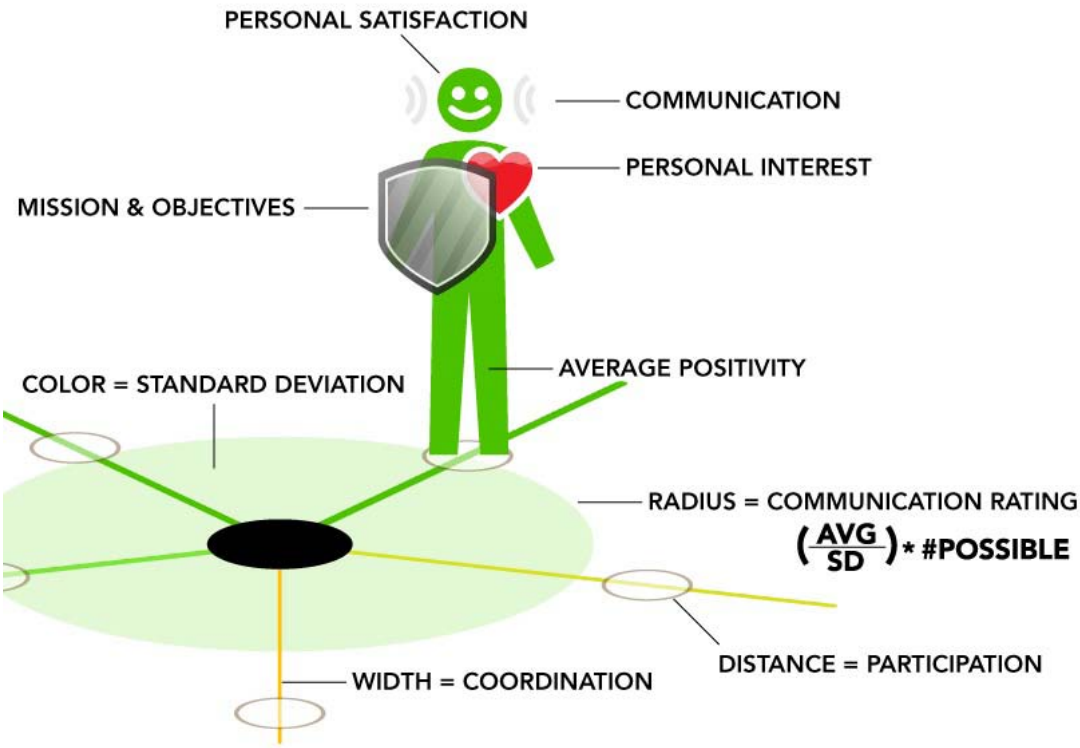


Figure 4 Data visualisation key

- *Semi-structured ethnographic interviews*: for students who participated in the global virtual teaming project to capture a retrospective on collaboration and its relationship to localisation and virtuality. These interviews provided a retrospective of the final outcome of the project by articulating what they believed facilitated their collaborative efforts, what hindered them, and ultimately, whether or not they deemed the project a successful collaboration.

Analysis: Making the invisible visible
Once data collection was complete, our team focused on constructing a visual narrative to effectively communicate a complex set of information at a glance. Survey responses were compiled into a subset of factors for both individuals and their teams, such as mission and objectives, communication, coordination, participation, personal interest and personal satisfaction. These factors are vital to successful collaboration, as outlined by Sawyer's (2007: 43) 'ten conditions for group flow'. Each factor was then visualised as variable attributes of a simple stick figure for individuals, and a spider plot graph for teams (Figure 4).

Figure 5 Making the invisible visible: A design team snap shot

Since surveys were conducted at various points in the project, this method of visualising factors also provided snapshots in time, which, when considered with empirical data collected during those same periods, yielded a rich new diagnostic layer to understanding what was happening within each project team at specific points in time (Figure 5).

The process of conducting this study substantially increased our understanding of the components and dynamics of collaborative efforts. A conceptual understanding of collaborative dynamics informed by qualitative research allowed for crafting a set of methods for collecting primary data on the collaboration process as it played out in real time. Observations previously categorised as individual intuition were articulated as explicit recognisable characteristics that could be referenced through shared language. For example, when a team gave a well-constructed presentation to the client that was cohesive in language and purpose, we could then say that they possessed a clear 'mission and objective' because the group shared a verbal and conceptual understanding of the subject and conveyed it in the presentation. Groups that were disjointed in their presentations, where individuals presented singular concepts, could perhaps be seen as having a strong *individual* 'mission and objective'; however, the group understanding and dynamic was weak. Prior to our study, we could have categorised the group as having performed 'well' or 'not well'; however, classifying their performance in terms of exhibiting (or lacking) a condition for group flow allowed us to have a central reference point and shared understanding of the language used to explain what was observed.

Applying the 'ten conditions for group flow' (Sawyer, 2007) as a basis for operationalising collaboration allowed us to become more effective in analysing and articulating data in relation to the concepts that were foundational to the collaborative process. While the complexity involving the holistic system of group and social dynamics continued to exist outside of our study, it was clear that a diagnostic survey could, in fact, serve as an accurate indication of the overall collaborative functioning of the individual teams.

Although the survey could not provide a holistic perspective of the working collaborative dynamic, quantitative data collected through the survey was used to capture a slice-in-time snapshot of their dynamics that could be used as a diagnostic tool. The data was visualised with consideration for maintenance of representational integrity and as much anonymity as possible. It was important to present the graphic depiction as a snapshot of an ongoing narrative.

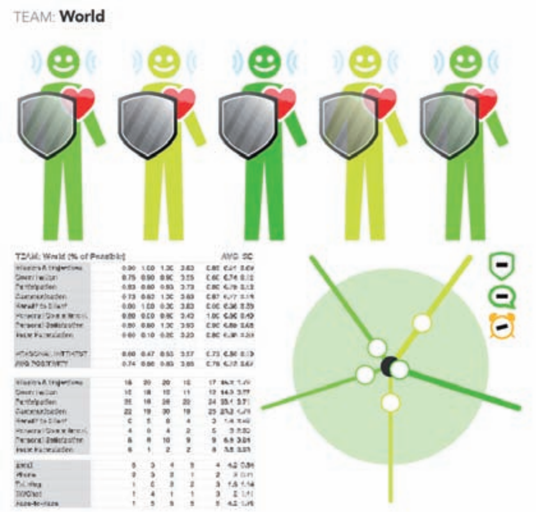
Findings: A story about collaboration

The purpose of this research was to study the process of collaboration, identify and articulate its components, and explore the possibility of producing a set of heuristics that could suggest an accurate assessment of the collaboration as a 'successful' endeavour.

While survey data did reflect individual and team dynamics, it could not account for group deliverables in regards to evaluating them as 'successful' or useful to the client; although, teams that did demonstrate stronger collaborative dynamics were more explicitly lauded by the client. While each team did produce a set of outcomes as directed by the instructor, evaluating those outcomes in terms of subjective quality was not within the scope of this project. Rather, our primary interest was in assessing the 'health' of the teams as it impacted the ability of team members to collaborate effectively as the projects were in process.

Four major findings of the study are as follows: first, the correlation between survey results and observation of client presentations. As previously mentioned, teams that demonstrated stronger collaborative dynamics also performed better in client presentations. This was attributed to the strength of the 'ten conditions for group flow' as recorded by the individual and group responses of the team to the survey. When assessing the characteristics the stronger teams possessed, their correlations were very high. An interesting point was that individual scores, while they may have ranked high in the presence for the 'ten conditions for group flow', did not indicate success for the overall team. In fact, within this, there could be individual variations to the perception of these 10 characteristics. For example, *mission and objective* was found to be the first unifying factor for the team in regards to shaping their efforts. However, we found that this characteristic could exist dually – the individual could perceive the mission and objective differently that that of his team. So while the individual could self-report a clear mission and objective for the project, it might not be shared by his teammates. This deviation hindered the team in their group efforts because one person believed his interpretation superior to that of his group and tried to push them towards his vision.

Second, teams that showed cohesiveness in terms of survey results tended to communicate better in client presentations as compared to



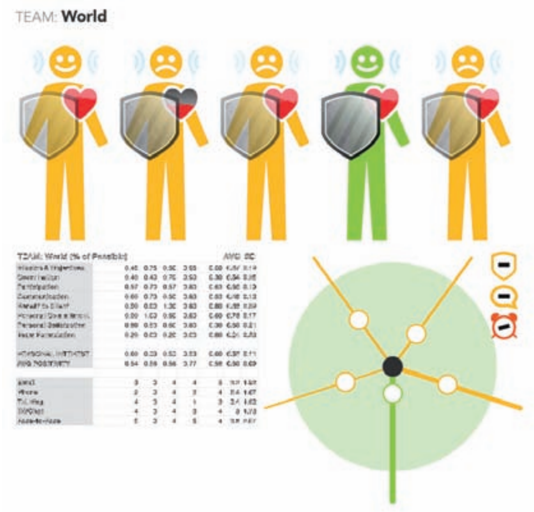


Figure 6 (left)
Team World (A)

Figure 7 (right)
Team World (B)

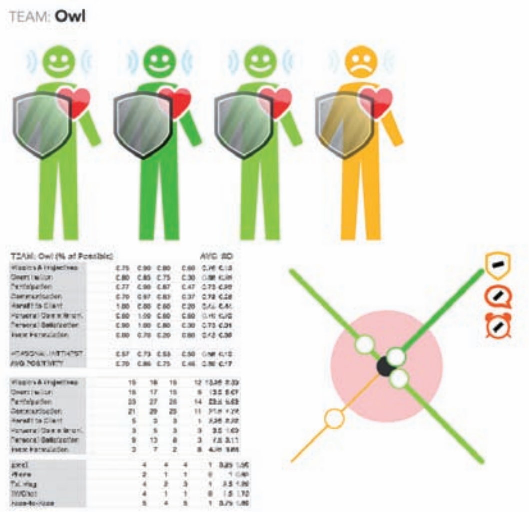
those who scored lower in relation to overall cohesion. This could be predicted based on the confessional-style interviews, particularly in those teams in which interaction between team members was observed to be problematic as it reinforced the lack of strength regarding the 'ten conditions'. The qualitative data was absolutely necessary to supplement what could not be captured in the survey. As mentioned above, the condition of *mission and objective* was problematic when individuals projected a solid understanding of the group mission, but in fact possessed an interpretation which deviated greatly from the group. This bit of data was revealed through the group observations and provided a real moment of insight for the team – specifically, how could a team score high in the *mission and objective* category, yet display such outward incoherence during work sessions and presentations? The confessionals and observations helped to piece the data together to form an understanding of the range of dynamics within the teams.

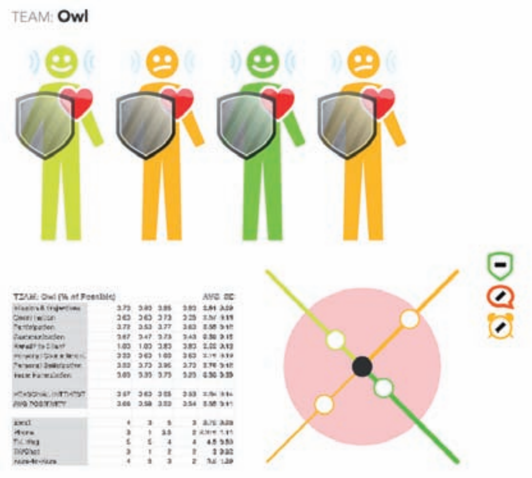
The third finding was, with the exception of one member of Team World (Figure 6 and Figure 7), team members who were less satisfied, less interested, less positive and less clear about the mission and objectives of the project tended to remain so. Even when there was some improvement in clarity of mission and objectives and an increase in the level of communication, other data points remained constant (Figure 8) or deteriorated (Figure 9). They also tended to lose interest as the project progressed. In the case of Team World (Figure 6 and Figure 7), we found that a strong start did not guarantee a strong finish: while three of the five team members started out with strong interest and clear understanding of mission and objectives, over time, positivity and personal satisfaction dropped precipitously. Particularly interesting in this team was that one member went from low positivity to high positivity with an increase in frequency of communication and clarity of mission and objectives (Figure 7). We can speculate that this individual assumed a leadership role for the team; however, we have no specific data that suggests what might have led to this reversal.

The fourth major observation centres on the critical nature of communication and participation in assessing the level of collaboration within the team. While not a startling finding, it confirms previous empirical studies in this area (Gluesing and Riopelle, 2009). This observation was particularly clear in the case of Team Flow Motion (Figure 10 and Figure 11), where over time strong communication and individual participation became even stronger, while personal interest increased along with greater clarity of mission and objectives. As their name suggests, this team seemed to have achieved what Keith Sawyer (2007) refers to as 'group flow,' a concept that he borrows from Mihaly Csikszentmihalyi (1990). The chemistry in this team was very positive. We observed a high level of mutual support among individual team members, each one respected for what they could contribute. Everyone indicated in the survey that their opinions were valued and

Figure 8 (left)
Team Owl (A)

Figure 9 (right)
Team Owl (B)





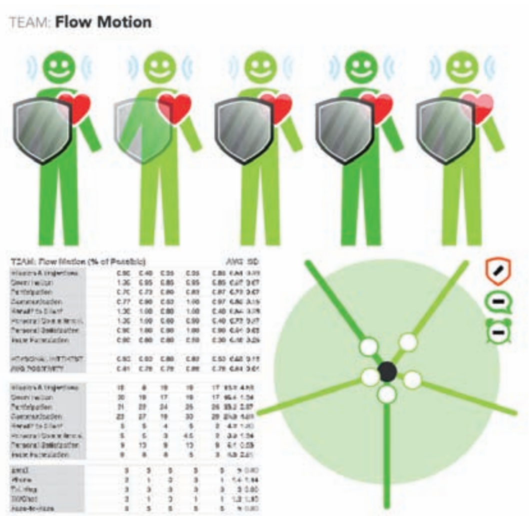
deeply listened to. Observation attributed this to the time spent together outside of the class because this team interacted as a social group rather than meeting solely for the purpose of the client project. The team rose above all the challenges they encountered because of their effective communication skills – enhanced by their social practice both in and out of the class setting. Leadership responsibilities were shared: it was observed that no single person was responsible for keeping the project on track. Work seemed to go smoothly and seamlessly. Team members enjoyed being together. In the end, Team Flow produced the most sophisticated final deliverable, exhibiting a deeper understanding of the core issues, which the client found very impressive. Their dynamic was seemingly tangible, the observations of their interaction was even discussed by other groups outside of the formal data collection and regular ethnographic sessions.

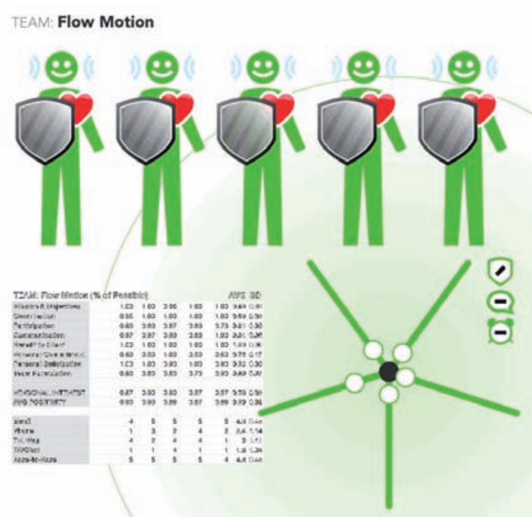
The power of visualisation

Our findings were derived from both direct observation and evaluation of survey responses. We learned that findings from one source of data collection (i.e. interviews, observation) were confirmed though analyses of the alternate methodology (i.e. survey data) and vice versa. While this provided a form of verification, the most compelling of our findings was not in the data collected per se, but rather in the impact that resulted from the visualisation of the survey data. Using culturally significant modes of colour, the data was affected by positive hues (green), through negative hues (red), to show where data correlated to marking a successful collaboration as contrasting to ones that were suffering.

Figure 10 (left)
Team Flow Motion (A)

Figure 11 (right)
Team Flow Motion (B)





Conclusions and future directions

By combining both Sawyer's and Wenger's theories of community formation and collaboration we were able to prove that successful collaborations do in fact contain the 'ten conditions for group flow' which are influenced by the formation of group identity in a community of practice. The strength of the 'ten conditions' does correlate to the level of collaborative group dynamic a team embodies. Additionally, Wenger's 'social theory of learning' provides a deeper conceptual and theoretical understanding of the individual construction of placement within the collaborative model, as their purpose and role is constantly negotiated through team interaction.

The final thought from this study is more of an open-ended question: if the diagnostic tool is used during collaborative endeavours, what is to be done when the group dynamic is suffering? Should an intervention be staged and how and when is it to be managed? While measuring dynamics of collaboration proves possible, there is no recommendation from this group regarding intervention or action. Rather, that decision is left to the discretion of our future collaborators.

Note

1. Collaborative Innovation Networks (COINs) is a partnership between MIT's Center for Collective Intelligence, the Savannah College of Art and Design's Design Management program, University of Cologne (Dept of Information Systems and Information Management), and Aalto University, Helsinki (SoberIT).

References

Csikszentmihalyi M (1990) *Flow: The Psychology of Optimal Experience*. New York: Harper Perennial.

Cultural Connections, Inc. (n.d.) Global Virtual Team Self-Assessment Instrument.

Gluesing J and Riopelle K (2009) Correlating Survey Data and Network Data to Understand Performance in Global Virtual Teams. Collaborative Innovation Networks (COINs2009). Savannah College of Art and Design, Elsevier.

Gluesing JC, Alcordo TC, Baba ML, Britt D, Wagner KH, McKether W. Monplaisir L, Ratner HH and Riopelle K (2003) The development of global virtual teams. In: Gibson CB and Cohen SG (eds) *Virtual Teams That Work: Creating Conditions for Virtual Team Effectiveness*. San Francisco: Jossey-Bass.

Sawyer RK (2007) *Group Genius*. New York: Basic Books.

Wenger E (1998) *Communities of Practice: Learning, Meaning and Identity*. Cambridge, UK: Cambridge University Press.

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Interaction design for sustainability

Perspective from the new practitioners

Abstract
This paper presents a case study of an international design team consisting of new practitioners of interaction design from different disciplinary backgrounds given the problem of how to encourage sustainable behaviour with interaction design in Sweden. Although the diverse backgrounds of the group, including new computer science, graphic design, and HCI practitioners from Greece, Germany, Spain, the Netherlands and Canada caused tension when trying to reframe this large design question about sustainability, following interaction methodologies together allowed the design process to push forward and these tensions ended up challenging the aspects of the design positively. After collective brainstorming, a literature review, and bodystorming activities, a design for aiding the picking and gathering of edible and useful plants in forests was chosen. In Sweden, this is a popular recreational activity with few restrictions, but still only a small percentage of the available berries and mushrooms are actually picked. Using the different backgrounds of the design team as well as the different perspectives of sustainability based on experiences in different countries, the team was able to apply interaction design methods to encouraging this sustainable activity. Methods used included brainstorming, bodystorming, scenario and storyboard development, sketching, lo-fi to hi-fi iterative prototyping and user testing, allowing visualisation to become the means of both discovering and resolving conflicts that arose in the design team. Through the use of interaction design methodologies to visualise potential solutions and pulling on the tension caused by diverse backgrounds, the large problem of encouraging sustainable behaviour was reframed to create a novel interaction design that not so much encouraged sustainable behaviour, but allowed a sustainable behaviour to be more accessible and easier to practice.

Keywords
design, HCI, interaction, methods, multidisciplinary

Introduction
In their report on interaction design, Lantz, Artman and Ramberg (2005) mention Preece, Rogers and Sharp's (2002) notion that interaction design is fed by a range of disciplines such as psychology, informatics, computer science, graphic design and industrial design, and also connect this with Fällman's dissertation 'In romance with the materials of mobile interaction' (2003). Fällman's reflection on design points to it not so much on a continuum between art and science, but rather a guiding tradition that spans many disciplines, not just Human Computer Interaction (HCI). Interaction design teams have been diversifying to include members such as ethnographers, industrial designers, and sociologists, along with the traditional computer scientists and engineers. It can be tempting to separate the design team members to avoid the inevitable conflict caused by different backgrounds and experiences, but these conflicts are not always negative. For instance, industrial designers may try to keep the technical design members away from the early stages of brainstorming and interface design, or not involve usability specialists until the user testing stage. This approach may be beneficial when the implementation is straightforward, but having

a diverse design team throughout the entire process could provide a larger range of insights into the limitations and also the design possibilities for such a complex problem as encouraging sustainable behaviour through interaction design. The interdisciplinary nature of interaction design means that the activity itself is about reframing and understanding the design gap instead of just finding a direct solution (Fällman, 2003).

This paper will present an interaction design project initiated in order to encourage sustainable behaviour, presenting a perspective from the new practitioners of interaction design from different disciplinary backgrounds and from different parts of the world. By presenting how the interaction design methods encouraged the discussion of differences and allowed tensions to arise, this paper will show how these new practitioners of interaction design with diverse backgrounds were able to visualise and reframe the complex design problem of encouraging sustainability into something tangible: an interaction design to aid in the gathering of useful plants in forests, a popular and sustainable practice in Sweden. These interaction design methods allowed for the visualisation which became both the means of discovering and resolving design team conflicts.

Interdisciplinary nature of interaction design

Interaction design for encouraging behaviour changes, such as sustainable behaviours, can find some of its roots in HCI and also in the more traditional safety engineering discipline of Human Factors Engineering (HFE). The HFE and HCI pioneers of the 1960s realised the benefit of involving users in computer science design (McCarthy and Wright, 2004) and they were further influenced by usability engineering which also produced cost savings and safety gains (Myers et al., 1996). HFE techniques such as requirements gathering created early success stories, but compared to the success of automating routine processing tasks, the traditional requirements gathering technique was problematic when applied to complex tasks in novel applications (Stewart and Williams, 2005). Innovative designs require something more than just requirements gathering in order to explore, visualise, and reframe design problems, such as encouraging sustainable behaviour. Just as HCI has become inherently multidisciplinary, benefiting from methods from sociology, anthropology, human factors, computer science, graphics design and others (Mackay and Fayard, 1997), having members of an interaction design team vary across these disciplines allows a broader range of knowledge to influence the design of a novel technology and more sets of eyes to help visualise the solution.

Often the combination of different disciplines can make it difficult to communicate design ideas. Borchers (2001) encourages having a common language, or design patterns, to aid in design conversations. Sundström et al. (2011) propose using example technologies in order to get the design team on the same page and to explore the possibilities of different technologies. These techniques point to the issues that can arise within teams from diverse disciplinary backgrounds, but the arguments that arise from these differences are not always negative. Although these discussions can be very time consuming and the differences may lead to tensions between team members, the different visions will challenge the design from many different angles. The end result should be a design that has already faced the critical eyes of members from various disciplines, and as per Mackay and Fayard, addressing HCI issues with multiple disciplinary lenses 'produce[s] results that are significantly more robust and useful' (1997: 9).

Given the problem of implementing an interaction design to promote sustainable behaviour, a six-member team of new practitioners was formed from different disciplines and different backgrounds. Two HCI specialists from Canada and the Netherlands joined three computer scientists from Greece, Germany and Spain, and one graphic design artist from Greece, all with work experience that ranged from two to five years. Although their experience and education varied, they were brought together as interaction designers with a complex problem to visualise and reframe: how can an interaction design promote sustainable behaviour in Sweden.

Interaction design methods

Brainstorming, bodystorming and literature review

The group started by brainstorming, as this method helps design teams quickly generate and organise a large number of ideas around a given problem (Löwgren and Stolterman, 2004). This discussion quickly turned into an argument as the members had various impressions of what would have the largest impact and what would actually be considered sustainable. An awareness campaign was suggested by the Spanish member based on a recent successful campaign in Barcelona to reduce water consumption. The Canadian member pushed for something to promote personal gardens based on a recent trend in Toronto for indoor gardening. The German member pushed the design idea towards sustainable food practices based on a restaurant food recycling programme for the homeless in Berlin.

After much discussion on the wide topic of sustainability, the team decided to reframe the problem into not so much promoting sustainable behaviour as much as making sustainable behaviour more attractive and easier to accomplish. The team narrowed the design focus to reducing transportation waste, unused local resources, and dependency on importing, with special emphasis on food sustainability. It was decided to focus on three possible issues and explore them further: (1) buying local products; (2) gathering and collecting food; and (3) growing and personal gardening.

The results of this brainstorming led to bodystorming, which involves the design team brainstorming in the locations or context of the design – this activity can challenge assumptions and dispel ideas that are taken for granted (Myers, 1999) and bodystorming activities can be more memorable and inspiring than brainstorming (Oulasvirta et al., 2003). Based on the narrowed focus of the design, the group explored two supermarkets, one health-food store, one forest and two gardening centres in Stockholm in order to become familiar with unfamiliar sustainable activities (Oulasvirta et al., 2003). Although this method would normally be completed by the ethnographers or HCI specialists on the team, the entire team was involved in the bodystorming activities. By doing these activities together, the members were able to get see with their own eyes what was possible in an unfamiliar Swedish context. The results of brainstorming and bodystorming sessions were able to be immediately discussed by the entire team, instead of one member presenting their findings, unavoidably from their viewpoint. Although this led to design idea conversations that were time consuming, the lack of limitation on what roles each member would play in the interaction design team fostered novel ideas and poignant criticisms. In the end, very few ideas were able to stand up to six individuals' insights on the problem, but through visualising and reframing the large problem again the members decided to focus on encouraging existing sustainable behaviours. The team agreed that a device that would provide expert knowledge on useful plants in the forests would encourage the picking, gathering and use of these plants, an already popular and sustainable Swedish activity.

Further literature review pointed to the potential sustainable practices that the gathering device might encourage, and also acted as a reality check for the interaction design team in order to ensure an actual sustainable product was created (Stegall, 2006). In Sweden, this gathering activity is a popular recreational activity (Egli et al., 2006), but comparing figures from 1977 and 1997, there is a significant decline in the amount being gathered (Yrjölä, 2002). All land in Sweden can be used for this collecting activity and there are no restrictions on their forests (Yrjölä, 2002). In 1977, it was found that only a small percentage of available berries and mushrooms were actually picked (Kardell, 1980), and harvesting does not adversely affect the future growth patterns (Egli et al., 2006).

Different ways to implement this gathering device were discussed among the group extensively, but an augmented reality mobile phone application was chosen over ideas such as augmented reality glasses and a unique hand-held device. This discussion was led by the computer science members, but some of the more novel technologies were brought up by the HCI specialists and graphic designer who were not limited in their vision by known technical constraints. The computer scientists believed the mobile phone application of augmented reality would be possible to prototype and this was supported by the HCI specialists, as the inability to evaluate the other implementations would be harmful to the entire design process (Greenberg and Buxton, 2008). In addition, creating an interaction design that would require separate hardware would not be promoting sustainability itself (Stegall, 2006).

Personas, scenarios and storyboards

The next step for the team was to define the potential users through further observations and interviews as the basis for creating personas (Blomquist and Arvola, 2002). More bodystorming was completed by the group in a forest with three couples interviewed, and also in a supermarket where five mushroom buyers were interviewed. The results of these activities gave more insight into the possible users, but the amount of information gained was not seen as sufficient to the HCI specialists for the group to visualise potential future users, so, in addition, a survey was sent by the German member to a known group that went on gathering trips together. Five people with a range of experience with collecting edible plants answered questions about the gathering activity.

From these sources, all six members were able to discuss the findings to define potential user groups by combining typical results. Although this activity was led by the HCI specialists, the insights provided by the computer scientists and graphic designer were considered equally useful. The user groups thus defined were quite general but they included aspects that would motivate the design. From these general groups, three personas were then created that were used as a common conversation point and helped to drive the design by allowing common goals for all the members of the design team. During the design process, the group tried to satisfy the needs and goals of each persona, an archetype of a user that they could visualise with a name and a face, described in terms of their needs, goals and tasks (Blomquist and Arvola, 2002). As personas are not stereotypes but rather typical users with exemplary types of behaviours (Cooper et al., 2007), they had characteristics such as, young children to take care of, issues with vision, and language problems. Although these were not necessarily common characteristics and were not wanted by the computer scientist members of the design team, they were pushed by the HCI specialists as appropriate challenges to the design. By creating these users together, the team was able to put a face to the sometimes faceless and distant user of the system being designed.

After the personas were created, the design team started exploring their possible tasks by creating scenarios (Blomquist and Arvola, 2002) – descriptions of the persona's interaction with the system which help focus the design to be more user-centred (Gaffney, 2000). These

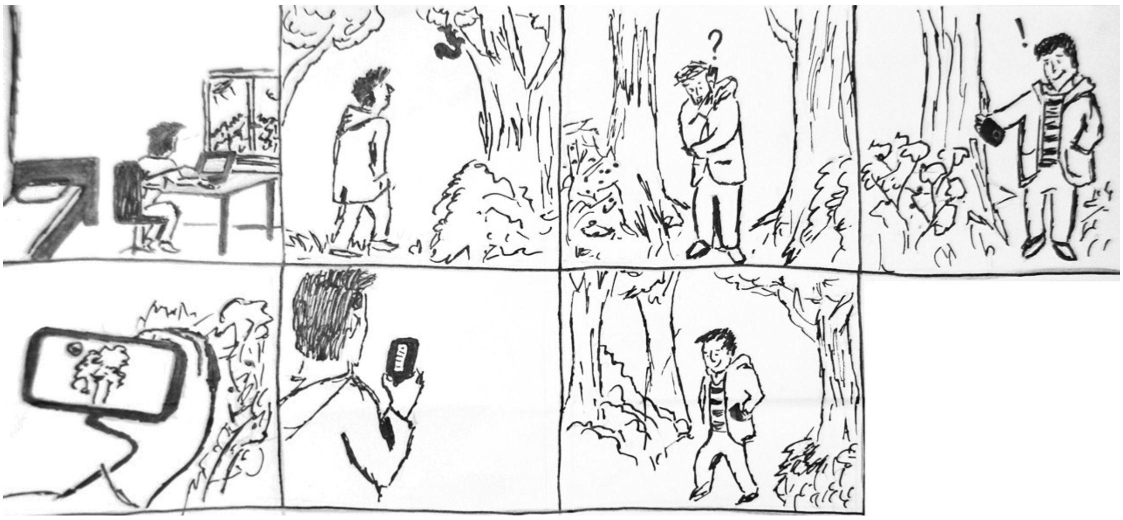


Figure 1 Storyboard by the graphic designer visualising use in the physical environment

scenarios visualising typical use and interaction possibilities of the system were discussed amongst all group members, but the graphic artist was able to take the story lines and quickly draw out the storyboards (see Figure 1), the most common form of sketching that allows flexibility in the depiction of use or physical environment (Löwgren, 2004). The quality of these drawings made the use cases of the application very clear for the whole team and it also introduced discussion of the ergonomic needs of the users. Although sketching is important in many domains, Fällman (2003) points out that sketching in HCI differs as it has to do with the physical interactivity of the system, elements that can be hard to visualise personally let alone share with other design team members.

Paper-prototyping and user testing

All six members of the team individually contributed to sketching out their ideas of a prototype, so no bias could be introduced to their design visions (see Figure 2 for an example). Although the quality of the sketches varied based on the drawing skills of the members, they were a useful tool to aid with verbal descriptions as they helped demonstrate the intended behaviour of the system (Rettig, 1994). Discussions amongst the group and comparison of ideas led to the rejection of some aspects of the design and the combination of similar details. The use of the sketches allowed ideas to be visualised, and therefore to be made easier to reflect on and criticize, and as the discussions among the group were still very strong and not all members agreed, three different prototypes were created to satisfy all the members. As there was still no common agreement, these designs were created as paper-prototypes, as the method is fast, brings early results, allows exploring many more ideas, and can substantially increase the quality of the design (Rettig, 1994).

Each prototype went through at least two rounds of user testing with various technically inclined students at a Stockholm university. All team members participated in the studies, with members switching roles during testing, such as facilitator and computer (see Figure 3). All members watched the testing and discussed the results directly after the tests, again allowing

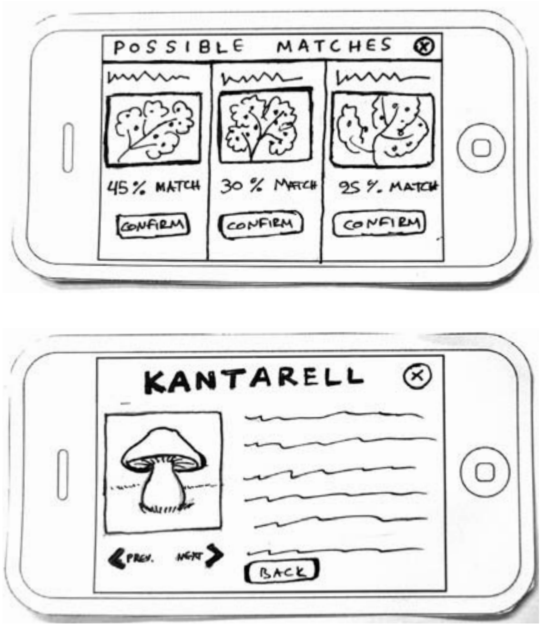


Figure 2 Paper prototypes by individual design team members depicting unbiased design visions

the members to be on the same page and avoiding the bias of one member presenting the findings through their eyes. Because the members all witnessed the issues with each of the prototypes, the arguments that led to the creation of three separate prototypes were resolved through the results of the testing. The design team was then able to create a final prototype on a whiteboard (see Figure 4) which the graphic artist used to create a detailed rendition on paper which would be the basis of the hi-fi prototype.

High-fidelity prototyping and evaluation

Although hi-fi prototypes are time consuming, they are used for testing the look and feel of the design for the users (Rettig, 1994). A hi-fi prototype was created to be played on an iPhone using Photoshop, Javascript and HTML (see Figure 5). Although the computer scientists led this activity, the graphic artist contributed to

Figure 3 Trading roles during paper-prototype user testing and observation

Figure 4 Collective team design on a whiteboard

the interface design through Photoshop and the HCI specialists contributed to discussing the interaction design of the HTML. Again, having all members contribute to the building of the hi-fi prototype allowed for design issues to be brought up and resolved right away, and the limitations of the technology were understood by all members of the team regardless of their technical expertise. The resulting hi-fi prototype was an amalgamation of all of the ideas of the six members, where the final design did not fully satisfy all the members' opinions but was enough of a compromise that the overall design was accepted by all members. The application on the iPhone was then tested on more students from the Stockholm university who found some interaction issues, and although prototyping is useless unless the design is refined based on the findings (Rettig, 1994), unfortunately because of time constraints, the hi-fi prototype was not modified nor re-evaluated to address all of these problems.

Figure 5 Screenshot from the hi-fi prototype

Conclusion

Given the wide and complex problem of encouraging sustainable behaviour in Sweden, the design team was able to use interaction design methods to reframe the problem into a tangible solution to make an already popular sustainable activity in Sweden easier to accomplish and therefore more accessible. Although these new practitioners had different backgrounds, both in their own education and experience, and also in their views of sustainability influenced by their respective countries, they were able to use these tensions to help visualise a novel interaction design. This visualisation became both the means of discovering and resolving conflicts in the design team. Through hours of arguments and discussions with a diverse design team, a design was visualised that did not necessarily satisfy all the concerns of all the members, but was acceptable to all members. Although diverse backgrounds can cause tensions within a design group, these tensions contributed positively to the generation of the design idea, and also opened up different possibilities with the technology and the interaction design. Having a diverse interaction design team and involving all team members in the interaction design methods was time consuming and frustrating, but the resulting design for a complex problem such as encouraging sustainability was stronger because of these tensions.

References

Blomquist Å and Arvola M (2002) Personas in action: Ethnography in an interaction Design Team. In: *Proceedings of 2nd Nordic Conference on Human–Computer Interaction*. Aarhus, Denmark 19–23 October. New York: ACM.

Borchers JO (2001) A pattern approach to interaction design. *AI and Society* 15: 359–376.

Cooper A, Reimann R and Cronin D (2007) *About Face 3: The Essentials of Interaction Design*. New York: Wiley Publishing Inc.

Egli S, Peter M, Buser C, Stahel W and Ayer F (2006) Mushroom picking does not impair future harvests – results of a long-term study in Switzerland. *Biological Conservation Journal* 129(2): 271–276.

Fällman D (2003) *In romance with the materials of mobile interaction*. PhD thesis, Umeå University.

Gaffney G (2000) *Scenarios, usability techniques series, information & design*. Available at: http://www.infodesign.com.au/ftp/Scenarios.pdf (accessed 2 December 2009).

Greenberg S and Buxton B (2008) Usability evaluation considered harmful (some of the time). In: *Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems*, Florence, Italy 5–10 April. New York: ACM.

Kardell L (1980) Skogsmarkens bär och svampar – en hotad resurs? *Sveriges Skogsvårdsförbunds Tidskrift* 78(5): 5–19.

Lantz A and Artman H and Ramberg R (2005) Interaction design as experienced by practitioners. In: *Proceedings of the First Nordic Design Research Conference*, Copenhagen, Denmark 29–31 May, NORDES.

Löwgren J (2004) *Sketching interaction design, Talk at Stockholm University*. Available at: http://webzone.k3.mah.se/k3jolo/Sketching/index.htm (accessed 2 December 2009).

Löwgren J and Stolterman E (2004) *Thoughtful Interaction Design*. Cambridge: The MIT Press.

McCarthy J and Wright P (2004) *Technology as Experience*. Cambridge: The MIT Press.

Mackay WE and Fayard AL (1997) HCI, Natural Science and Design: A framework for triangulation across disciplines. In: *Proceedings of the 2nd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, The Netherlands 18-20 August. New York: ACM.

Myers M (1999) Investigating information systems with ethnographic research. *Communications of the AIS* 2(23): 1.

Myers B, Hollan J, Cruz I, Bryson S, Bulterman D, Catarci T, Citrin W, Glinert E, Grudin J and Ioannidis Y (1996) Strategic directions in human-computer interaction. *ACM Computing Surveys* 28(4): 704–809.

Oulasvirta A, Kurvinen E and Kankainen T (2003) Understanding contexts by being there: case studies in bodystorming. *Personal and Ubiquitous Computing* 7(2): 125–134.

Preece J, Rogers Y and Sharp H (2002) *Interaction Design – Beyond Human–Computer Interaction*. New York: John Wiley & Sons, Inc.

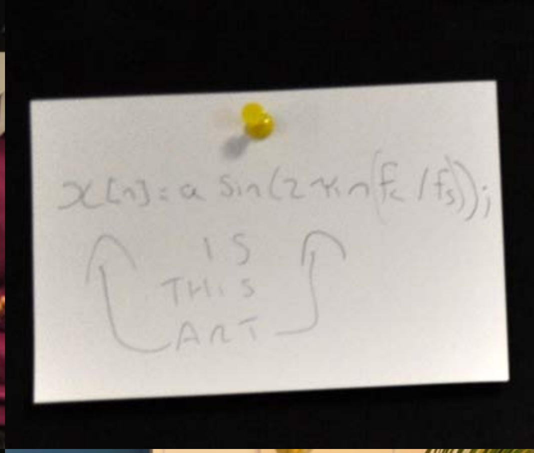
Rettig M (1994) Prototyping for tiny fingers. *Communication ACM* 37(4): 21–27.

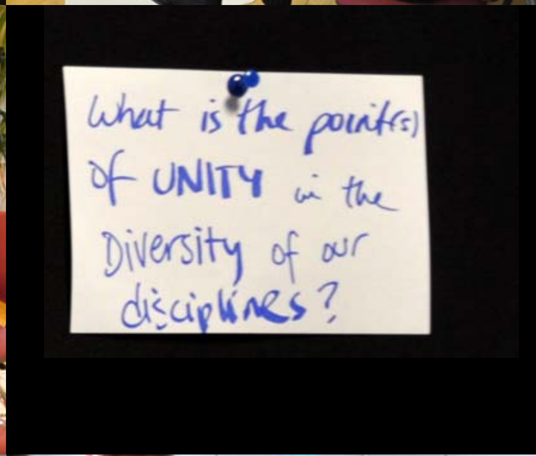
Stegall N (2006) Designing for sustainability: A philosophy for ecologically intentional design. *Design Issues* 22(2): 56–63.

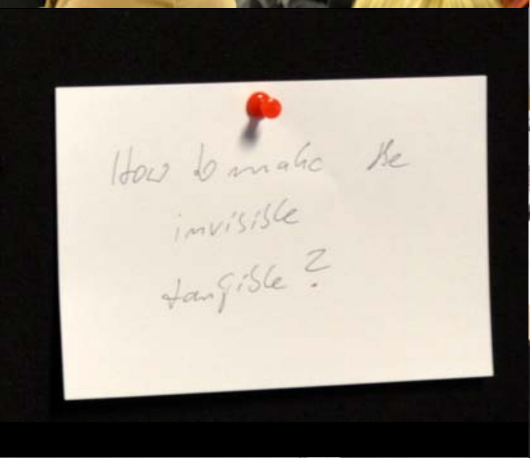
Stewart J and Williams R (2005) The wrong trousers? Beyond the design fallacy: Social learning and the user. In: Rohracher H (ed.) *User Involvement in Innovation Processes: Strategies and Limitations from a Socio-Technical Perspective*. Munich: Profil-Verlag, 39–71.

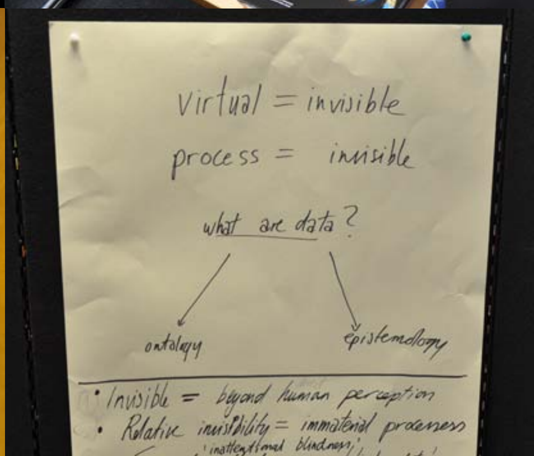
Sundström P, Grufberg K, Wirström N, Solsona J, Lundén M and Taylor A (2011) Inspirational bits –towards a shared understanding of the digital material. In: *Proceeding of the Twenty-Ninth Annual SIGCHI Conference on Human Factors in Computing Systems*, Vancouver, Canada 7–12 May. New York: ACM.

Yrjölä T (2002) Forest management guidelines and practices in Finland, Sweden and Norway. In: *European Forest Institute Internal Report No. 11*. Joensuu: European Forest Institute.


x[n] = a sin(2πn(fc/fs));
IS THIS ART


What is the point(s) of UNITY in the Diversity of our disciplines?

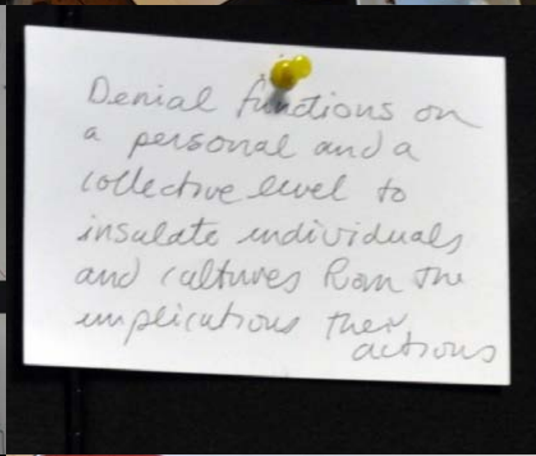

How to make the invisible tangible?

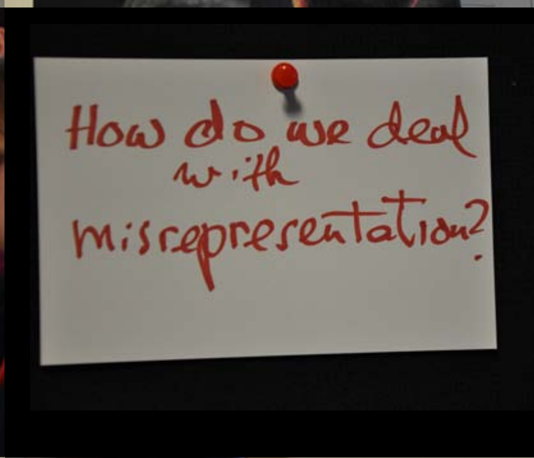

virtual = invisible
process = invisible
what are data?
ontology
epistemology
Invisible = beyond human perception
Relative invisibility = immaterial processes



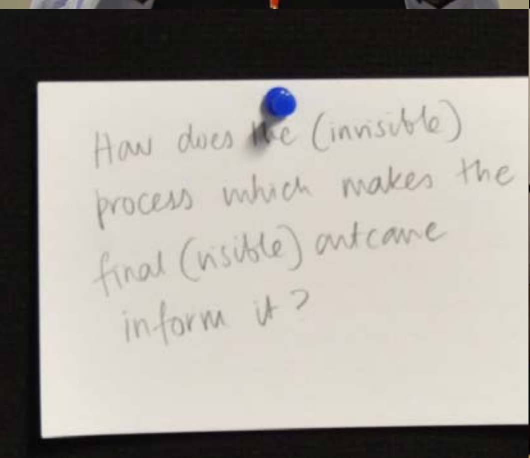

LISTENING
How does the invisible become visible?
Relationships
Reformulation
Dialogue
Models
Alternatives
Measurable

aesthetics
clarity
relationships
holistic
visualization
hierarchy
systems
communication
Denial
value systems
EMERGENT THEMES OF SUSTAINABILITY DESIGN & VISUALIZATION
efficiency vs. effectivenes
EDUCATION
TRANSFORMATIVE LEARNING / TRANSFORMING SOCIAL PRACTICES
COMMUNITIES CONNECTIONS
exhibition design
theatre
'Qualitative Growth'


Denial functions on a personal and a collective level to insulate individuals and cultures from the implications their actions


How do we deal with misrepresentation?





How does the (invisible) process which makes the final (visible) outcome inform it?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Visual models and new cosmology

A proposed approach via art–science collaboration

Abstract
This paper outlines the theoretical foundation of a proposed collaboration between Ole Hagen and colleague David Cheeseman and Dr Roberto Trotta and colleagues at the Astrophysics Group at Imperial College London. The 'research laboratory' for this project will take the form of a post-Newtonian orrery, or large kinetic sculpture. The premise is to make a physical structure where visual ideas can be tested and discussed, prior to it being completed as a work of art. Data visualisation is normally an issue of finding more effective modes of communication, in order to make information visible. In contrast, what this project seeks to make visible, using cosmology as an example, is the fundamental relationship between abstract thought and 'visual thinking' in science, and how this inform our views of reality. The paper asks how a fine art project can visualise such problems as whether visual ideas can give rise to new scientific theory or whether visual ideas are rooted in habitual human perception to such a degree that they cannot address phenomena beyond direct perception. Such problems might be invisible when we focus on communication alone. The problem of how visualisation influences thought further poses the question of the status of the model vis-à-vis reality. In this way it also highlights ongoing philosophical debates between versions of realism and idealism with regard to the role of consciousness in the cosmos.

Keywords
art, astrophysics, cosmology, interdisciplinary collaboration, physical installations, science

Models of reality and visual schemes
Cosmology is concerned with models in the broadest sense of the word, as coherent pictures of the deep structures of reality or a mapping of the unknown. Many magico-mythical explanations of the universe and its origin have been very durable and may have satisfied human desire for causal necessity in the face of chaos (Harrison, 2003). Contemporary cosmology is still concerned with issues of necessity and coherence, but theoretical physics provides speculative tools that are less limited by what is directly observable, or imaginable based on perception. There can even be theoretical grounds for proposing phenomena that are causally disconnected from the observable universe. In any case, relative phenomena, that are on the cusp of observation, by being the cause of measurable effects on the micro or macro level, still pose a challenge to visual representation. How, for example, can a visual language that is grounded in direct perception describe phenomena that are not, without misrepresenting them? The task of designers is often to use visualisation in a way that illustrates the invisible without laying claim to being a direct representation. Often communication is about presenting existing knowledge in a pragmatic way that makes knowledge more accessible.
A model is by definition a representation of 'something else' by virtue of which it makes sense (Chadarevian and Hopwood, 2004). The status of this 'something else' has long been a matter for debate in the crossover between science and humanities. In a debated recent work, Quentin Meillassoux (2008) has argued that the humanities have been guilty of a type of idealism, where the 'great outdoors' has been subjected

to 'correlationism', the idea that we can only say something about the way the world appears *to us*. For Meillassoux the preoccupation with discourse that has been established by Foucault (1972) and others has reduced science to an idea of historical consensus that doesn't properly acknowledge the mathematical possibility of thinking a world without humans. In the light of this debate, using cosmology as an example, examining the status of the visual model is about more than the pragmatic problem of how to communicate the invisible. It can be about the more fundamental relationship between visual thinking and abstract theory. In this respect, making the invisible visible is more about examining the 'hidden' ideas embedded in this relationship. A correlationist position would be to claim that all our ideas about the world can be understood to be models of the unknown. Hence, looking at the way visual models have influenced the bigger models or ideas about the cosmos would be best studied as a history of how visual languages are rooted in cultural paradigms.
If, from this point of view, visual models where described as rooted in perception, then it would be in a 'deceptive' perception, in the sense that what validates subjective perception are consensus schemata, not objective reality. In contrast a realist position could claim that there is a direct correspondence between mathematical truth and visual perception. If our brains are structured to think in patterns that correspond to a 'great outdoors' independent of us, in the sense that thought is a product of nature, visual models, such as that of the DNA helix for example, could be seen as emerging in ways that can genuinely get closer and closer to the deep structures of reality. Moving beyond the problem of visualisation as the problem of how to communicate an accepted idea, to the problem of how visualisation influences thought, is to look at the visual model from a meta-perspective. In collaboration with scientists at the Astrophysics Department at Imperial College London, I'm planning a fine art project that will look at the visual model as a kind of 'site' where these different ideas of representation and reality can become visible. For its speculative, grand narrative impact, cosmology is chosen as the scientific context for this project, while fine art is the applied strategy for how to experiment with visual thinking. The 'research laboratory' for this project will take the form of a post-Newtonian orrery, or large kinetic sculpture. Fine art practice has so many examples of strategies that are less about communicating a given content and more about creating a gap between form and content, where the process of thought is what becomes visible, both in terms of maker and viewer. As an artist I will draw on this tradition.

The post-Newtonian orrery as research laboratory

On the one hand then, there has long been a post-positivist climate in the humanities, where the assumption that science represents a type of knowledge that is factual and value-free, as opposed to knowledge of a purely aesthetic or subjective kind, such as art, (Tauber, 2009) has been contested. On the other hand, Quentin Meillassoux and others (Mackay, 2007) have recently argued that this stand is in itself incompatible with contemporary science, for example with regard to the measuring of cosmic background radiation that allows us to think, on mathematical grounds, a past prior to any human presence. How can a fine art project show how our ideas about visual perception and the human place within the cosmos are embedded in our relationship to visual models? And what type of 'new knowledge' would a collaborative project of this type be likely to produce?

The philosophers Deleuze and Guattari (1994) famously proposed that the task for art is to produce 'affects' and 'percepts' while philosophy produces concepts. Just as a 3D science model only makes sense through its use, one aspect of this project is its kinesthetic elements, producing movement and affect. The basic structure of this sculptural orrery will be a rollercoaster type track (Figure 1) that circulates around a series of platforms, that are themselves rotating, clockwise as well as anti-clockwise. The platforms will serve as the base, not for the known planets of the solar system, but for sculptural tableaux representing post-Newtonian features of the universe, such as black holes, wormholes, multidimensional configurations and dark matter. Encircling the platforms on the tracks will be mobile vehicles. Each of these little carts will be fitted with a rotating mirror.

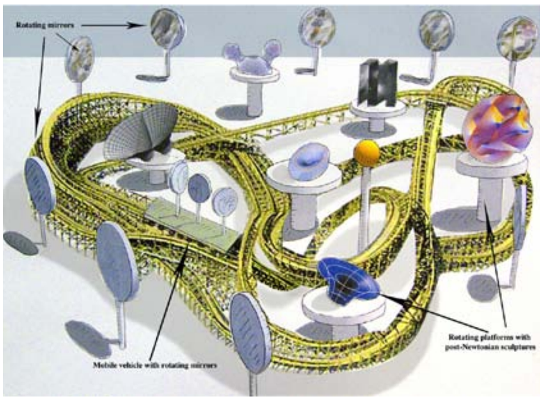

Figure 1 Ole Hagen, *Sketch for a Post-Newtonian Orrery*, 2011, collage on paper

Tall, rotating mirrors will surround the whole installation as well. There are two aspects to this basic structure, one aesthetic and one experiential.

Contemporary art cannot escape aesthetic references, so instead it borrows and imitates aesthetic languages. In one attached visual example (Figure 2), the artist Mhari Vari's planetary installation, the sun is a Sun newspaper, Mars a Mars-bar football and so forth, showing the absorption of cosmological terminology into popular culture. Then in a contrary example, by the artist Brian Haddock (Figure 3), art is mimicking the research-laboratory aesthetics of science. Both are examples of how fluently art breaches different aesthetics.

In the case of my kinetic orrery, its history and aesthetics is the public spectacle and its relation to cinema. The mechanical orrery, a simple device to illustrate Copernican principles, showing the planets rotating around the sun, arose from an interest in Newtonian natural history in the eighteenth century. But there is also a history that links the orrery to adult science education as spectacle in a way that functions as a forerunner to cinema (King, 1978). Theatrical orreries like R.E. Lloyd's Dioatrodoxon and Adam Walker's Eidouranion, were like 'gesamtkunstwerk' in their inclusion of lights, music, mirrors and so forth. Later versions of this type of installation included rear screen projections that can be seen as forerunners of magical lanterns and eventually cinema. Sergei Eisenstein thought of cinema as a 'fourth dimension', in terms of art, because of its temporality (Gammel, 2002). These days virtual modelling might in many ways have replaced 3D modelling in science. But screen-based representations are very much embedded in cinematic language. The movement of the camera in cinema determines a point of view,

Figure 2 Mhari Vari, *Haste ye back*, 2010, 8 x 7.5 m, mixed media installation

Figure 3
Brian Haddock, *The Wonderful Prokaryotes*, 2010, mixed media installation

and the illusion of time is essentially one based on movement. In this installation we have several 'points of view' in the form of mobile vehicles. A film or a video game is dependent on editing and cross cutting to shift between different points of view. This proposed installation references the basic scheme of a cinematic language, but can incorporate several points of view. The viewer is aware of the different points of view of each mobile vehicle that in a sense is a 'camera' to the degree that it reflects its surroundings through its rotating mirror. But just as the viewer can take in more than one point of view, and move between them, thus asserting some participatory control, the speed of the different platforms of tableaux, and the mirrors surrounding the installation, will retain some autonomy and randomness to the installation that is not simply dependent on the viewer's position. The idea here being that the Newtonian notion of a clockwork mechanism is still present in this structure, but the whole is never repeated in exactly the same way, introducing an aspect of relativity based on movement. That way the sculptural elements we introduce into the installation will be reconfigured according to the autonomy of the whole, and the whole will be constantly reconfigured through the movement of its parts.

There is therefore the premise here that there are visual schemes present based on recognisable aesthetics, such as the orrery and the cinematic. But these schemes should not determine the reading of the work as a set of signifiers. The fragmentation created by the mirrors, and the changing configuration, will ensure that both the scientific and the artistic aesthetic references are relative to the experience of the moment. So the structure represents some principle or idea of what a post-Newtonian model could be, in a poetic sense. This structure is obviously not scientific in a way that corresponds to real solar system distances or measurements. I see it as an open ended laboratory, in that it just gives some variables within which we can introduce and experiment with the main elements, which are the sculptural tableaux that will sit on these rotating platforms. So it is a structure for collaborative experimentation where the artists (we will be two artists working on this project) and scientists (there could be three scientists involved) will have a chance to physically test out different sculptural features to see how the appearance of the whole installation is affected.

At the outset, I said that I was interested in a type of meta-model that could highlight the relationship between visual thinking and theory. The structure I have provided does not in itself settle the score as to whether some visual models are 'closer to reality' or whether all models are just cultural products that illustrate further models ad infinitum. But in conversation with the scientists I have arrived at a series of sub-questions that lend themselves to visual experimentation.

A physical, figurative model is necessarily tied up with everyday perception. While a Feynman diagram of the motion of elementary particles is a workable abstract representation (Miller, 2000), it doesn't convey a sensory understanding very well. So when it comes to figurative models, the first thing we can test is whether there are examples where a visual idea obscures or hinders new theory, by being too grounded in common-sense perception. The transition from classical to non-classical concepts has, for example, rendered the solar-system model of the atom obsolete. When still being sustained in the public imagination, the globular atom could be a case where visual thinking restricts non-specialist understanding of potentially paradigm-shifting ideas (in quantum physics). If we can think of further examples, we might be able to see how the habits of our biologically determined perception limits or hinders our understanding of new ideas or a more accurate perception of reality (depending on our position). On the other hand, can we think of examples where simple visual ideas from everyday perception have aided speculative or counter-intuitive insights? Given our 3D bodies, multidimensionality is not something we can picture very easily. Yet, it is not impossible that the image of the string or the membrane have served to assist the ideas of string theory and m-theory in a way that could be supported by mathematics. I'm not expecting that this 'laboratory' will give rise to new scientific theories of this kind. But what we can find out, given the above examples, is exactly where the clashes occur between habitual thinking and visual ideas that stimulate new thinking, and what makes one visual idea better than another in this respect.

The type of 'knowledge' that is likely to be produced then, has to do with finding commonality between art and science. For example, we might observe how art and science are subsumed by the same habitual visual schemes as well as how a creative invention or process can occur through creative processes with interdisciplinary parallels. We are not searching for practical science models, but for models that encompass visual, kinesthetic and tactile perception to bring an idea to the public imagination. Such an idea could very well be a 'true' principle of some kind. One of the visual inventions we have come up with thus far, in preliminary discussions, is an idea for how to produce a simple hologram through the use of concave mirrors. A sculptural tableaux at the bottom of such a mirror could in principle produce a hologram, which would be an effective way of showing that a seemingly physical object that we perceive can be the illusion of a curvature in space.

Conclusion

Data visualisation is still an issue of more effective modes of communication, like those emerging from new technologies. Scientists and designers may be able to find new visual models that have practical applications in this sense. In contrast, this proposed art and science collaboration focuses less on communication of existing knowledge and more on invisible aspects of the relationship between theorising and visual thinking. It could be a mapping of where art and science share the same habitual modes of visual thinking or how creative ideas help to 'unlearn' old knowledge. We're setting up a sculptural situation where we can test out visual ideas on a human scale that lead to artistic results, where the outcome is some form of exhibition. The sculptural ideas discovered will be subject to the movement and affect of the orrery. Affect is a form of physical reaction that can be as much of an interruption to thought as a stimulation. In this way our artist's type of 'laboratory' is about creating clashes between different languages and ideas, from the poetic to the scientific, while all along subjecting these ideas to the changing constellation of an actual encounter with a spatio-temporal installation. This is not just about revealing post-Newtonian features of the universe in an artistic language, but also about revealing 'cosmology' in the sense of fundamental ideas that perhaps direct our attitude towards visual models and thought.

References

Chadarevian S de and Hopwood N (eds) (2004) *Models: The Third Dimension of Knowledge*. Stanford: Stanford University Press.

Deleuze G and Guattari F (1994) *What is Philosophy?* Trans. H Tomlinson and G Burchill. London: Verso.

Foucault M (1972) *The Archaeology of Knowledge and The Discourse of Language*. New York: Pantheon Books.

Gammel L (2002) *Exploring the Invisible, Art, Science and the Spiritual*, Princeton: Princeton University Press.

Harrison, E. (2003) *Masks of the Universe, Changing Ideas on the Nature of the Cosmos*, Cambridge: Cambridge University Press.

King HC (1978) *Geared to the Stars, The Evolution of Planetariums, Orreries and Astronomical Clocks*. Toronto: Toronto University Press.

Mackay R (ed.) (2007) *Collapse, Philosophical Research and Development vol. 1 and 2*. Oxford: Urbanomic.

Meillassoux Q (2008) *After Finitude, An Essay on the Necessity of Contingency*. London: Continuum.

Miller AI (2000) *Insights of Genius: Imagery and Creativity in Science and Art*, Cambridge, MA: The MIT Press.

Tauber AI (2009) *Science and the Quest for Meaning*, Waco: Baylor University Press.

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Concrete vs abstract visualisation

The real world as a canvas for data visualisation

Abstract

The world itself and our embodied experience of it are underused in data visualisation. This paper addresses what happens when data are represented iconically rather than indexically and outlines a form of data visualisation that can be considered the inverse of 'augmented reality'. Whilst traditional charts are generally more direct and efficient when viewers bring their own questions to the data, a more concrete approach is shown to be valuable in presenting data to 'unengaged' audiences. It is also valuable as a reality check by giving viewers a 'feel' for the quantities involved.

Data visualisation is usually abstract. Whilst sensual – drawing on available visual culture and viewers' familiarity with 'natural scenes' – visualisations tend to represent *relationships* between real entities and not the entities themselves. 'Concrete visualisation' is the process of transforming entities that are usually represented abstractly as numbers in a table or lines on a chart into objects in space (or a representation of real 3D space) available to our senses. For instance, representing a quantity of water as a volume of water in relation to familiar objects is an example of concrete visualisation. It is distinct from 'imaging' because it is idealised objects that are represented, not specific objects (as in, for example, medical MRI imaging). Developments in media including 3D mapping and augmented reality increase the scope for co-opting reality to play a role in its own representation.

This paper looks at a range of concrete visualisations to better understand the strengths and weaknesses of both concrete and abstract visualisation.

Keywords

concrete visualisation, data visualisation, info-graphics, scientific visualisation

Introduction

We don't understand invisible objects on their own terms. We don't even meet them half way. Instead image-makers transform invisible objects into things we *can* see, and they acquire rich and multi-sensory associations in the process. Over-emphasis on the *visual* aspects of visualisations has two negative consequences in particular: it means image-makers have less control over how viewers 'make sense' of data and it means many visualisation opportunities are missed. As sophisticated consumers of visual media, we have a ready-made toolkit available for making sense of data representations,[1] but we also have other tools at our disposal. For instance we know what it's like to walk across a park or climb a flight of stairs. Basic, embodied experiences like that can also be co-opted to make sense of data. Although vision is the primary sense through which other sensory experiences are communicated, imaging and visualisation are not merely visual. We experience the invisible with our whole being.

The world itself, and our experience of it are very much underused in data visualisation, which tends (with good reason) to remain abstract and numerical. When making sense of a time-series on a graph, say, it makes no difference what quantity is varying or the scale of either axis – the same visual techniques can be applied to

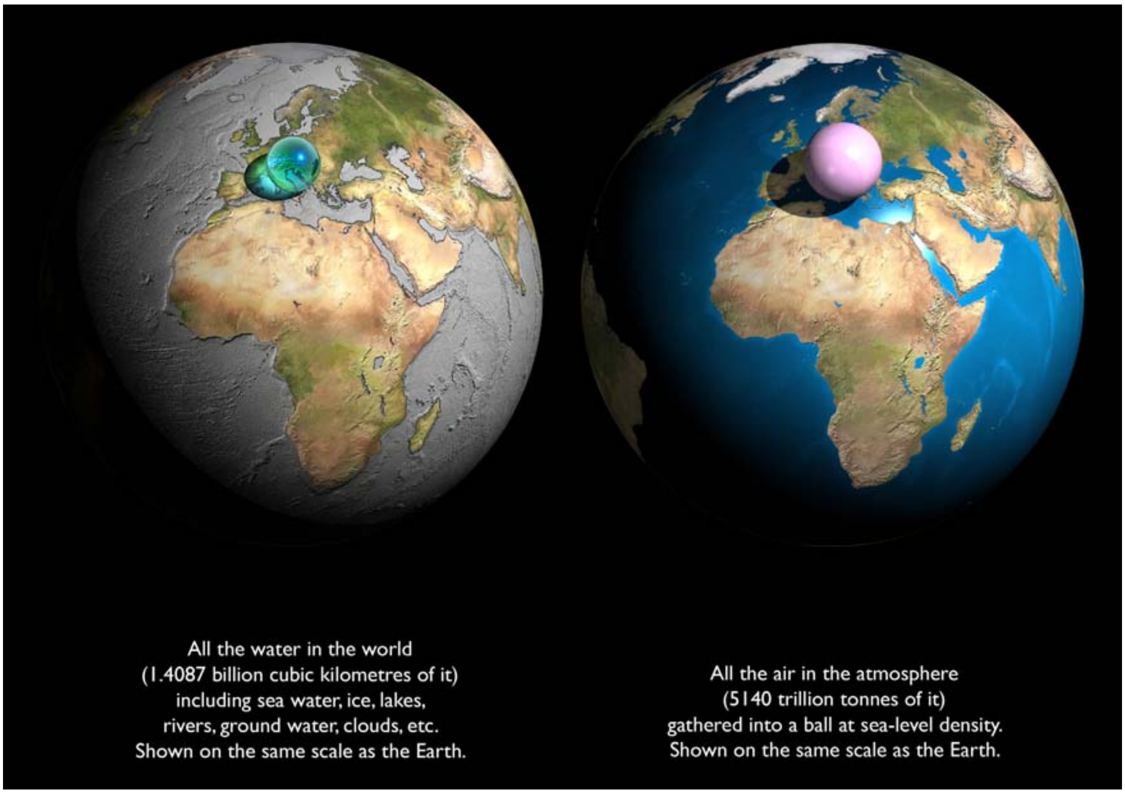

Figure 1 *All the water* and *All the air*

any data once it has been abstracted. But there is a cost to abstraction because, for instance, a time-series that operates over millennia is not the same as one that operates over decades, although they may look superficially similar. Abstraction can alienate viewers from the physical reality the graph points to, effectively disarming a range of other critical skills that could be applied to 'make sense' of the data.

This paper looks at approaches to data visualisation that provide quantitative insight physically rather than purely numerically or geometrically; approaches that draw on more than just our visual experience to make sense of data visually. The focus is on carbon emissions data, and on the graphical techniques I have developed myself (in collaboration with colleagues) but there are many other applications and techniques, some of which are discussed less formally elsewhere.[2]

Visualisation that eschews abstraction and instead communicates a sense of physical scale I have taken to calling 'concrete visualisation'. Abstraction is a valuable tool and the range of quantities that lend themselves to concrete visualisation is limited. However, when it is appropriate it can open up data to a new kind of scrutiny, and with imagination even inherently abstract quantities such as energy can be re-cast in concrete terms.[3] With concrete visualisation, and especially with emerging technologies such as augmented reality, there is scope to make the world itself part of its own explanation.

Figure 1 is a simple example of concrete visualisation that exemplifies what 'using the world itself as its own explanation' can mean. Just two data points are visualised: 1.4087 billion cubic kilometres of water and 5140 trillion tonnes of air, which would not warrant graphical representation at all if we were visualising them abstractly. Nevertheless, although the image is impoverished from the point of view of 'data density', visualising these data concretely provides a new kind of quantitative insight into the world.

It is interesting to note how and why the image works. It is not just visual familiarity with the globe that provides a sense of scale; it is also viewers' experience of travel. Being able to relate the diameters of the spheres to journeys

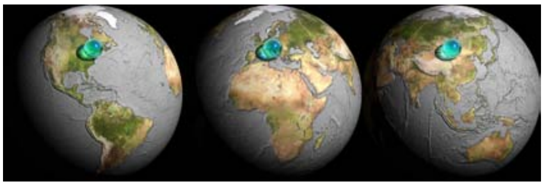

Figure 2 Three version of *All the water* for three different audiences

one has actually made gives another dimension to viewers' understanding of the quantities involved. For this reason, I made two additional versions – one centred on North America and one centred on Asia – to help non-Europeans/ Africans relate to the image directly (see Figure 2).

Since its early days, scientific visualisation has focused on large datasets. With the introduction of computing to science, visualisation pioneers hoped the nascent field would provide insight into the massive amounts of data that had started to be collected automatically and generated in simulations (see for instance, McCormick, et al.,1987: 4; see also Nieman, 2000: 99). 'Data-mining' was an early application of visualisation – the search for nuggets of meaning in mountains of data. Similarly, and with good reason, the infographics community celebrates graphics that convey complex ideas and multi-dimensional data (see for instance the examples discussed in what many consider the 'manifesto' of infographics: Tufte, 1983).

However, there are occasions when it is valuable to visualise 'simple' ideas and small datasets. Sometimes ideas that are simple numerically are nevertheless difficult to grasp in other ways, or they get lost in the process of abstraction. Concrete visualisation is by no means limited to small datasets and simple ideas, but this is the realm in which concrete visualisation has had the most impact to date.

This idea of borrowing aspects of the world itself to visualise abstract data is not new in scientific visualisation. Philip Robertson mapped it out explicitly in an account of what he called the 'natural scene paradigm' (Robertson, 1991). But up to now, scientific visualisation has aimed only to make data look like the world (e.g. make an undulating iso-surface look like a mountain, because we are good at looking at mountains and working out what we are looking at with a single glance). Concrete visualisation works differently by representing data as actual physical objects in the world rather than merely borrowing some of the qualities of physical objects and so encouraging engagement on a kinaesthetic level as well as a visual level.

My own interest in the concrete visualisation comes from my academic work on the visual culture of science (see Nieman, 2000); from my work as an artist who makes mostly numerical art (see Nieman, 2010h, 2010i); and from my work with Carbon Visuals (www.carbonvisuals.com) a company that visualises carbon dioxide emissions (I'm the Creative Director and one of the founders of the company).

Making invisible gas visible

One of the problems with making sense of climate change is that its cause is invisible. Although human activity adds 957 tonnes of carbon dioxide to the atmosphere every second (Boden et al., 2010) and we have increased the concentration of carbon dioxide in the atmosphere by 40 per cent we cannot see anthropogenic greenhouse gases. The problem is compounded by the way we measure carbon dioxide in units of mass, which makes sense from an accountancy point of view but does not provide a feel for the scale of the problem. People understand mass predominantly through weight – the force of gravity on objects. The buoyancy of gases means we have literally no 'sense' of their mass; the only handle we have on carbon dioxide is numerical. Few people have a sense of 'how much' a kg or a tonne of carbon dioxide is.

Because the units are not intuitive, only those who are already numerically engaged with climate change can have any sense of scale for carbon statistics, which has a serious impact on the kinds of action that are available. Most people have a very sketchy understanding of the carbon emissions for different activities. One form of action that has been encouraged by the BBC amongst others is to unplug mobile phone chargers when they are not in use (MacKay, 2009: 81). This does indeed make a difference – about the same over a year of driving 3.7 km in a medium sized car, or in other words, the difference it makes each day is the same as one third of a second of driving.[4] So the difference it makes is trivial in comparison to actions that require much less effort. An intuitive sense of scale for carbon emissions could support behaviour change, as well as climate negotiations.

Though volume is more intuitive than mass when thinking about gases, people do not have an intuitive feel for a volume expressed numerically (e.g. 535 m^3) the way they might for a distance (e.g. 535 metres). This is where our embodied experience can help because people have a sense of what it *feels* like to occupy volumes and areas even if this sense is understood numerically only occasionally. Farmers may have a feeling for a scale of 10 hectares and boilermakers may have a feeling for quantity like 10 m^3, but for most of us, the sense of scale is understood well, but not understood numerically.

The task then is to visualise quantities in such a way that people can draw on their rich experience of the world whilst avoiding numbers that cannot be understood intuitively. Often the best unit of volume to use is the volume of the room one is inhabiting at the time. The goal is a quantitative understanding of whatever statistics are relevant, but one that also provides a *feel* for the quantities involved. An example is the rate mentioned above: the average rate of total carbon dioxide emission from burning fossil fuels was 957 tonnes per second in 2006. The number seems large but by itself doesn't provide a feel for the rate. Nine hundred and fifty-seven tonnes per second is undistinguished as number. A day after coming across it readers may find themselves wondering, 'was that 957 tonnes a second or a day?'

To give viewers a sense of scale we found a context that viewers could relate to both visually and kinaesthetically and then animated the emissions to provide a volumetric sense of the rate in real time (Figure 3).

The global emissions animation illustrates just a single number (a rate) but by providing a feel or sense of scale for the rate it helps put other emissions statistics into context. The concrete

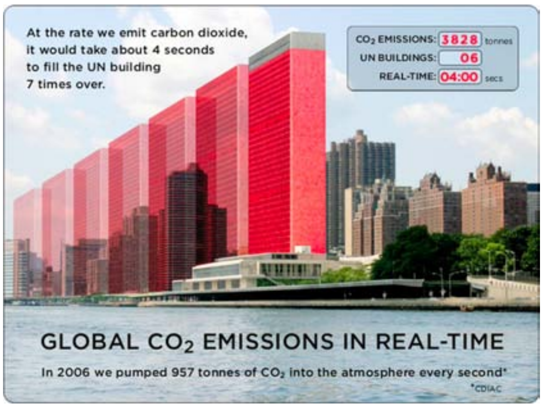

Figure 3 Still from animation showing the rate of global emissions of carbon dioxide (Lucy Blackwell and Adam Nieman). This and other concrete animations are available here: http://carbonquilt.org/gallery/videos

representation is more likely to 'stick' because it combines many different ways of judging quantity. Ideally it would also have a soundtrack that accurately recreated the sound of gas escaping into the air at that rate.

Figure 4 compares concrete and abstract representations of the same time series. For audiences already engaged with the numbers and who are coming to the data with specific questions, such as 'are we on target to reduce our emissions' the abstract bar-chart is probably more direct. However, the concrete bar-chart works on a physical level as well as a numerical and visual level. For audiences not already engaged with the data, the concrete bar-chart

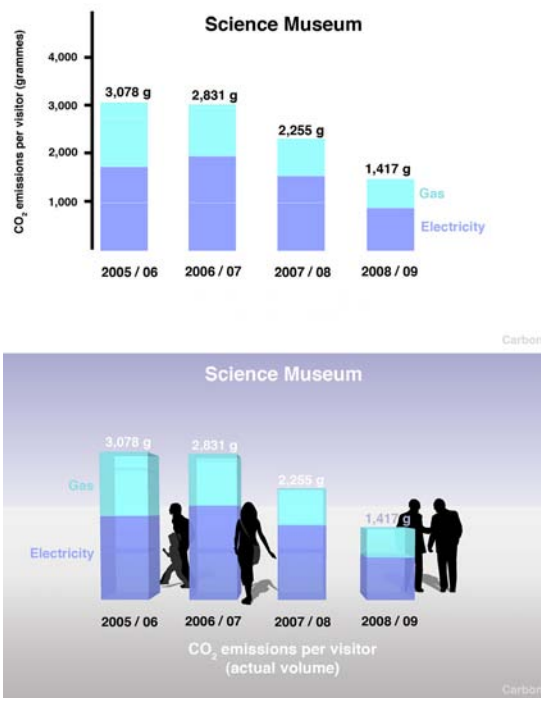

Figure 4 Emissions per visitor for the Science Museum, London (annual emissions divided by annual number of visitors. Top: abstract; bottom: concrete)

is both easier to read (because it does not require numerical engagement) and tells a more compelling story. In short, if the audience is bringing their own questions to the data then an abstract representation is usually appropriate; if instead you are trying to bring the data to the attention of an unengaged audience then a concrete representation is likely to be more appropriate.

One of the obvious differences between an abstract and a concrete bar-chart in Figure 4 is the additional detail that the image maker must provide to allow the data to be read as an actual physical representation. In general at Carbon Visuals we subscribe fully to Edward Tufte's approach to data visualisation with its emphasis on parsimony and data-density and its complete intolerance of 'chart junk', which is an extraneous decoration that does not assist in reading the data. From a first glance at the examples of concrete representations in this paper it would appear that we have broken every rule. If they were attempting to perform precisely the same role as abstract visualisations then it would be fair to categorise these images as 'truly horrible'. But judged by the different standards we must apply to concrete visualisations, they exhibit the same preoccupations – the same focus on data and a similarly parsimonious aesthetic.

For concrete visualisation to work to its full potential, it has to be understood to be 'just' visualisation. The same underlying principles of visualisation apply even if they manifest themselves differently. The Carbon Visuals aesthetic places the focus wholly on the data. The function of every element of the image is to provide a feel for and quantitative understanding of the data represented. It should not detract from the data nor anchor the image to particular value judgements. We could envisage, for instance, a concrete visualisation of emissions from Drax Power Station (the biggest coal-fired power station in the UK) being used both by protestors who want the power station closed (to show size of the impact the power station has) and by the company that operates the power station (to show how economies of scale make it more efficient than smaller power stations, for example).

In Figure 4 (bottom) all the 'decoration' is functional – aimed at allowing a viewer to relate to the quantities kinaesthetically and visually – and it is as simple as possible. Gradient in the sky and ground is read as atmospheric perspective that helps viewers to see the scene in three dimensions. The silhouettes are the only element of the image that provides a physical sense of scale. The virtual camera is placed at eye-level to help viewers place themselves in the image.

Carbon Quilt

The Carbon Quilt is a novel visualisation technique that co-opts the world both literally and metaphorically in making carbon emissions data comprehensible and gives a physical meaning to the idea of a 'carbon footprint'. Understanding the Carbon Quilt concept takes a few moments of concentration, but no more than other visualisation techniques. Even pie-charts, when we first come across them, require training.

Imagine the whole world's carbon dioxide emissions for a fixed period (for example a day or a year). Now imagine that the emissions are not evenly mixed in with rest of the air but instead form a layer of pure carbon dioxide gas near the surface of the Earth (see Figure 5). A year's emissions would form a layer about 4 centimetres thick; a layer formed from a day's emissions is about as thick as a piece of paper. We can think about this as the world's carbon footprint, and appropriately it covers the whole world. The world's footprint is made up of many individual emissions. These can be conceived as individual 'patches' that together make up the layer (like a patchwork quilt). Each patch is the

Figure 5 The Carbon Quilt conceives the carbon dioxide added to the atmosphere by human activity as a layer of pure carbon dioxide across the whole planet. Annual emissions would produce a layer about 4 cm thick (image: Lucy Blackwell)

same depth and because of this, its area tells us both the absolute size of the emissions and their relative contribution to the whole.

In 2006 total carbon dioxide emissions from fossil fuels and cement manufacture was over 30 billion tonnes (Boden et al., 2010) which corresponds to carbon dioxide gas that would fill a cube over 25 km high or form a layer around the whole world 3.16 cm thick. The total emissions from the UK were 569 million tonnes of carbon dioxide, or 1.88% of the whole (Figure 6). This can be conceived as a 'square' patch 3131 km wide (such a patch would cover 1.88 per cent of the surface of the planet). The United States' patch, by comparison is 10,824 km across and represents 19.06 per cent of the whole.

In addition to these huge carbon footprints, we can equally well visualise much smaller footprints. The UK per capita figure for emissions from fossil fuels and cement manufacture was just over 9 tonnes in 2006 (Boden et al., 2010) which corresponds to a square patch 398 metres across. In other words, an average UK citizen's carbon footprint is a patch about 400 metres across, with an area of about 16 hectares or 39 acres (see Figure 7). In contrast, an average American's footprint is a patch 567 metres across (32 hectares, 79 acres) and an average Somali's footprint is a patch 25 metres across (0.06 hectares, 0.15 acres). Any footprint can be expressed in these terms and understood in three ways simultaneously: as an absolute quantity; in relation to other footprints on a similar scale; and in relation to global emissions.

One of the main things that concrete visualisation adds in the case of the Carbon Quilt is an ability to compare quantities on a huge range of scales. Abstract visualisation is very limited in what it can do to extend the scale – we can employ logarithmic scales but these can prevent viewers developing a true sense of the range in the data. The power of concrete visualisation in this case can be explained with an extreme, example. We will compare two very different footprints: the normal operation of a large power station and a single use of a low-energy light bulb. The comparison itself is uninteresting and

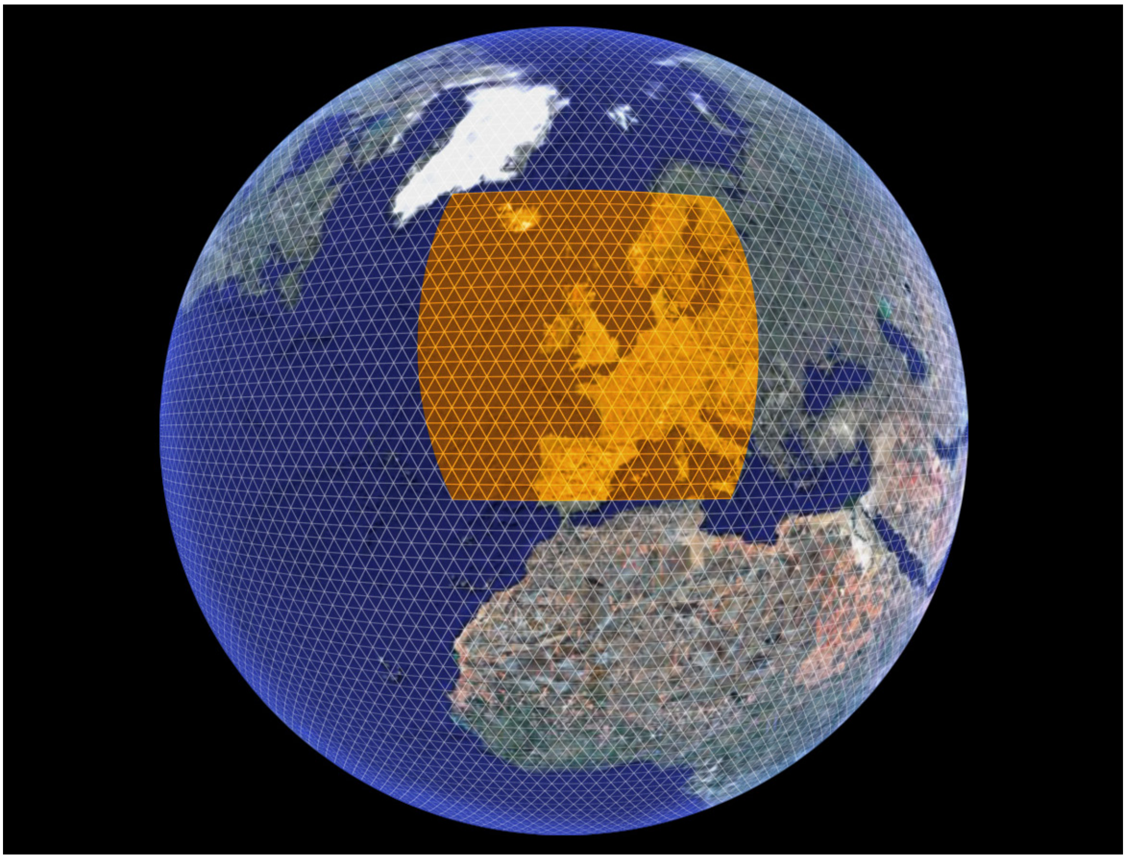

Figure 6. The UK's carbon footprint (569 million tonnes CO_2) as a 'patch' of the Carbon Quilt 3131 km across (image: Lucy Blackwell and Adam Nieman)

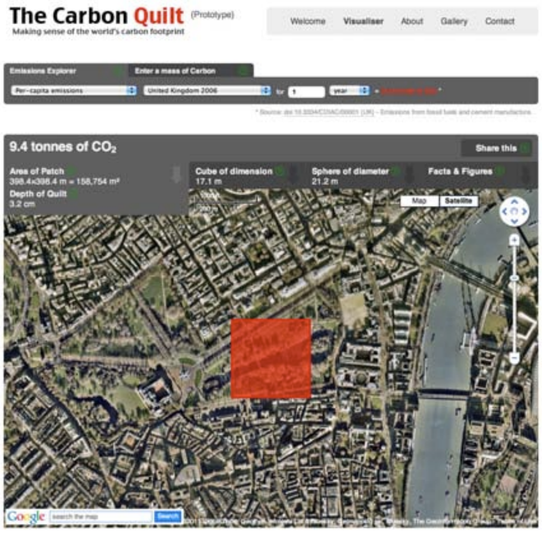

Figure 7 UK per capita carbon dioxide emissions as a patch of the Carbon Quilt, centred on St James's Park, London. The Carbon Quilt interactive tool (www.carbonquilt.org) allows users to view any quantity of carbon dioxide in relation to any location that helps them make sense of the scale and also offers other concrete visualisations of the same quantity.

forced; the point is to explore the extremes of comparison because there are many interesting comparisons in between that the Carbon Quilt does give us access to.

Drax Power Station's emissions in 2006 were 21,168 kilotonnes of carbon dioxide,[5] which corresponds to a patch 599 km across. The footprint of a low energy light bulb left on for an hour is 6.3 grammes CO_2 (e)[6] which corresponds to a patch 27 cm across. The annual carbon output of Drax is 3 trillion times greater than the hourly output of the light bulb. If we tried to plot these two data points on an abstract graph we would fail, but because we can relate physically to a huge range of areas on Earth, we can have a feel for a comparison even this extreme.

The Carbon Quilt is mainly a tool for exploration. In its interactive version (www.carbonquilt.org) it allows users to explore emissions statistics and build up a feel for them. It employs the Google Maps API to allow users to place patches anywhere on Earth and also offers a range of other concrete visualisations. It also allows users to embed visualisations in their own sites (http://embed.carbonquilt.org/) or to share links with specific data to say, for instance, 'look at my carbon footprint'.

The current aim is to improve the 'exploration' of the data – to make it easier for users to compare emissions data and to 'make sense' of the result and to provide access to a much larger range of emissions data.

Conclusion

There are good reasons for representing data abstractly but it would be a mistake to conclude that abstraction is always the best approach. Concrete visualisation gives the world itself a role in its own explanation. Developments in media including 3D mapping and augmented reality increase the scope for co-opting reality.[7] Billions of years of programming (i.e. evolution) have given us a remarkable interface with the real world, much more powerful than any data interface we've built. Concrete visualisation transforms our embodied experience of the world into a tool for analysis.

Notes

1. This toolkit emerged over centuries through 'dialogue' between scientific visual culture and wider visual culture, but that is another story, which is discussed in depth in Nieman (2000).
2. For a discussion of ways of visualising the Deepwater Horizon disaster, see: Nieman (2010e, 2010f, 2010g); for other examples see: Nieman (2010a, 2010b, 2010c, 2010d); see also The Carbon Quilt Gallery: http://carbonquilt.org/gallery/images and Carbon Visuals website http://www.carbonvisuals.com.
3. A good example is Buckminster Fuller's conception of 'energy slaves' – a unit of energy based on the average output of a hard-working man doing 150,000 foot-pounds of work per day and working 250 days per year.
4. Assumptions: charger power: 0.5 Watts; medium-sized car efficiency: 30.4 mpg; CO_2(e) per litre of petrol consumed: 2.7329 kg (DECC, 2010); Driving speed: 100 kmh^{-1}.
5. 25.2 TWh at 0.84 kg CO_2 per kWh (Drax Group, 2007)
6. Emissions (all scopes) from UK grid electricity in 2008: 0.57098 kg CO_2 (e) per kWh (DECC 2010: 12). Low energy light bulb (equivalent to a 60 W incandescent bulb): 11 W.
7. Elsewhere (Nieman, 2009b) I have discussed an alternative approach to augmented reality that places emphasis on how the technology can be used in reverse to co-opt the real world in making sense of data rather than merely adding a layer of data to help make sense of the world. For more general points about augmented reality see Nieman (2009a).

References

Boden TA, Marland G and Andres RJ (2010) Global, regional, and national fossil-fuel CO2 emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, TN, U.S.A. doi 10.3334/CDIAC/00001_V2010.

DECC (2010) *2010 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting*. Available at: http://archive.defra.gov.uk/environment/business/reporting/pdf/101006-guidelines-ghg-conversion-factors.pdf

Drax Group plc (2007) Annual Report and Accounts 2007. Available at: http://www.draxgroup.plc.uk/files/financialreport/44948/Drax_Group_plc_Annual_Report_2007.pdf

MacKay DJC (2009) *Sustainable Energy – Without the Hot Air*. Cambridge: UIT. Also available for download as PDF at: http://www.withouthotair.com/download.html

McCormick BH, DeFanti TA and Brown MD (1987) Visualization environments: short-term potential. *ACM SIGGRAPH Computer Graphics* 21(6): 1–16. Doi: 10.1145/41997.42002.

Nieman A (2000) The popularisation of physics: Boundaries of authority and the visual culture of science. Unpublished PhD thesis, University of the West of England. Available at: http://www.sci-five.com/writing/wholethesis.pdf

Nieman A (2009a) A history of the future of computing: Why AR is where it's at (blog post, 25 October). Available at: http://adamnieman.posterous.com/a-history-of-the-future-of-computing-why-ar-i

Nieman A (2009b) RAD: Augmented reality turned on its head (blog post on the Carbon Quilt blog, 25 October). Available at: http://carbonquilt.posterous.com/rad-augmented-reality-turned-on-its-head

Nieman A (2010a) If carbon dioxide is a 'trace gas' why is it a problem? (blog post, 31 January). Available at: http://carbonquilt.posterous.com/is-carbon-dioxide-good-or-bad-and-if-theres-n

Nieman A (2010b) Allotment: what would we each get if we shared the world out fairly? (blog post, 25 March). Available at: http://adamnieman.posterous.com/allotment-what-would-we-each-get-if-we-shared

Nieman A (2010c) Landcover islands: a vision of a tidier world (blog post, 25 March). Available at: http://adamnieman.posterous.com/land-cover-islands-a-vision-of-a-tidier-world

Nieman A (2010d) BBC One Planet's carbon footprint (blog post, 7 April). Available at: http://carbonquilt.posterous.com/bbc-one-planets-carbon-footprint

Nieman A (2010e) How much oil is gushing from BP's Deepwater Horizon rig? And what does that mean? (blog post, 21 May). Available at: http://adamnieman.posterous.com/how-much-oil-is-gushing-from-bps-deepwater-ho

Nieman A (2010f) BP's Deepwater Horizon oil animation (blog post, 27 May). Available at: http://adamnieman.posterous.com/bps-deepwater-horizon-oil-animation

Nieman A (2010g) How much oil is 4.9 million barrels of oil? Getting a feel for the Deepwater Horizon spill (blog post, 9 September). Available at: http://carbonquilt.posterous.com/how-much-oil-is-49-million-barrels-of-oil-get

Nieman A (2010h) Here we are (blog post, 8 November). Available at: http://adamnieman.posterous.com/here-we-are

Nieman A (2010i) Artists' statement and selected work. Available at: http://www.zangtumbtumb.com/adam

Robertson PK (1991) A methodology for choosing data representations. *IEEE Computer Graphics and Applications* 11(3): 56–67. Available at: http://doi.ieeecomputersociety.org/10.1109/38.79454

Tufte ER (1983) *The Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press.

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MAPSustain
Visualising biomass and biofuel research

Abstract
This paper discusses the visual and interaction design of an online website that supports the interactive exploration of research on biomass and biofuel research. The dataset used covers 13,506 publication records from MEDLINE, the Department of Energy (DOE) and Thomson Reuter's Web of Science (ISI), as well as the United States Patent and Trademark Office (USPTO) patents, and funding by the National Science Foundation (NSF), the National Institutes of Health (NIH), and the US Department of Agriculture (USDA) for the years 1965 to 2010 (see details in Kong et al., forthcoming). The analyses and visualisations reveal where research and development (R&D) takes place in the United States and also in topic space. Results aim to guide researchers gaining an overview of relevant expertise and research, industry representatives interested in identifying potential collaborators and competitors, or agencies interested in supporting or promoting a specific area of sustainability research.

Keywords
geospatial, Google Maps, knowledge mapping, network analysis, sustainability, visualisation

Introduction
The number of scientific publications and patents is increasing continuously; the expertise profiles of researchers are changing over time, making it difficult to identify potential collaborators and synergies. Highly interdisciplinary research areas such as sustainability research might draw and combine approaches and technologies from many different domains making it even harder to keep track, manage, understand and build on existing works and efforts. Financial support might come from different funding institutions, for example the DOE and USDA funded the development of technologies and efficient processes to produce biofuels, bioenergy, and other bio-based products with more than $33 million dollars in 2010 (US Department of Energy, 2010), yet it is desirable to coordinate efforts.

The MAPSustain project presented here extends prior work by Zoss et al. (2010) and aims to help researchers, industry, funders and the general public to navigate information in an easy-to-use online interactive map outlining funding awards, publications produced and patents granted in the fields of biomass and biofuel research. It is also the goal of MAPSustain to foster collaborations and increase the sharing of knowledge on similar research projects. The remainder of the paper is organised as follows. The next section explains the inner workings of MAPSustain, including data preparation and system architecture; subsequently, the MAPSustain interface design and interactivity are presented; finally, the paper concludes with a discussion of related work and an outlook.

MAPSustain data
MAPSustain is drawing upon a dataset that covers 13,506 records on 'biomass' and 'biofuel' research and technology (R&T) retrieved from different publication, patent and funding datasets spanning the years from 1965 to 2010. The three categories come from seven sources:

1 Funding category, consists of NIH, NSF and USDA sources;

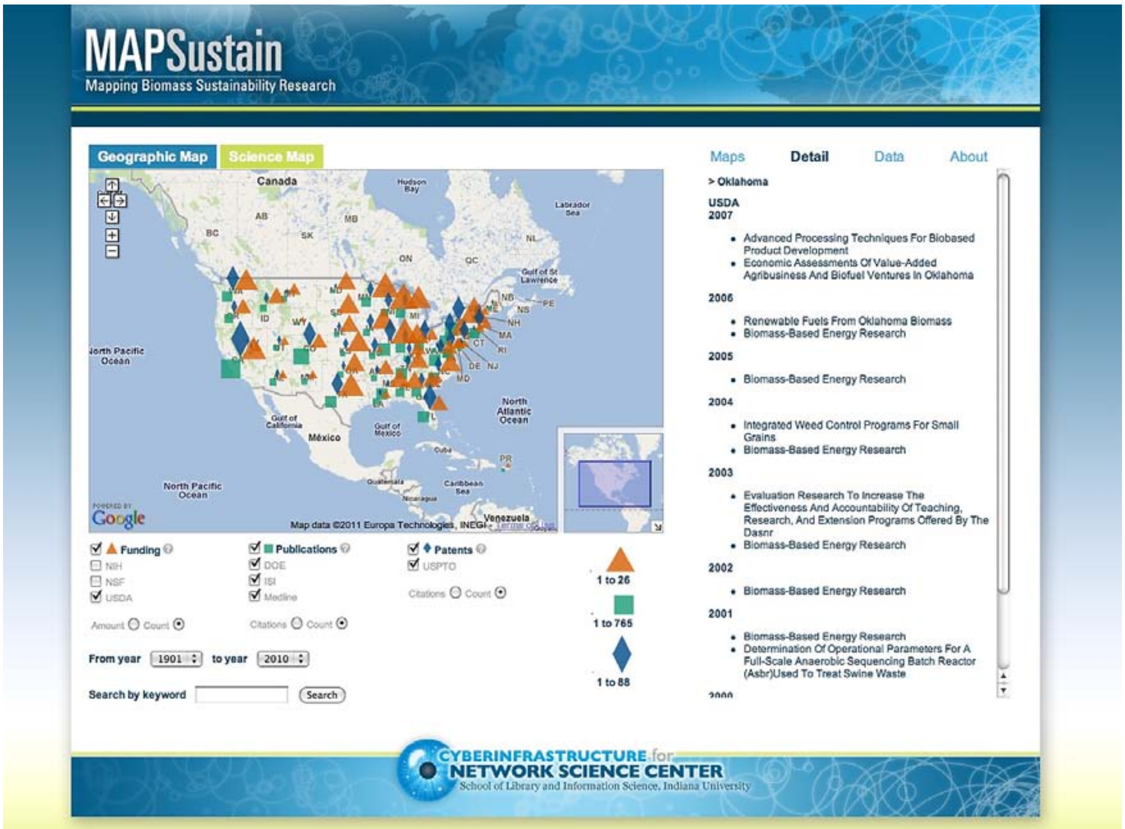

Figure 1
MAPSustain geomap interface at http://mapsustain.cns.iu.edu

2 Publications category, consists of DOE, MEDLINE and ISI sources; and

3 Patents, consists of USPTO data.

The different data categories were geocoded and science coded (see details in Kong et al., forthcoming), and overlaid on a geospatial map and a map of science. Figure 1 shows a snapshot of the interface with the map on the top left, a search and filter panel below, and a text panel on the right. The latter has four different tabs that provide more information on the maps and geo/science location used, details on search results, information on the data used, and background information on the project itself.

A user of the site has the choice of using either a geospatial map of the US or the UCSD Map of Science (University of California San Diego). The UCSD map is the product of a large study by researchers at the University of California San Diego using 7.2 million papers and over 16,000 separate journals, proceedings and series from Thomson Scientific and Scopus over the five-year period from 2001 to 2005 (SciTech Strategies Inc., 2010). The researchers used citations between the papers and journals to cluster journals into small groups of highly related journals. The map of science is composed of 554 individual nodes that are connected by links if their respective journal sets are related. Each cluster node is labelled by the content area, shared by the journals in the cluster and colour-coded by its overarching scientific domain. Both maps use Google's map API technology.

The geospatial map shows where research and development (R&D) efforts are conducted. The UCSD Map of Science topic map is used to communicate what topics are covered, for example how interdisciplinary R&D efforts are on a certain topic.

The MAPSustain icons

MAPSustain uses three basic geometric shapes to represent the three categories of information overlaid on both the map of science and the geospatial map. Funding is represented by orange triangles, publications are represented by green squares, and patent information is represented by blue diamonds.

The shapes of the icons were influenced by the principles of Gestalt (Koffka, 1935). Five visual perception concepts seem to be particularly relevant: *similarity*, *continuation*, *proximity* and *figure/ground* and are frequently used in the practice of graphic design (Behrens, 1998). When developing the interface and running through how both the geographic and map of science would be seen and used for MAPSustain, it became apparent that the icons needed to be some of the most basic and non-complex of shapes due to the way that the information on the maps would be rendered and displayed at both the zoomed in and zoomed out states. Specifically, the concepts of *similarity*, *proximity* and *figure/ground* were used in the icon design.

Since the map of science already has circles on it in the form of nodes, circles to represent a category were ruled out in favour of other shapes that would stand out from the maps when they are over-laid on either the geomap or the map of science. The shapes chosen: triangles, squares and diamonds, are at once recognisable as markers for information over both maps.

These shapes allow the user to access and see ‘easily and comprehensively’ (Keller and Tergan, 2005: 12) the areas of science that have generated more or less funding, publications produced, or patents granted on the map of science, or using the geographic map, the regions of the United States where funding is going or where it has gone, publications produced by researchers, and who has been granted patents for their research.

How the icons function

When the MAPSustain web page is loaded, the geographic Google map is automatically loaded with the most general zoom level and all check boxes in the user control panel selected. Placing the cursor over one of the icons located within a state, a tool-tip window will appear and display either the publications, patents or funding records for that state, depending on which icon the cursor is over. The icons are size-coded, so when they are displayed on a map that is zoomed out, a user can see areas that either have more or less activity and can compare areas of more or less research. This is helpful for someone doing research and is interested to see who is studying and publishing, or how many records of funding are being granted for research and who is receiving the funding in particular geographical areas.

The map of science panel is similar to the geographic map panel, except that users are able to visually distinguish the areas of science where most research is being performed. As on the geomap, when the page is first loaded, the map is presented at the most general zoom level and all boxes in the user control area are checked, giving the user an instant rendering of what research is being performed in what major areas of science. The icons are size-coded on this map like on the geomap, to give the user a visual idea of where and what amount of research is being performed.

An option that the map of science has that the geographic maps does not, is that users have the choice of either seeing the nodes in colour, or in grayscale. At the macro-level, having this option does not make a lot of difference in term of legibility. But, when a user zooms into the map, the 13 disciplinary research areas on the UCSD map of science split into 554 sub-disciplines and the option to view the map in plain black and white helps users more easily distinguish the icons from the nodes when they are layered on top of one another. For example, when a user zooms into the *Medical Specialties*, *Chemistry* or *Biotechnology* sections of the map in the colour-mode, the icons become less apparent. There are two main factors that make this effect happen. The first one is the use of size coding for breaking apart the main groupings of information when the map is viewed from a zoomed out stage, which causes the icons to decrease in size and get ‘lost’ when they are positioned over a node of the same or similar colour. The second is due to the particular colours chosen for the icons, since because the map uses 13 different colours to distinguish the disciplines of the nodes, it was impossible to select icon colours that were completely dissimilar to the colours already present in the map.

How the MAPSustain interface works

The MAPSustain interface is laid out in two columns for both the geomap and map of science. The first column on the left is the main area that a user interacts with. This column is made up of the Google map API on the top, and right below it are the main categories (Funding, Publications and Patents) of the datasets that a user can use to display desired information in the map area. Below those main choices a user can break down what they'd like to see further in order to get a more detailed view of desired information, having the ability to display amounts, citations, counts and the option to search between a set range of years, and the option to search for keywords.

The column on the right is reserved for displaying textual information, either about MAPSustain itself under the 'maps', 'data', or 'about' tabs, or hyperlinks that correspond to an icon that is clicked on in either the geographic or science map.

Related work

Many examples exist of online maps that support the interactive exploration of complex datasets. Among them are:

- USAID's HealthMap, an interactive map that uses Google Map Javascript API code (HealthMap, 2011). HealthMap is a non-profit project that gathers reports and data from multiple sources to provide a comprehensive, geographically organised picture of what is happening in health and development worldwide, see Figure 2.

Figure 2 HealthMap interface

- Mapping the Measure of America, developed by the American Human Development Project, explores and displays data to indicate populations' overall health, education, and standards of living by measuring the average income for each state, see Figure 3. These numbers are combined, resulting in an overall score on a scale of 1 to 10. Both the maps and interface use a Flash-based design (American Human Development Project of the Social Science Research Council, 2010).

Most of these existing maps use the Google Maps Javascript API or Adobe® Flash as the main development software for the interface and

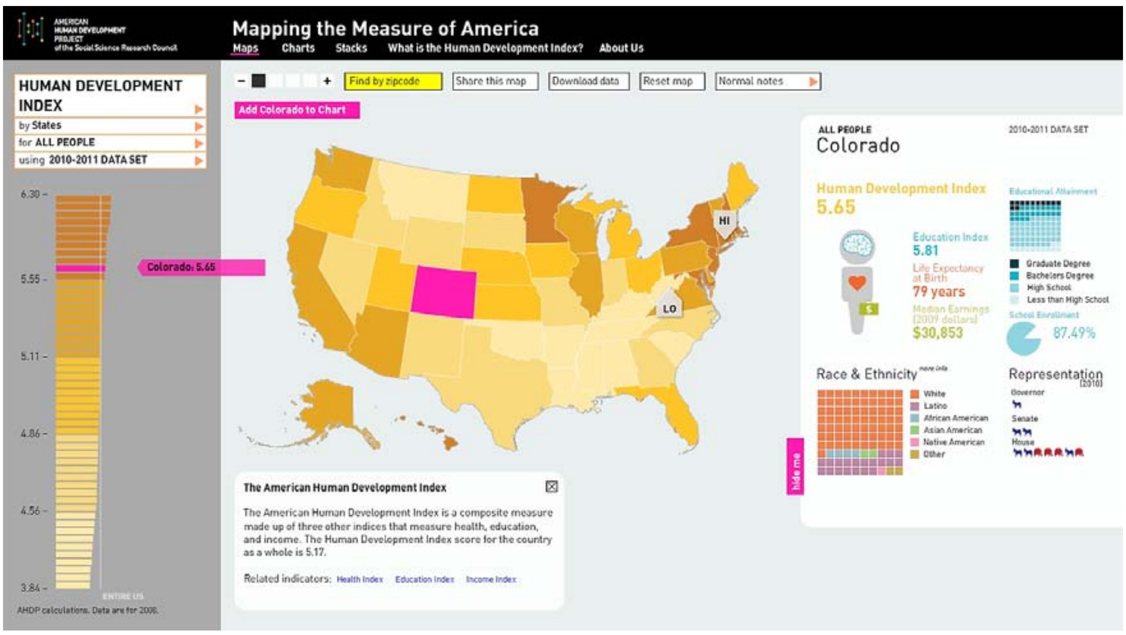

Figure 3 Mapping the Measure of America interface

interaction design and for displaying the data. The current MAPSustain service uses the Google Maps Javascript API code due to its flexibility.

Outlook

MAPSustain not only helps people see the where, what, and who about funding, publications, and patents concerning biofuel and biomass research, but it also provides an avenue to connect and collaborate. By having the information displayed visually over a geographic map, one can easily see the areas of the United States that are getting the most funding, what areas are producing the most publications, and where patents have been granted. If you choose to see more, click an icon and more information will be displayed in the right column. Clicking on the hyperlinks in that column will take a person to a corresponding website (depending on what is selected in the check boxes) that will display even more information about the particular searched subject. Listed within the web page that is brought up, will most likely be the name and affiliation of the researcher(s) who have either received funds, published something relevant, or was/were granted a patent. By knowing this information, one can follow up with the researchers, ask questions, and possibly collaborate on future projects.

Further development in terms of how data is gathered and rendered is needed to make the design of MAPSustain more efficient. One of the drawbacks of the Google maps API is that every time a user zooms into or out of the map, the data needs to be re-aggregated and re-rendered, which can be slow at times, depending on which browser is used and the particular area that is being viewed. In addition, we would like to optimise the legend design so that the smallest icon is more easily legible. Currently, the icon size is correctly calculated and displayed yet further work is needed to automatically generate easy-to-read legends.

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References

Alpert SR (2003) Abstraction in concept map and coupled outline knowledge representations. *Knowledge Creation Diffusion Utilization* 14(1): 31–49.

Alpert SR and Grueneberg K (2000) 'Concept mapping with multimedia on the web', *Journal of Educational Multimedia and Hypermedia* 9(4): 313–331.

American Human Development Project of the Social Science Research Council (2010) *Mapping the Measure of America.* Available at: http://www.measureofamerica.org/maps/ (accessed 5 February 2011).

Behrens RR (1998) Art, design, and Gestalt theory. *Leonardo* 31(4): 229–303. Available at: http://www.jstor.org/stable/1576669 (accessed 10 January 2011).

HealthMap (2011) *Global Health, Local Information*. Available at: http://healthmap.org/en/ (accessed 5 February 2011).

Keller T and Tergan S-O (2005) Visualizing knowledge and information: An introduction. *Knowledge and Information Visualization* 3426(4): 1–23. Available at: http://www.springerlink.com/index/MHNBDL1G9C6W2YCQ.pdf (accessed 11 January 2011).

Koffka K (1935) *The Principles of Gestalt Psychology*. London: Lund Humphries.

Kong CH, Ma N, Zoss AM, Stamper MJ and Börner K (forthcoming) Analyzing and mapping biomass and biofuel science and technology.

SciTech Strategies Inc. (2010) *Maps of Science.* Available at: http://mapofscience.com/wdau.html (accessed 1 July 2011).

US Department of Energy (2010) *DOE, USDA Announce Funding for Biomass Research and Development Initiative*. Available at: http://www.energy.gov/news/8949.htm (accessed 10 January 2011).

Ware C (2004) *Information Visualization: Perception for Design*. San Francisco, CA: Morgan Kaufmann.

Zoss A, Conover M and Börner K (2010) Where are the academic jobs? Interactive exploration of job advertisements in geospatial and topical space. *Third International Conference on Social Computing, Behavioral Modeling and Prediction*, Bethesda, MD, pp. 238–247.

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Authority and authenticity in future archaeological visualisation

Abstract
Increasingly, archaeologists are using virtual reconstruction as a method for visualising archaeological data. Whilst these visualisations have improved the way archaeologists create interpretations and present their data to the public, they also pose a number of problems. One of these is associated with the 'authority' of virtual visualisations. Archaeologists often create visualisations based on a single interpretation of the archaeological data, or only present a single outcome from the varied interpretations they considered. However, by presenting a single view of the past, there is concern that a viewer's faith in an interpretation is increased, denying them the right to think for themselves. Another concern is with the 'transparency' of visualisations. Most archaeologists consider it important that a viewer is made aware of the data used to create a visualisation, yet despite a host of technologies and policy documents there remains little consensus on how this can be achieved.

Despite numerous attempts by archaeologists, these problems have remained largely unresolved. However, based on the application of several innovative techniques for visualising and recording the provenance of archaeological data, it is suggested that we have made a significant step forward in addressing them. This suggestion is based on involvement with a larger research project, RCUK PATINA. The PATINA project aims to revolutionise research spaces through the use of wearable prototypes which will enhance research objects by bringing the digital into the physical world, through projection and other interfaces. The PATINA project is also interested in capturing, recording and replaying a researcher's activities in order to support the sharing and publication of research.

Early research for PATINA has highlighted that there are likely to be significant implications resulting from the way archaeological data could be visualised in the near future. For example, the use of an augmented reality interface combined with gestural input might transform the act of interpretation into one of 'performance'. Another possibility is that archaeologists could simultaneously and collaboratively create virtual visualisations. Wearable technologies also permit data to be visualised anywhere, which has numerous implications for fieldwork practices.

Keywords
archaeological visualisation, authenticity, authority, computer graphics, procedural modelling, reconstruction

Introduction

Archaeologists are constantly striving to 'make visible the invisible', by inferring the behaviour and actions of long-gone communities and societies through the remnants of their material culture. Not only are archaeologists engaged with the task of excavating these remains and interpreting their meaning, it is also their duty to make these interpretations accessible to the wider public through the presentation and dissemination of their excavations. Nowadays, virtual reconstruction has become synonymous with the presentation of archaeology to the public. Anyone who has watched the television programme *Time Team* will be familiar with archaeological visualisation; as the excavation and survey develop snapshots of the data and the interpretations built upon them are revealed through three-dimensional graphics, digital composites and other illustrations, and as the third day permitted for excavation draws to a close the viewer is taken on a 'fly-through' of a reconstruction of the site, based on the data accumulated by the archaeologists. Computers have been used to create these visualisations of archaeological sites and artefacts since the beginning of the 1980s (Miller and Richards, 1994). Archaeologists and technical specialists now frequently use computer graphics and a variety of reality based modelling techniques to think about and to 'reconstruct' cultural heritage monuments and artefacts on a daily basis. However, as with the adoption of any new technique by a scientific discipline, the use of computer visualisation in archaeology has resulted in a number of theoretical issues being raised. Among these, two significant issues for archaeologists regard the authority and authenticity of archaeological visualisations.

Based on our current and on-going involvement with the RCUK PATINA project, we outline two research topics we have recently been exploring, the potential of procedural modelling and portable technologies for archaeological visualisation. We outline in this paper how we feel these technologies and techniques may be well positioned to address some of the longstanding issues associated with producing archaeological visualisations, and identify some of the new issues archaeologists might have to face in relation to the increased availability and portability of visualisation tools 'on site' at archaeological excavations.

Archaeological visualisation

The adoption of visualisation techniques in archaeology has improved the discipline in numerous ways. Virtual reconstructions help archaeologists to communicate their data and ideas in an accessible and engaging way, which would be unachievable using traditional text-based accounts and methods of dissemination. Increasingly archaeologists are also using visualisation as an analytical tool to aid the understanding of archaeological data. For example, virtual environments allow a variety of hypotheses to be tested that would be too costly or impractical to examine physically, such as the impact of lighting on the interpretation of an archaeological structure (see e.g. Papadopoulos and Earl, in press).

The authority of archaeological visualisations

One of the most common concerns is that photorealism increases the authority of a reconstruction; the viewer might interpret the visual realism as a definitive statement or the 'historical truth'. For example, Eiteljorg (2000) argues that modern archaeological visualisations can be so convincing that viewers will accept them without challenge. Archaeologists are also concerned that visualisations gain authority as a result of being presented without alternative possibilities. By presenting a single, static view of the past, visualisations may present a 'politically correct' view that denies the viewer 'the right to think for themselves' (Miller and Richards, 1994). In contrast to creating a physical model, virtual visualisations should make it easy for archaeologists to conceive a number of possible visualisations (Ryan, 1996). Both Frischer et al. (2000) and Goodrick and Gillings (2000) suggest that the reason this has occurred is because virtual reconstructions are likened by archaeologists to the traditional 'artist's impression', which attempts to encapsulate the past in a 'single moment' from one perspective. This view of virtual visualisation, as a form of advanced illustration, remains as prevalent today as when Reilly (1990) first suggested it.

The authenticity of archaeological visualisations

Archaeologists are also highly concerned with the accuracy and authenticity of any archaeological visualisation. Frischer et al. (2000) describe these as two sides of the same coin; accuracy pertains to the way the archaeological data is used to create a visualisation; authenticity to the way the viewer experiences this archaeological data. Miller and Richards (1994) were the first of numerous archaeologists to raise concerns with the authenticity of virtual visualisations, observing that large audiences were frequently being presented with visualisations which were divorced from the academic discussion associated with their development. Bateman (2000) describes this as the 'dislocation' of highly technological images from their original archaeological context. Earl has however advocated the use of the full range of visual and other stimuli afforded by computer simulation, supported by textual critique, rather than deliberately downgraded or partitioned visualisations (Earl, 2006). The technological mode of production further compounds the problem of authenticity for archaeologists. Whilst the concept of the 'artist's impression' is often regarded as being subjective, and is associated with imagination and creativity, computer-based techniques tend to be associated with accuracy and objectivity (Earl and Wheatley, 2002).

Many of the problems faced by archaeologists regarding the authority and authenticity of visualisations are summarised by Bakker et al. (2003):

- How do you deal with contrasting visions? Do you choose one option or do you give alternatives?

- How do you cope with lack of knowledge or missing data?

- Do you show the difference between what is 'certain' and what is 'doubtful' or even extremely dubious? What about acknowledgements? To what extent does a visualisation have to be verifiable? How detailed do you have to be?

Addressing these problems

Numerous archaeologists have attempted to tackle these issues with a mixture of success. As of yet it can be argued that there are no definite solutions to the problems identified by Bakker et al. (2003). One of the first, and perhaps best, attempts to address these issues was by Roberts and Ryan (1997), who created a virtual visualisation which could be interactively changed by the viewer. Although the parameters a viewer could vary were limited, this remains one of the first and only examples of a virtual visualisation designed to highlight to the viewer the relationship between the archaeological visualisation and the underlying data. Since Roberts and Ryan, many other archaeologists (such as Barceló, 2001; Eiteljorg, 2000; Frischer et al., 2000), have suggested that interactivity presents one of the best opportunities for overcoming the problems associated with the authenticity.

As for authority, one suggestion by archaeologists such as Swogger (2000) and James (1997) is to create multiple visualisations of an archaeological structure and to use them all for dissemination. Barceló (2001: 231) states that:

> the goal of the visual model should not be 'realism' alone … it is the ability to view (the visual model) from all angles and distances, under a variety of lighting conditions and with as many colour controls as possible, which brings about real information.

Surprisingly, despite the ease at which computer graphics can be used to represent multiple hypotheses, few archaeologists have attempted to do so (Ryan, 1996).

The London Charter was devised to establish some definitive guidelines for producing visualisations of cultural heritage (Beacham, 2006; Beacham et al., 2006; Denard, 2009). Whilst the Charter did not make any radical new proposals, it aimed to consolidate previous research into a number of recommendations for best practice (Beacham, 2006). The Charter attempted to address the problems of authenticity, such as its recommendation that supporting evidence should accompany a visualisation to indicate the nature and degree of factual uncertainty of a hypothetical visualisation (paragraph 4.1) (Beacham, 2006). However, the Charter is a set of principles, not methods, and it does not attempt to suggest how this is to be achieved. The researchers behind the creation of the London Charter also introduced 'paradata', a term used to describe the data which documents the interpretative processes associated with the creation of the visualisation, as they felt that this was distinct from the concept of 'metadata' associated with the final multimedia produced as a result of the visualisation process. Others have disagreed with this distinction, or the extent to which one can usefully separate one's own interpretations from the underlying processes and data.

Future possibilities

Procedural modelling

One emerging field of computer graphics which holds a great deal of promise for overcoming the problems associated with the authority and authenticity of archaeological visualisation is 'procedural modelling'. Procedural modelling makes use of a set of rules and functions input by the user in order to generate a 3D model. It is most commonly used in the entertainment, architecture and urban planning industries for the efficient creation of 3D buildings and cities (Watson et al., 2008). Many archaeologists are keen on the potential of this approach, as it has many similarities to the interpretive process in archaeology. For example, an archaeologist could reconstruct a structure based on architectural rules derived from similar buildings at other sites of the same period (Müller et al., 2006).

Archaeologists have typically used procedural modelling to model scenes that contain a large number of 3D models, such as the Rome Reborn project which reconstructed the entire city of Ancient Rome as it may have appeared in AD 320 (Figure 1). Attempting to do this using traditional 3D modelling tools would require a large amount of time and effort, and would most likely be too expensive for most project budgets (Müller et al., 2006).

Procedural approaches could now be in a position to address many of the problems associated with the authority of archaeological visualisations. One feature of procedural modelling is that it uses stochastic variation to generate 3D content, which makes it easy to create a large number of different models that are all based on the same archaeological

Figure 1 Procedural modelling was used to recreate the city of Ancient Rome. Source: http://www.romereborn.virginia.edu/ (accessed 9 June 2011)

evidence. Assuming the archaeologist subsequently presents these models so that they are immediately comparable, preferably in very large numbers and potentially as part of an interactive interface, then we feel the issues associated with the authority of disseminating a single representation of the evidence would be overcome.

Stochastic rules could also be used to create visualisations which respect the different levels of certainty ascribed to interpretations of the archaeological data. Using procedural modelling in the future, it may be possible to associate a calculation of the level of certainty with each visualisation procedurally generated, so that a viewer could interactively choose between probable or more fanciful reconstructions (as suggested by Niccolucci and Hermon, 2004). A further advantage to this method is that none of the models are aesthetically compromised, unlike the use of other techniques such as non-photorealistic rendering (Haegler et al., 2009).

Procedural modelling also takes a step in the right direction to overcoming the problems associated with the authenticity of archaeological visualisations. Procedural modelling requires the user to script their visualisation using a 'shape grammar' (Stiny and Gips, 1972), a structural and semantic description of the architecture. Therefore the interpretive process an archaeologist undergoes whilst creating a reconstruction using procedural modelling is recorded and made explicit. A consequence of this is that it becomes much harder for an archaeologist's interpretation to overlook any gaps in the data.

Although this description in itself is enough to address a large part of the problem with the authenticity of reconstructions, should an archaeologist wish to make their interpretive process even more explicit their description or script can easily be annotated to highlight where extrapolation or imagination was required to create the reconstruction (Haegler et al., 2009). Clearly the types and degrees of interpretative difference that can be represented in this way do not spread across the whole breadth of interpretative practice but they provide a useful way in to the limitations of monolithic interpretations. In fact they need not even attempt to replicate separate interpretative strands but rather stand as placeholders: pointers that such differences exist in, for example, the material components of a given structure.

The PATINA project

The PATINA project, with which our research is associated, aims to provide researchers with new opportunities to create research spaces that emphasise the primacy of research material, and support the sharing of research activities as well as results. Through recording of research practice the project will also enable you to 'walk in the footsteps' of other researchers, and explore how the provenance of your developing ideas links with theirs through shared objects that exist both online and in the real world.

The consortium will build wearable prototypes that can enhance research objects by bringing related information back into their research space. By relying on portable technologies that are worn or carried, we aim to explore the effects of freeing research from institutional infrastructures. These technologies will also provide the means to capture, record and replay the researcher's activities to support intuitive archiving, sharing and publication of interactions with research objects. The design of the technologies will draw on theoretical frameworks of space developed from studies of research spaces as diverse as libraries, museums, homes and archaeological fieldwork sites.

As PATINA focuses on the use of wearable and portable technologies, we anticipate many issues of interest will arise from taking technological devices into 'the field'. The act of creating a virtual reconstruction is generally a solitary pursuit which can take place in the field but more usually takes place in an office or lab-based environment. Even when a visualisation is created in the field (e.g. Earl et al., in press) it tends to focus on assisting with the interpretation of the evidence and thus is likely to be lower in fidelity than a static visualisation produced as a representational device. Whilst hardware and software enhancements make for a faster and more visually complex, physically accurate modelling and rendering pipeline modelling rapidly and on the fly is not conducive to predictive rendering.

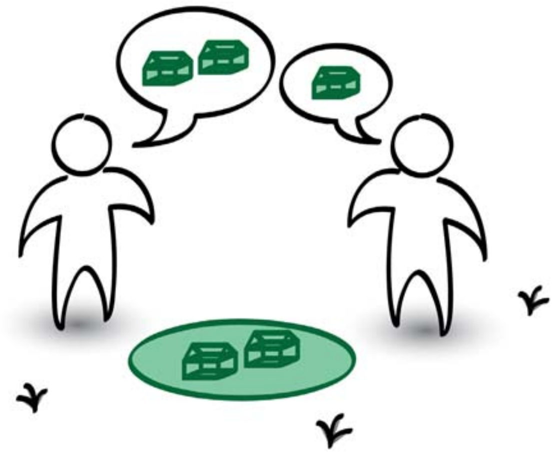

Figure 2 Being able to visualise and collaboratively create a reconstruction whilst in the field would be a new and exciting prospect

Technically, the challenge of creating and manipulating a virtual reconstruction in the field has become a possibility due to an increase in the portability and robustness of modern computing hardware. Laptops and computers are already frequently deployed at excavation sites, and more novel technologies such as tablet computers and mobile devices have been trialled in these environments. The way we experience computer generated content is changing as well, due in part to a growing interest in augmented reality, where a live view of a real-world environment is augmented by computer graphics.

Actively creating and manipulating a virtual reconstruction in the field, based on the evidence as it is arises, has some interesting consequences. One such consequence is an enhanced provenance of the interpretation of the site, resulting from the capture of previous iterations of an archaeological site's reconstruction. In this case it is anticipated that the changes to the reconstruction over time would be of as much interest as the final output. Another interesting consequence would be the potential for an archaeologist's surroundings to influence his or her reconstruction, an idea that has been embraced by archaeological illustrators working in traditional media and which results in the 'artist's impression'. This is especially relevant when one considers archaeology is all about a practice occurring in space, that is the creation of places.

Another of the aims of the PATINA project is to explore the possible ways in which researchers might collaborate in future research environments. Whilst the concept of a VRE (virtual research environment) for archaeologists has been explored by numerous researchers, actually creating a reconstruction collaboratively is generally unexplored. However we feel that this is an interesting possibility, especially given our research into the potential offered through procedural modelling.

In our system separate procedural rule sets (a semantic description of a specific architecture) will be merged in order to create 'hybrid' structures. It is therefore possible to imagine archaeologists with contrasting theories about a structure merging their ideas procedurally to explore the resulting visualisations together, or apart (Figure 2). The visualisations will be expressed in multiple options, demonstrating the parameter space implicit in each new modification to the underlying logic. It would also be possible to open up the interpretation to a broad audience of citizen researchers where hybrid model trends ebb and flow as rule sets are created, modified and destroyed. This possibility also raises interesting questions about the authorship of a reconstruction, as this would not be clearly apparent from the visualisation itself.

This paper has explored two areas of research – procedural modelling and portable technologies – that we feel could potentially revolutionise archaeological visualisation, and address some of its longstanding issues. The PATINA project above all else is concerned with the creation of new spaces within which to undertake research, and to explore the implications of these to our practice – whether academic, citizen researcher, specialist or novitiate. Computer graphic simulations form one potential component of the research space and it is our intention to enable as much as possible of the fluidity and creativity of day-to-day research encounters in space to pass into their development and critique.

References

Bakker G, Meulenberg F and Rode JD (2003) Truth and credibility as a double ambition: Reconstruction of the built past, experiences and dilemmas. *The Journal of Visualization and Computer Animation* 14(3): 159–167.

Barceló JA (2001) Virtual reality for archaeological explanation: Beyond 'picturesque' reconstruction. *Archeologia e Calcolatori* 12: 221–244.

Bateman J (2000) Immediate realities: An anthropology of computer visualisation in archaeology. *Internet Archaeology* 8. Available at: http://intarch.ac.uk/journal/issue8/bateman_index.html

Beacham R (2006) 'Oh, to make boards to speak! There is a task!' Towards a poetics of paradata. In: Greengrass M and Hughes L (eds) *The Virtual Representation of the Past*. Farnham: Ashgate, 171–178.

Beacham R, Denard H and Niccolucci F (2006) An introduction to the London charter. In: Loannides M, Arnold D, Niccolucci F and Mania K (eds) *The e-volution of Information Communication Technology in Cultural Heritage: Where Hi-tech Touches the Past: Risks and Challenges for the 21st Century*, short papers from the joint event cipa/vast/eg/euromed.

Denard H (2009) The London Charter for the computer-based visualisation of cultural heritage (version 2.1). Available at: http://www.londoncharter.org/ (accessed 13 February 2010).

Earl GP (2006) At the edges of the lens: Photography, graphical constructions and cinematography. In: Evans TL (ed.) *Digital Archaeology*. London: Routledge.

Earl G and Wheatley D (2002) Virtual reconstruction and the interpretative process: A case-study from Avebury. In: Wheatley D, Earl G and Poppy S (eds) *Contemporary Themes in Archaeological Computing*. Oxford: Oxbrow Books, 5–15.

Earl GP, Keay SJ and Beale G (in press) Archaeological computing for recording and presentation of Roman Portus. In: Keay SJ and Paroli L (eds) *Proceedings of the First Portus Workshop, Rome, March 2008*. British School at Rome Monographs.

Eiteljorg H (2000) The compelling computer image: A double-edged sword. Available at: http://intarch.ac.uk/journal/issue8/eiteljorg_index.html

Frischer B, Niccolucci F, Ryan N and Barceló J (2000) From CVR to CVRO: The past, present, and future of cultural virtual reality. *Virtual Archaeology between Scientific Research and Territorial Marketing: Proceedings of the VAST EuroConference, Arezzo, Italy*, 1–12.

Goodrick G and Gillings M (2000) Constructs, simulations and hyperreal worlds: The role of Virtual Reality (VR) in archaeological research. *On the Theory and Practice of Archaeological Computing* 51: 41–58. Oxford University School of Archaeology.

Haegler S, Müller P and Van Gool L (2009) Procedural modeling for digital cultural heritage. *EURASIP Journal on Image and Video Processing*, 1–11, doi:10.1155/2009/852392.

James S (1997) Drawing inferences: Visual reconstruction in theory and practice. In: Molyneaux BL (ed.) *The Cultural Life of Images: Visual Representation in Archaeology*. Oxford: Routledge, 22–48.

Miller P and Richards J (1994) The good, the bad and the downright misleading: Archaeological adoption of computer visualization. In: Huggett and Ryan N (eds) *CAA94 Proceedings of the 22nd CAA Conference*. Oxford: Tempus Reparatum.

Müller P, Wonka P, Haegler S, Ulmer A and Van Gool L (2006) Procedural modeling of buildings. *ACM Transactions on Graphics* 25(3): 614–623.

Niccolucci F and Hermon S (2004) A fuzzy logic approach to reliability in archaeological virtual reconstruction. *Proceedings of CAA2004 Budapest, Archaeolingua*.

Papadopoulos C and Earl G (in press) Formal three-dimensional computational analyses of archaeological spaces. In: Paliou E, Lieberwirth U and Polla S (eds) *Spatial Analysis in Past Built Spaces – Workshop*, Berlin, 1–2 April 2010.

Reilly P (1990) Towards a virtual archaeology. In: *Computer Applications and Quantitative Methods in Archaeology*, Oxford: Archaeopress, 133–139.

Roberts JC and Ryan N (1997) Alternative archaeological representations within virtual worlds. In: Bowden R (ed.) *Proceedings of the 4th UK Virtual Reality Specialist Interest Group Conference – Brunel University*. Uxbridge, Middlesex, 179–188.

Ryan N (1996) Computer based visualisation of the past: Technical 'realism' and historical credibility. In: Higgins T, Main P and Lang J (eds) *Imaging the Past: Electronic Imaging and Computer Graphics in Museums and Archaeology*, No 114 in Occasional Papers. London: British Museum Press, 95–118.

Stiny G and Gips J (1972) Shape grammars and the generative specification of painting and sculpture. In Freiman CV (ed.) *Information Processing* 71, 1460–1465.

Swogger J (2000) Image and interpretation: The tyranny of representation? In: Hodder I (ed.) *Towards Reflexive Method in Archaeology: The Example at Çatalhöyük*. Cambridge: McDonald Institute for Archaeological Research, 143–152.

Watson B, Pascal M, Veryovka O, Fuller A, Wonka P and Sexton C (2008) Procedural urban modeling in practice. *IEEE Computer Graphics and Applications* 28(3): 18–26.

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Moving architectures

Visualising and analysing relationships in nineteenth-century architectural competitions in Switzerland

Abstract
Our cities are changing and this implies changes in many fields of our activities, research and everyday life. Architecture, urban design and planning are the main tools for making design decisions which structure and articulate these transformations. The problem we are dealing with, when we are talking about the creation of our cities, is to visualise the complexity of urban procedures and the 'urban futures' that they 'produce'.

In our collaboration between the disciplines of human geography and informatics we worked on the collection of historical data about architectural competitions held in Switzerland in the nineteenth century. We analysed these historical data in order to better understand how cities were created and developed; in other words, we addressed this complex problem using architectural competitions as an epistemic vehicle. Competitions are platforms for communication where different people (architects, clients, engineering and financial specialists, etc.) and objects (designs, models, competition briefs, etc.) come together, and where decisions are made about the future urban environment. We have developed a visualisation tool, which is able to represent the disparity of an architectural competition in space and in time: the networks it brings together, the actors it involves, their role and their spatiotemporal trajectories. Our visualisation tool presents the information as a navigable landscape enabling the interactive manipulation of the visual interface and leading to a deeper understanding and knowledge discovery.

In the article, we discuss the challenges associated with the analysis of the data on architectural competitions, present our visual analytics tool and the findings it enables. Finally, we elaborate on the advantages and potentials of our interdisciplinary collaboration.

Keywords
architectural competition, complexity, flows, metamodelling

Introduction: A view of cities through a 'competition' frame

This article discusses the inter/transdisciplinary process for visualising the complexity of urban procedures in order to understand the 'urban futures' they 'produce'. In our collaboration between the disciplines of human geography and informatics we worked on the collection of historical data of architectural competitions held in Switzerland in the nineteenth century (from the archives www.seals.ch, Hypathie ACM EPFL [Frey, 1998]). We analysed these historical data in order to better understand how cities were designed, transformed and developed; in other words, we address this complex problem using architectural competitions as an epistemic vehicle.

Competitions act as platforms for communication where different people (architects, clients, engineering and financial specialists, etc.) and objects (designs, models, competition briefs, etc.) come together, and where decisions are made concerning the future urban environment (Kohoutek, 2005).

Architecture is a practice that is conditioned by its artistic and technical means and (by the entanglement of the latter) with the productive forces related with the building sector. Furthermore, architecture enables a society to transcribe (or translate) its ideals and objectives into its built environment (Carmona, 2009; Viollet-Le-Duc, 2010), and in that sense constitutes an event, a political moment of becoming (Van Wezemael et al., 2010). In this sense:

> Architecture is always the ultimate realisation of a mental and artistic evolution; it is the materialisation of an economic level/status. Architecture is the pinnacle of realisation for all artistic production because architecture signifies the construction of an atmosphere and fixes a way of living. (Jorn, 1954)

From this point of view, the research on architectural competitions as processes of shaping our cities is a transdisciplinary subject and it not only requires an understanding of disciplines such as architecture, but also of human geography.

However insights from the related fundamental fields of science are not widely adopted. The fragmentation of knowledge makes understanding between people from different disciplines and with different expertise difficult (Volker, 2010). This is one of the main concerns of this article: to bridge the gap between the 'art of architecture' and a wider 'political' understanding of architecture by using visualisation as a medium.

Geographies of architecture

First, in this article we present a transdisciplinary understanding of architecture that highlights its complex nature. From this point of view, geographical concepts are the entry points of an architectural discussion towards more fluid concepts such as territory, especially influenced by the work of Deleuze and Guattari (1987, 2004).

Territory moves through the long history of 'geo-architecture', and is neither wholly aesthetic and subjective nor empirical, but rather explorative and experimental of the particular material and discursive strategies that tie concepts and flows to the earth – to points of fixity. Deleuze and Guattari state that architecture is the art of (the adobe and) the territory since it 'positions its ensembles – houses, towns or cities, monuments or factories – to function like faces in the landscape they transform' (Deleuze and Guattari, 1987: 191). Thus, in the case of architecture we can understand these 'faces' as the forms where things come together in one (form), the points of fixity of flows. From this point of view, geographies of architecture are less interested in

> architects drawing on maps, or making them ... it is more about architects considering how the architect and the architect's creations tie concepts to the earth, produce difference on the earth ... It might be most comprehensible in a cartographic enterprise, but it can take other, less explicitly geo-visual forms. (Gissen, 2008: 67)

Informatics and geographies of architecture: Towards an ethicoaesthetic visualisation

After exploring a transdisciplinary understanding of architecture, we focus on Swiss architectural competitions in the nineteenth century. We view these competitions as processes producing Deleuze and Guattari's points of fixity, the particular material and discursive strategies that tie architectural concepts and flows to the earth.

In other words, for the collection of data, architectural competitions can be thought of as datascapes of architectural concepts, definitions, expertise, technologies, materials and diverse actors (Latour and Yaneva, 2008) that geographies of architecture bring to light. In order to study and communicate these kinds of datascapes, the collection of data is organised in a 'complexifying database', based on the 'diagrammatic metamodelling cartographies' of Guattari (Guattari, 1979; Watson, 2009).

The collection of data from architectural competitions in a database has many advantages as the Hypathie (Frey, 1998), Europan France competitions and Canadian database illustrate (Chupin, 2008). They can be considered a repository of architectural knowledge of the built or non-built and they promote research on architectural design, architectural judgement, etc. However both databases are a systematic collection of relevant information and they illustrate the (predefined as) ‘important’ characteristics of the data (Frey, 1998: 15–16). According to the Deleuzeguattarian conceptual framework, information is always relevant for the emergent whole and the importance of the information cannot be predefined (DeLanda, 2002: 40–41).

The aforementioned thoughts were the base for structuring the collaboration between geographies of architecture and informatics. This collaboration, which is presented in detail below, was realised in two steps, creating two important links:

- First step: the creation of diagrammatic models as E/R diagrams[1] for organising a ‘complexifying database’

- Second step: the creation of a cartographic expression for communicating aspects of this complex datascape.

From archives to data: the ‘complexifying database’

Collecting data from archives of architectural competitions of the nineteenth century means that we need to understand the complexity of competitions and find ways of working with this complexity. With this in mind, data are collected and modelled directly while studying the archives with the aim of producing a ‘map’ of the competition process.

This collection of data related to competitions is based on the complexifying, ‘ethicoaesthetic’ cartographies of Guattari. For Guattari (Watson, 2009) cartographies or metamodelling is an ‘ethicoaesthetic’ paradigm, enabling for singularity and complexity. Metamodelling is oriented towards experimentation and helps us to formulate a liquid scenario of spatiotemporal organisations. Metamodelling and mapping refers to questions of ‘how’ and ‘why’ (Van Wezemael, 2010b), or, as Watson (2009) states, to ‘diagrammatic thinking’.

In Guattari’s ‘ethicoaesthetic’ paradigm ‘ethic’ emphasises the decisions and choices involved in any act of modelling or mapping (Watson, 2009). In the case of data collection from competition archives ‘ethic’ is expressed by the preservation of the complexity of the collected data, in other words by not reducing the complex (and singular) nature of each competition case by formulating abstract typologies. In order to introduce these concepts, two rules are formulated for the data collection:

- Rule a: the research is structured as a bottom-up approach study of competition components, with no presupposed hierarchies or relations

- Rule b: the research of these populations includes as much specificity, detail and elements as possible, leading to a rich data collection.

Furthermore, ‘aesthetic’ in Guattari’s paradigm (Watson, 2009) emphasises the creative productivity that such cartography enables. In the collection of data from competition archives this is expressed by the creation of diagrammatic models, which allow us to work with data, the components and their relations in many creative ways.

The starting point for collecting and modelling the data is what we already know about an architectural competition. Thus, a competition is:

- the answer to a specific building problem;

- the different human networks that are involved;

- the frameworks of procedures implemented; and

- the production of design outcome(s).

These are not used as predefined categories of competition components, but as (possible) points of fixity and the (possible) relations between them. These components are treated like ‘territories for exploration’, or the flows that an architectural competition brings together and ties to the earth.

In this sense the transformation of diagrammatic models to E/R diagrams highlights:

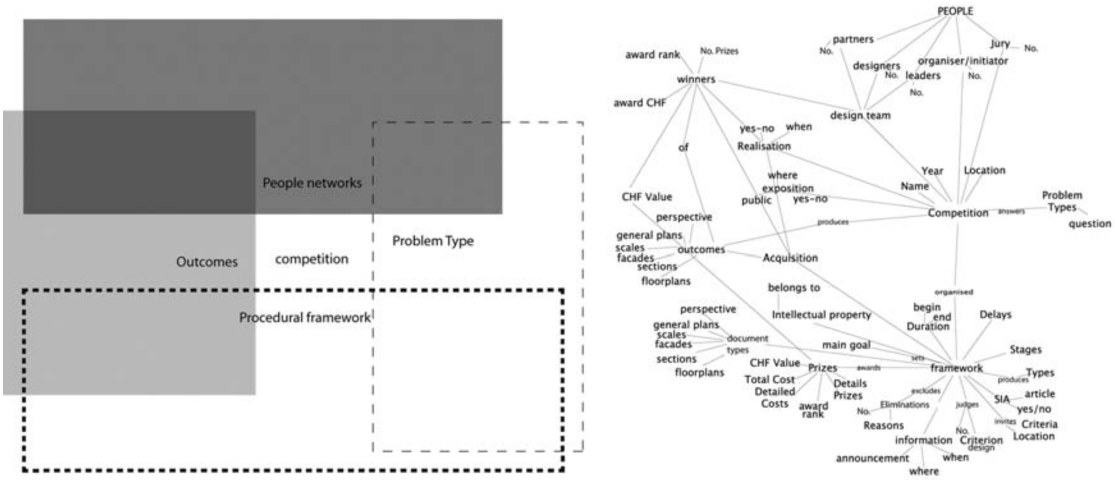


Figure 1 Starting point for modelling architectural competitions (left) and the final diagrammatic model of 50 Swiss competition cases in the nineteenth century (right)

- a dynamic data collection of competition components and their in-between relations from the archives. The E/R diagrams chart each singular case and enable an understanding of the complexity of each competition. Metamodelling enables us to assemble the E/R diagrams in a cartography of the fluid organisation of all 50 cases.

- a base for organising the archives' datascape in a database environment. According to these E/R diagrams the database of Swiss nineteenth-century competitions is created.

This 'topological collection' of data illustrates how the competition process 'works': it enables us to trace existing relations and discover 'hidden' ones between the competitions' components. The following examples illustrate how two hypotheses from the test study of Swiss post office competitions (nine competition cases from 1885 to 1899) are studied by their reflection in the dataset. Each example expresses a hypothesis-scenario that refers to a potential set of relations for the components of these competitions. The scenario is set up step-by-step with questions formulated in SQL language (see Appendix).

Example 1
The jury and its composition can influence the outcome of a competition. Thus, it would be interesting to see if there is a pattern, a recurrence of jurors involved in the post office competitions from 1885 to 1899.

Using SQL queries we found that the Sach-jurors (the non-experts, important people concerned by the issue, that is politicians, future users) form a much more homogenous pattern. Two post office directors (E. Hohn and H. Lutz) are jurors in four out of eight

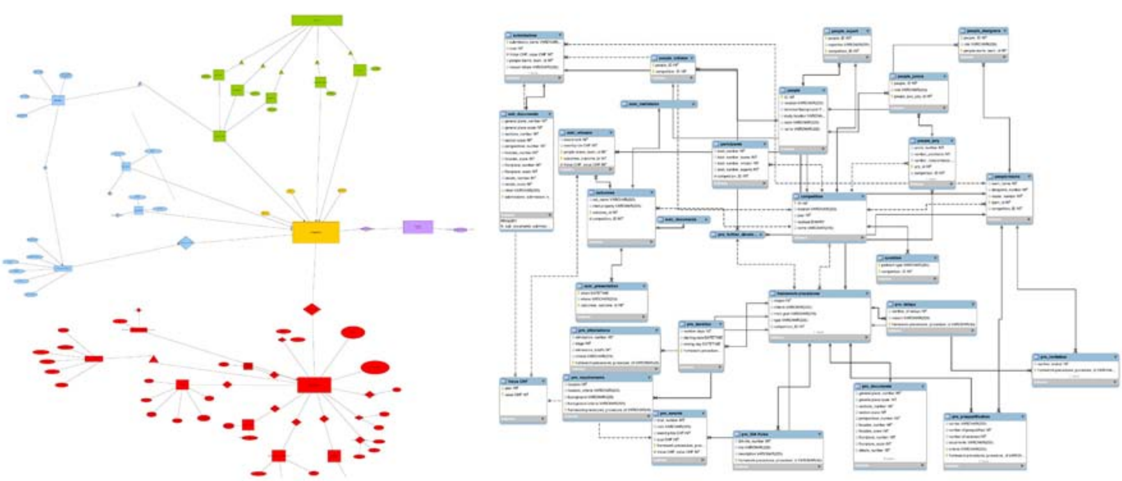


Figure 2 Two versions of the E/R diagram of 50 Swiss competition cases in the nineteenth century: with yEd (left) and MySQL Workbench (right)

competitions, and A. Flu(c)kiger (as an adjunct of the Federal Inspector and later as Director of the Federal Buildings administration) was juror in all of them. That means that the jury of the post office competitions had a changing architectural representation and a more or less stable federal one. This 'stable surveillance' from the federal state could be a possible explanation for the similarity of the post office competition outcomes, despite their difference in architectural opinions and their different locations.

Thus, with this example we traced the relation between the political (the federal state) and the 'apolitical' (design problems): how the commun-ication/couplings between the different fields of reality (politics, aesthetics, law, economy, etc.) were established using architectural compet-itions as a punctual platform of communication.

Example 2

Another interesting result is the network of participating architects related to the post office competitions.

Five architects (G. Gull, J. Camoletti, J. Beguin, A. Rychner and A. Fuchslin) were winners and jurors in different competitions. For instance, J. Camoletti was a juror in Luzern in 1885, and then in Geneva in 1888 he twice won the second prize for his two projects Lumen and Postillon (Waldner, 1889: 144). In 1892 he was again juror in the post office competition in Zurich. A. Rychner won in 1829 in Neuchatel and two years later was in the jury of Winterthur. Similarly A. Fuchslin was in the jury in Neuchatel and after two years he won a prize in Winterthur.

With this example we illustrate that despite the heterogeneity in the composition of the Fach-jurors, within professionals participating (as jurors or as designers) in the post office competitions of the nineteenth century there is not significant differentiation: it seems that these competitions were a platform for 'recycling' knowledge and professional relations for the participating architects.

Concluding, we can state that the produced architectural critique and outcomes of the post office competitions in the nineteenth century, the generation of architectural knowledge in other words, were formulated in a quite closed network of people composed of the federal government (Example 1) and a network of architects in Switzerland (Example 2).

By means of the examples mentioned above, we demonstrated that the 'complexifying database' is a tool for tracing relations and, thus, contributes to a better understanding of how competitions work and how the urban environment is produced. However, the fundamental problem that we face when we try to work with and communicate the results from the competitions' 'relational' analysis is the complexity of the problems and questions we deal with: a growing mismatch between data size and the human ability to understand and interact with data, as it is shown in Figure 3. Thus, we had to create bridges between the

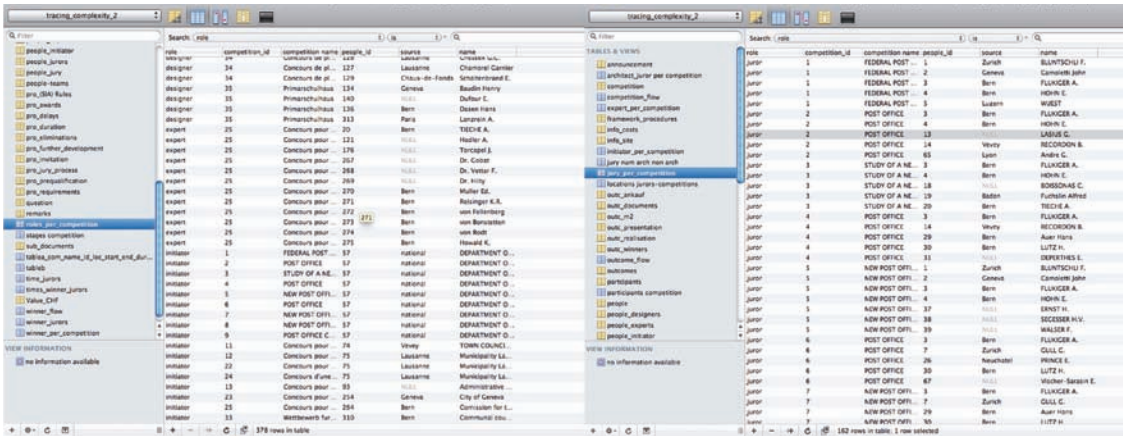


Figure 3 The tables of participants (clients, jurors, architects) from competitions in the nineteenth century (source: the authors)

'ethicoaesthetic' cartographies and scientific modelling-visualisation and try to solve the problem of communication and visualisation of the research results.

Cartographic expression of architectural flows

In the previous part we study, with the help of the diagrammatic models and the 'complexifying database', the complexity of architectural competitions as processes was shown. Competitions bring together different kinds of flows, creating points of fixity and forming 'faces' out of these flows. In this part we illustrate a strategy for visualising architectural competition processes.

Making visible a competition is frequently understood as making visible the realised building, or the (images of the) winning project. In this sense only the final, stable and fixed representations of the outcomes of these complex processes are communicated. However, the goal of this interdisciplinary collaboration is to communicate and visualise the spatiotemporal trajectories; to highlight 'the force field' of tendencies a competition can bring together and tie on earth.

As in the examples presented earlier, we focus on (or select the 'territory' for exploration of) human networks involved in competitions. In this sense every actor-participant is a vehicle with which architectural concepts and styles, technical knowledge, different concerns and priorities and, generally, ways of dealing with reality, travel. More precisely in this visualisation we represent on a geographic map the locations in which the architectural competitions took place and the places the participants of these competitions came from.

A geographic map from Google map/earth (http://maps.google.com/maps) is selected as a base for this visualisation. Although maps present a selection of the complexity of reality, they are very flexible and effective tools: they have the ability to present, synthesise, analyse and explore the real world by visualising it in an abstract way, using design codes or symbols in order to realise the most suitable outcome. Another advantage of maps is that, due to the internet, web maps are available to a wide and diverse population. That makes them mobile, addressing a wider network of people, and also flexible because they have to accommodate multiple expressions and goals. Thus the traditional role of a map is to 'present', but today the map should also be seen as a flexible interface to spatiotemporal data, since maps offer interaction with the data behind the visual representation and encourage exploration (Andrienko et al., 2010).

Along these lines, we created the TimeMap visualisation 'Moving Architectures' (Figure 4) with the goal of supporting the reasoning about the spatiotemporal aspects of the architectural competition data.

More precisely, in Figure 4 the relations between the competitions and their participants are shown by the blue (for jurors), red (for designers), green (for initiators) and purple (for experts)

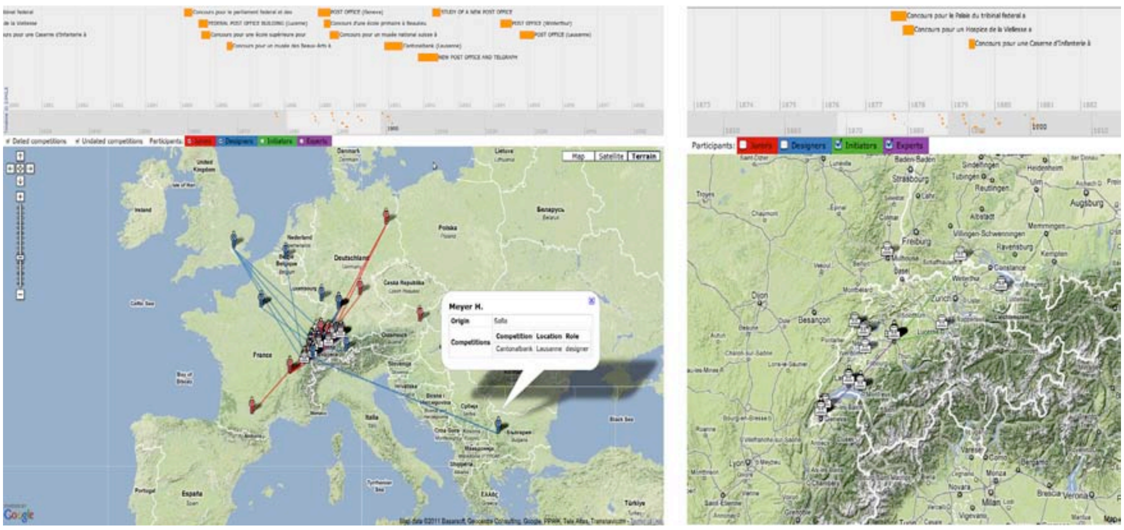
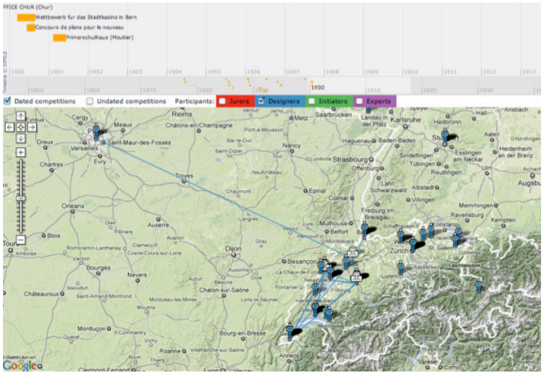


Figure 4
The Moving Architectures map (Architectural Competitions' TimeMap) (available at: http://diuf.unifr.ch/people/boyandii/ac/)



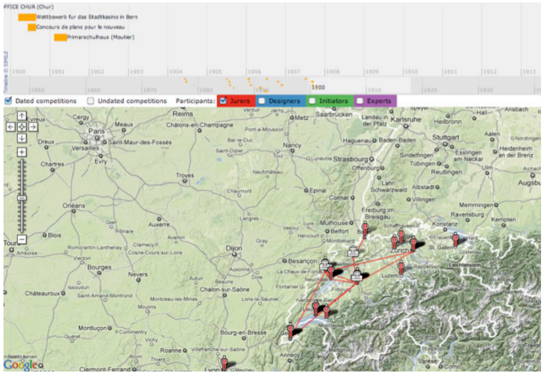


Figure 5 (left) Moving Architectures map, three competitions in 1900–1901, network of designers (source: the authors)

Figure 6 (right) Moving Architectures map, three competitions in 1900–1901, network of jurors (source: the authors)

lines connecting them to the location of the competition. The upper half of the view is a timeline showing when the competitions took place and their durations. By sliding the timeline the user can focus on a specific time period, so that only the competitions of this period are then shown in the map. By clicking on the competition location (white buildings icons) or on the participants, their detailed information appears in tables. This visualisation makes visible one invisible territory of architectural competitions: the information on human networks becomes a navigable landscape. At the same time, it enables a deeper understanding and knowledge discovery in two ways.

Firstly, using the Moving Architectures map we make visible which actors were involved in each competition, the knowledge and trends that were negotiated and materialised in the outcome of the competition. For example, in the following images (Figures 5 and 6) we can directly see the network of designers involved in three competitions during 1900–1901 (blue lines) in Bern, Moutier and La Chaux de Fonds. This network was mainly located in the French speaking part of Switzerland.

In Figure 6 we can see the network of jurors (red lines) involved in these competitions, making visible the network of people that were regarded as experts. This network of jurors covers the Swiss territory. Thus at a glance we understand what kind of networks were active in these competitions and which architects were active in entering one, two or the three contemporary competitions. In this way the Moving Architectures map can forward the study of the field of architectural competitions by illustrating patterns of participants related to competitions types, to building types, to the realisation of the competition, etc.

Concluding the first point, we can argue that making visible the relations between competitions' human networks, space and time is of great value for research of historical data but also for contemporary competitions, as the rules SIA-142 and the directions for organising a competition by the SIA (Swiss Association of Engineers and Architects) illustrate. More precisely in the directions *Wettbewerbsbegleitung Wegleitung der SIA-Kommission 142* (SIA, 2002) we see that 'making visible' (and thus communicable) this type of information is important for the organisation of contemporary competitions since a successful competition's organisation is not based on 'indexes' of peoples' biographies but rather on the relations between people, places and time. The SIA's *Wettbewerbsbegleitung* refers to:

- *the specific group dynamic of the jury* (SIA, 2002: 7): more precisely the selection of jury members is possible only in terms of 'mutual compatibility'. SIA states that the 'jury dynamic' strongly relates to the aim of the competition and not the individual biographies of the jurors
- *the heterogeneity of the jury*: the recurrent engagement of the same juror in a region and the relation of a juror with the location of a competition must be avoided in order to ensure a quality and an unbiased procedure (SIA, 2002: 7–8).

Secondly the collaboration for creating the Moving Architectures map has an important effect and shapes the core of the research on architectural competitions. At this point it would be interesting to reflect on the exact process of collaboration between the three disciplines and the differences they illustrate.

As already stated, the study of architectural competitions requires an understanding of disciplines like architecture and human geography (transdisciplinarity). More precisely, geographies of architecture deal with the structures and relations of architectural competitions and consist of a continuous linking and re-linking in specific issues and configurations of knowledge (Lattuca, 2001: 116). In contrast the collaboration between informatics and 'geographies of architecture' focused from the beginning on the problem of organising the data and communicating the results: each discipline contributes its own knowledge or approach to the research of architectural competitions by attempting to integrate the contributions of the two disciplines (interdisciplinary collaboration), this is described in detail in two steps – from archives to data: a 'complexifying database' and Cartographic expression of architectural flows.

However, we use the database not only as an organisation tool but also as a tool for theoretical modelling (similar directions can be found in the work of Gomes [2008] and Chupin [2008]). Additionally we use the Moving Architectures map as a way of studying the 'becoming' in competitions: by making visible the concept of flows, the Moving Architectures map presents a different way of reading relations in architectural competition research. The spatiotemporal visualisation of architectural competitions' human networks represents (as any map) a selection of the complex characteristics of these processes. Thus, although we know more, 'we know more about less' (Weick, 2006): we know more about the relations and flows between people involved in architectural competitions without referring to their other contextual characteristics as depicted in the diagrammatic models (discussed above). In other words the Moving Architectures map represents a part of the wider network of 'territories' that the diagrammatic models map out and in that sense the diagrammatic models are the 'reference' that guide the research on architectural competitions.

Nonetheless, the Moving Architectures map is an opportunity for a 'stop': in order to 'make visual', we 'slow down' to 'gather' and connect knowledge (Appelbaum in Law, 2004), but more importantly to make sense from the acquired information (e.g. Figures 5 and 6). According to Law (2004) the stop has its costs since we learn less about certain things, but we learn a far wider range of realities. In this sense the Moving Architectures map does not hold all the answers for architectural competitions but it makes visible (thus communicable) the flows of people that allow architecture to travel and generate the image of our urban environment.

Discussion: Exploring further, tracing the virtual

In this article, we discuss the challenges associated with the analysis of the data of architectural competitions; we present our visual analytics tool Moving Architectures map and the findings it enables. More precisely 'Geographies of Architecture' of competitions in the nineteenth century are illustrated in two ways:

- In creating diagrammatic E/R models – and creating the 'complexifying database', a database of architectural, social, political and economical components of competitions and the relations between them.

- In creating a cartography of this datascape, which illustrates the flows of actors from these different architectural, social, political and economical fields, using as entry points architectural competitions.

The Moving Architectures map removes the frame of analysis usually associated with the static outcomes and realisations of architectural processes. It shows that the productive forces that shaped the urban and architectural environment cannot be studied as static objects but must be studied with new concepts related to their mobile and fluid character. In this perspective making visible the flows of people involved in competitions is important for the research on architectural competitions and the built forms: it illustrates the circulation of technical and architectural knowledge and their (possible) points of fixity in the urban environment.

These relations are sometimes easily traceable from the archives but sometimes are hidden. For example, in architectural competitions only the winning projects are disseminated, the losing projects tend to be forgotten. However these projects have an architectural value that goes beyond their selection by a competition jury: according to Chupin (2008, 2011), architectural and urban history is made up of project-to-project transfers and influences and in this sense architectural competitions are repositories of unrealised projects and potential. Competitions refer to both what is actualised, built and fixed on the earth, and what remains possible (Van Wezemael, 2010a). As future goals, the data analysis and visualisation will focus on making visible the relation (and the transformations) between realised and unrealised projects of architectural competitions.

Furthermore, in conjunction with improving the visualisation in a way that facilitates study and comparison of architectural competitions in the aforementioned dimensions (e.g. to facilitate the user to select and compare the competitions, to include detailed characteristics of the projects such as address, photos, plans, etc.), future work will address the topic of a 'multidimensional' visualisation: a visualisation that does not simplify the object of study or reduce the dimensions of data, but rather a visualisation that can actively refer to the object's multidimensional relational portrait.

The openness of the above questions makes it interesting to reflect on Van Wijk's (2006) thoughts about the cooperation between users (or experts) and visualisation researchers:

> If the expert is interested in explorative visualization, then he's probably aiming at advancing the state of the art in his domain. This also means that he's not exactly sure and cannot express what he's looking for, except that he's aiming for new insights .... Insight is complex, deep, qualitative, unexpected, and relevant. (Van Wijk, 2006: 6)

This quote, on the one hand, illustrates the difficulties of this kind of research studies: we explore abstract concepts and relations between the data without a clear image of the potential end products. On the other hand these difficulties are the new territories for exploration, the invisible areas that visualisation brings to existence.

In this article, we present how the exchange of concepts between human geography and architecture provides a new way of looking at architecture. Furthermore we demonstrate that in order to explore this new way of looking, informatics – as the systematic exchange of methodologies (like the 'complexifying database' and the Moving architectures map) and research inputs – is of great value: it 'fills out' and 'gives body' to unexplored relations and thus enables an active exploration of empirical data collection for further research and a wider audience.

Concluding, the collaboration between architecture, geography and informatics is a corner stone of studying liminal spaces between disciplines related with architectural competitions and the production of the built environment: they intertwine the research of such a field with the process of giving it an intelligible form. The Moving Architectures map creates a frame that enables us to move around the datascape, to focus and 'slow down', thus making visible hidden aspects of the production of urban forms.

Note

1. The Entity/Relational (E/R) model is used as a basis to most databases and is a way of organising real-world objects in the tables of a database. The E/R model is based on the mathematical concept of the variant 'relation' because relations are more easily understood than tables. In an E/R model we can distinguish two parts:
   – the E/R diagram which is a conceptual schema. It describes an entity (object) type or relationship type. This means that a relation should contain information that actually belongs together logically
   – the logical schema which represents the 'arrangement' of information stored. The E/R diagram can be

transformed to the logical schema, which is a descriptive, written representation of the table. (Source: Geographic Information Technology Training Alliance [GITTA]: http://www.gitta.info/LogicModelin/de/html/index.html)

References

Andrienko G, Andrienko N, Heidrun S et al. (2010) Space and time. In: Keim D, Kohlhammer J, Ellis G and Mansmann F (eds) *Mastering the Information Age: Solving Problems with Visual Analytics*. Goslar, Germany: Eurographic Association, 57–86.

Boyandin I, Bertini E, Bak P et al. (2011) Flowstrates: An approach for visual exploration of temporal origin-destination data. In: Hauser H, Pfister H and van Wijk JJ (eds) *Eurographics/IEEE Symposium on Visualization 2011 (EuroVis 2011)*. Oxford, Malden: Blackwell Publishing.

Carmona M (2009) Design coding and the creative, market and regulatory tyrannies of practice. *Urban Studies* 46(12): 2643–2667.

Chupin JP (2008) Documenting competitions, contributing to research, archiving events. In: Peyceré D and Wierre F (eds) *Architecture et archives numeriques*. Geneva: Infolio, 523–544.

Chupin JP (2011) Judgement by design: Towards a model for studying and improving the competition process in architecture and urban design. *Scandinavian Journal of Management* 27(1): 173–184.

DeLanda M (2002) *Intensive Science and Virtual Philosophy*. London: Continuum.

Deleuze G and Guattari F (1987) *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press.

Deleuze G and Guattari F (2004) *Anti-Oedipus: Capitalism and Schizophrenia*. London, New York: Continuum International Publishing Group.

Frey P (1998) Histoire & archives architecturales: Elements methodologiques & informatiques. Doctoral thesis, EPFL.

Gissen D (2008) Architecture's geographic turns. *LOG* No. 12: 59–67.

Gomes LJ (2008) L'archivage numérique des projets 'Europan' comme situation d'analyse scientifique du concours d'idées en architecture, Université de Montréal, Montréal.

Guattari F (1979) *L'inconscient machinique: essais de schizo-analyse*. Paris: Recherches.

Jorn A (1954) Architecture for Life. *Potlatch* No.15.

Kohoutek R (2005) *Der unmögliche Wettbewerb. Wettbewerb! Competition! Ö. G. f. Architektur*. Wien: ÖGFA: 124–129.

Latour B and Yaneva A (2008) Give me a gun and I will make all buildings move: An ANT's view of architecture. In: Geiser R (ed.) *Explorations in Architecture: Teaching, Design, Research*. Basel: Birkhäuser, 80–89.

Lattuca LR (2001) *Creating Interdisciplinarity: Interdisciplinary Research and Teaching among College and University Faculty*. Nashville, TN: Vanderbilt University Press.

Law J (2004) *After Method, Mess in Social Science Research*. New York: Routledge.

SIA (2002) *Wettbewerbsleitung Wegleitung der SIA-Kommission 142 ingenieur- und für Architektur- und Ingenieurwettbewerbe*. Zurich: SIA.

Van Wezemael J (2010a) Transformative practice as an exploration of possibility spaces. In: de Roo G, Hillier J and Van Wezemael J (eds) *Planning and Complexity: In Depth Analysis*. Aldershot: Ashgate, 287–307.

Van Wezemael J (2010b) Modulation of singularities – a complexity approach to planning competitions. In: Hillier J and Healey P (eds) *The Ashgate Research Companion to Planning Theory*. Aldershot: Ashgate Publishing, 273–290.

Van Wezemael J, Silberberger J, Paisiou S et al. (2010) Mattering the Res Publica. *DisP* No.184: 52–59.

Van Wijk JJ (2006) Bridging the Gaps. *IEEE Computer Graphics and Applications* 26(6): 6–9.

Viollet-Le-Duc E (2010) *Histoire D'un Hotel de Ville Et D'une Cathedrale*. Whitefish, MT: Kessinger Publishing.

Volker L (2010) *Deciding about Design Quality: Value Judgements and Decision Making in the Selection of Architects by Public Clients under European Tendering Regulations.* Leiden: Sidestone Press.

Waldner A (1889) Concours pour l'etude d'un nouvel hotel des postes a Geneve-Rapport du jury. *Schweizerische Bauzeitung* XIII (24): 143–144.

Watson J (2009) *Guattari's Diagrammatic Thought*. New York: Continuum.

Weick KE (2006) The role of imagination in the organizing of knowledge. *European Journal of Information Systems* 15(5): 446–452.

Appendix: SQL scenarios

Figure a
Example 1:
Recurrence of jurors

Observations	SQL Query	Explanation
Are there jurors that were involved in a post office competition from 1885 to1899 three or more times? What is the technical background of those persons?	Select 'Juror Name', 'Juror Background' from 'Jury per competition' group by 'juror name' having count (*) ≥ 3	Trace the name and the technical background of the jury members that appear as jurors more then 3 times

Figure b
Example 1: Table

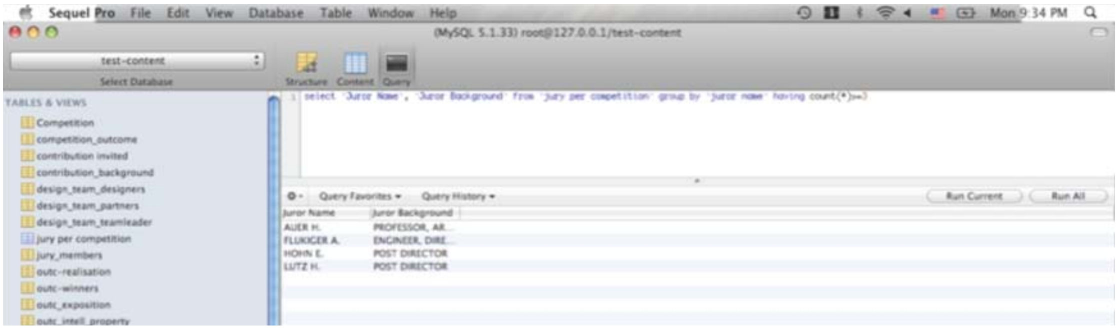
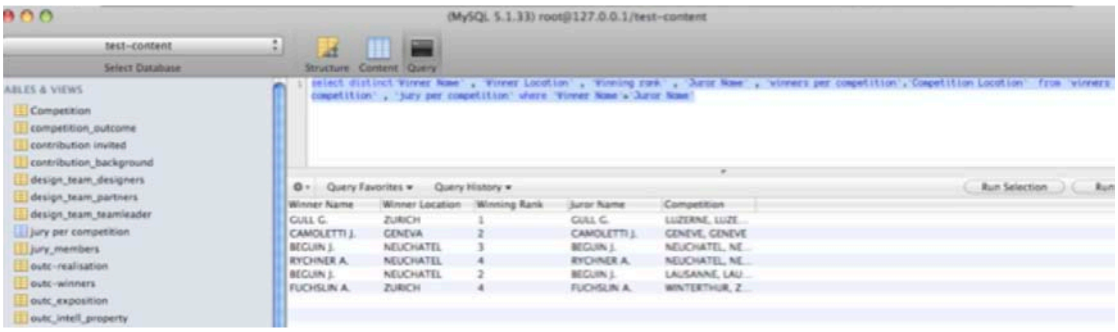


Figure c
Example 2: Guilt monopolising the post office competition in the nineteenth century

Observations	SQL Query	Explanation
There are people that enter these competitions as jurors in one competition and as participants in another.	Select distinct 'Winner Name', 'Winner Location', 'Winning rank', 'Juror Name', 'Winners per competition'. 'Competition Location' from 'Winners per competition', 'Jury per competition' where 'Winner Name' = 'Juror Name'	Select the names, location for Jurors and Winners and their prize rank from the combinatory tables 'Winners per competition', 'Jury per competition', when the name of the Winner is the same as the name of the Juror

Figure d
Example 2: Table



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An Eyeful of Sound
Using animation to document audio visual synaesthesia

Abstract

> I don't know if you've ever heard a goat eating carrots? It's almost too much, it's so lovely.[1]
>
> To be honest, um, I see things really flowingly … within my head … very flowingly, and forward moving, and really hard to describe … (Julie Roxburgh and Emma Suddaby, *An Eyeful of Sound*, 2010)

What would it be like to have abstract animated visuals accompanying every sound and musical passage that you ever heard? This was the basis of the filmic investigation into audio-visual synaesthesia, which culminated in the making of a short animated documentary, *An Eyeful of Sound*. The aim of the project was to convey the immersive experience of having audio-visual synaesthesia to a wider audience. This paper looks at the problems inherent in doing so, how the collaborative process worked, and what effect this had on the directorial role. It will also discuss more broadly why non-fiction animation has the particular qualities that are suited to taking such an intensely subjective viewpoint.

An Eyeful of Sound (2010) was a Wellcome Trust funded collaborative project between synaesthetic people, researchers and filmmakers. It won the 'Nature' Award for Scientific Merit at the 2010 Imagine Science Film Festival, New York, as well as several other international prizes.

Keywords
animated documentary, animation, non-fiction animation, synaesthesia, synesthesia

As an animator it seemed to me that having audio-visual synaesthesia would be like having an abstract animated film playing permanently in your head. What would it be like to have Oskar Fischinger style visuals accompanying every sound and musical passage that you ever heard? That was the basis of this investigation into this brain trait, which culminated in the making of *An Eyeful of Sound*.

An Eyeful of Sound was an animated film commissioned by the Wellcome Trust and made in collaboration with neuro-psychologist Dr Jamie Ward (University of Sussex) and a group of people with audio-visual synaesthesia. The idea was to use animation to convey to the audience the intensely subjective and immersive experience of those who process the world this way; to show not tell the audience what having this extra-sensory processing is like. The film attempted to turn the uniquely subjective synaesthetic visuals that were triggered in the interviewees' brains into accurate visual external representations. This paper looks at the problems inherent in doing so, how the collaborative process worked and what effect this had on the directorial role. It will also discuss more broadly why non-fiction animation has the particular qualities that are suited to take such an intensely subjective viewpoint.

Rather than the pejorative word 'condition' I will use the term 'trait' to describe synaesthesia throughout. Condition implies the need for medical attention, whereas none of the synaesthetic people I have ever interviewed or read about experience their synaesthetic status as any kind of drawback or disability. Indeed, as

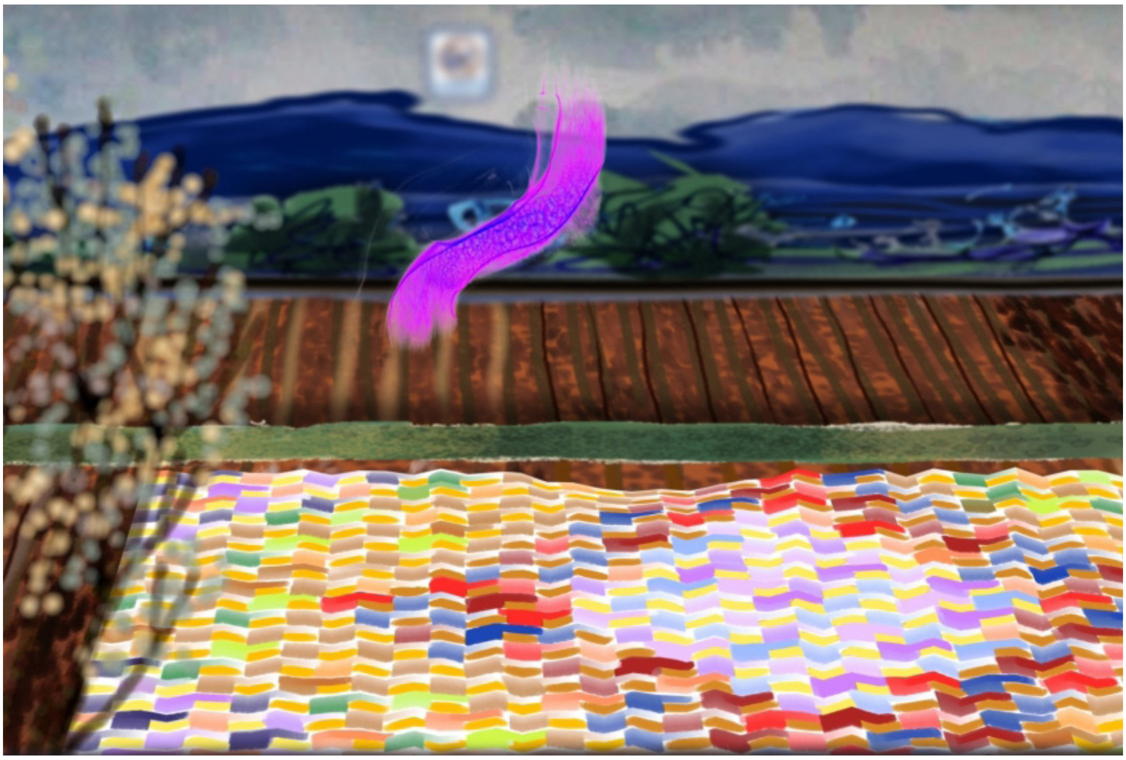

Figure 1 Still from *An Eyeful of Sound* (2010)

Jamie Ward (2008: 3) notes, 'On the contrary, to a synaesthete, it seems like there is something *absent* in the experiences of the people around them'.

Synaesthesia is a brain trait where when one sense is stimulated more than one sense will react. A suggestion for why this might happen is that in a synaesthete's brain senses may have more neural connections (Harrison, 2001: 20–22) than in a non-synaesthetic brain, so they will experience a second (third, fourth ...) sensory perception simultaneously with the one being externally stimulated. Synaesthesia may manifest in many different ways. This can mean that synaesthetic people might have coloured days of the week (e.g. Monday being red, Tuesday being yellow, etc.), coloured letters, words or numbers[2] (grapheme-colour synaesthesia), they may smell or taste sounds[3] or even feel touch when they see others being touched (mirror-touch synaesthesia). Any of the senses can be linked in this way and for some people many senses can be linked, for example one of the interviewees we worked with could hear, see *and* physically feel sounds. Equally, senses can be linked in both directions, for example one of our subjects could see a red traffic light, and she could hear the sound that that particular shade of red triggered in her head, but then subsequently she saw another colour triggered by that sound – and it wasn't red.

Audio-visual synaesthesia can be experienced *associatively* (the subject may hear the word Thursday and see that it is bright pink in their 'mind's eye') or they may *project* the colour externally onto the object (so they would hear 'Thursday' and see the colour pink outside of their body). This associator-projector[4] dichotomy is an interesting one as it echoes stages of the creative animation filmmaking process; from imagining how it will look to making the image in the real world – and literally projecting it onto a screen.

Synaesthesia was first studied in the late nineteenth and early twentieth centuries but then had a hiatus for almost 50 years when very little was published on the subject (Harrison, 2001: 26). However, it has enjoyed a resurgence in interest in recent years, and, according to Harrison 'the rise of cognitive psychology in the 1960s allowed the psychological (and neuroscientific) community to indulge once again in speculation about the nature of "states of mind"' (2001: 53). Synaesthesia is now recognised as a documented brain trait that can give valuable broader insights into how everyone's brains work. It is important to note that each person who has it experiences that synaesthesia uniquely. Whilst a C note played on a cello may appear as a gold silky sinuous shape with metallic glints moving from left to right to one synaesthetic person, to another (with exactly the same kind of synaesthesia) it may be a rough brown spongy blob shooting off from right to left.

Animated non-fiction has a patchy history, which interestingly follows a similar time-scale to the study of synaesthesia. Animation has been used in a non-fiction context within filmmaking from the earliest development of cinema.[5] As narrative fiction in general began to dominate commercial film production in the twentieth century there was a long period when animation was 'ghettoised'[6] into a Disney bubble, before regaining status and interest in the late twentieth century.[7] Animation has been used to visualise abstract scientific or technical concepts, from Max Fleischer's hand drawn 2D animated training films such as *How to Read an Army Map* (1918), to the digital animation used in documentary series such as *Wonders of the Universe* (2011). In this mode animation can visually simplify and explain to an audience in a similar way to a textbook illustration, a version perhaps of what Bill Nichols (1991: 34) calls the 'expository' mode of documentary, with the images intended simply to educate and inform.

Animation has also been used to perform a 'mimetic substitution' (Honess Roe, 2010), to represent lost or non-existent footage. For example Winsor McCay's drawn animation *The Sinking of the Lusitania* (1918) which was screened as part of contemporary newsreels in the absence of live action footage of the event, or *Walking with Dinosaurs* (1999) which was presented in a documentary format as if the events depicted were profilmic.

Finally animation can also be used in a non-fiction sense to detail an internal perspective, the 'subjective mode' (Wells: 1997). Tim Webb's film *A is for Autism* (1992) was made collaboratively with the autistic subjects of the film, conveying a set of personal experiences. Here the medium is used for its ability to show the world from an intensely subjective perspective not using photo-realism but taking advantage of animation's ability to utilise different styles and types of animation, including hand drawn and stop motion.

In *An Eyeful of Sound* animation can be said to have been used purely as a visual aid (explaining to some degree the scientific context to this brain trait), subjectively (using a personal and internal perspective) and performing a mimetic substitution (the synaesthetic reactions which cannot be photographed). However subjective the film may be, the filmmaker is *not* the subject of it and neither is it from their perspective. It

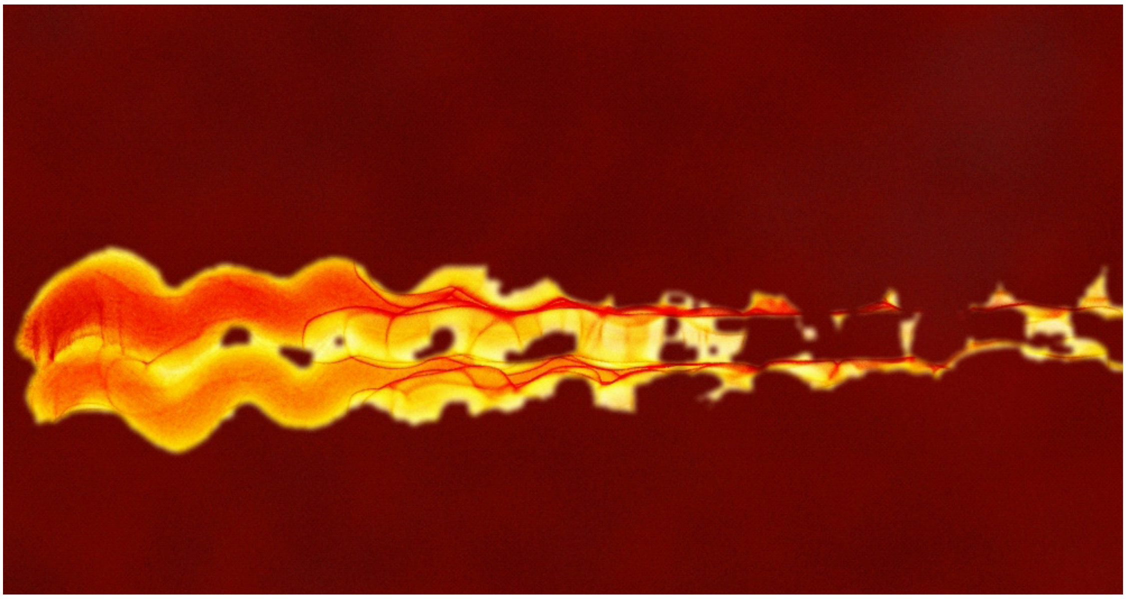

Figure 2 Tessa's synaesthetic reaction to a violin note

can be said to be illustrative, yet it was intended to do more than just record a sound track and illustrate it. The mimetic substitution must be taken on trust, since only the subject of the film can authenticate its accuracy. This film could be seen therefore both as an amalgamation of these modes and an extension of them. Paul Ward argues that animation is good at representing the internal and subjective in the documentary genre, saying that it 'can perfectly trace the contours of … a shifting and rapidly condensed thought process in a way that is out of reach for live action' (2005: 91). Animation has the ability to express and transgress the 'boundary between seeing and imagining' which VS Ramachandran (2011: 86) describes as being the most elusive in neurology (and which he studied by looking at the reactions of a projector synaesthete). Because of that transgressive ability it can deal with non-fiction subjects, like synaesthesia, which would be impossible to represent indexically.

In order to make this film the usual perspective of artist/director had to be shifted. *An Eyeful of Sound* was to be an animated documentary, arguably 'a creative treatment of actuality'[8] in its broadest sense. It was intended to immerse the audience in the experience of synaesthesia. The role of the artist therefore became aligned more with the role of a facilitator or reporter, suppressing personal artistic intent in order to better represent to an audience what the interviewees were explaining.

First of all I collected a group of about 60 everyday distinct sounds, for example; a pencil falling off a table, a car being remotely locked, an apple being bitten into, the sound of someone walking through tall grass. The sounds were chosen after discussion with the synaesthetic subjects who offered some of the sounds that induced their synaesthesia most strongly (Julie has a particular fondness for the sound of someone in squeaky shoes walking along a linoleum covered corridor). The methods used to capture their synaesthetic responses to the stimuli were threefold; firstly to play sound to the interviewees over headphones and get them to describe it verbally (which was recorded), secondly to get them to draw or paint a picture of the sound as they heard it, and finally to choose the exact colours of the sound from a Munsell colour chart. Thus the sounds that the composer and sound designer would be using in the sound track could be cross-referenced visually from this evidence and the sound could be animated 'correctly' (from that synaesthetic person's perspective). Once a digital image had been made of the synaesthetic response it would be sent back to that synaesthetic person for comment and critique; to see how accurate it was. In this way we attempted to facilitate an external representation of their necessarily internal and subjective experience.

We also interviewed Dr Jamie Ward to give another perspective of the way in which synaesthesia might work in the brain. This provided a counterpoint to the intensely subjective stance, presenting more of an imitative perspective as discussed earlier. Although the film includes the words of a leading scientist in the field, his opinion is not valued more highly than the experiences of the other interviewees, who comment on (and occasionally contradict) his words. This was to undercut any notion of a 'voice of god' narrator, and also to represent a non-synaesthete in the film as a counterpoint to the highly synaesthetic reactions. At one point he says rather wistfully; 'If I were to have synaesthesia I would have the coloured music variety … to actually experience that way I think would be wonderful'. He clearly does not experience synaesthesia yet the audience can via the substitutive animation. By using animation, which is primarily a visual medium, I can balance the authority of the verbal (which is the domain of the documentary) and allow the actual (visual) experience of synaesthesia to upstage the

Figure 3 Tessa listening to sounds and drawing her response

Figure 4 Julie's original sketch of the sound of a cockerel crowing and a still from my animated interpretation of it

gravitas that might be assumed by the sound track.

Animation is essentially a laborious and solitary process of working frame by frame. Twenty-five frames are needed for one second of moving image, and so this ten and a half minute film was made up of 15,625 frames. Given the constraints of this medium the process had to be accessible and clear to the geographically scattered participants. Whenever a milestone was reached in the animation process (making a mock-up of the digital image, animating a section, and so on) they would be sent a DVD of the image and sound together so that they could feedback on how 'right' it was. We also set up a blog about the production which the film participants were made administrators of. These channels of communication allowed them to comment on work in progress and make specific the changes that they felt were necessary, for example:

> The beginning is fine, but really it would be better just to have a thick white cloud moving continuously from left to right with the little silvery things as they are. It is the flower-like images which are wrong. What is the final sound of silver? It looks like a very thin vertical pole. Black balls are not there in the music at all![9]

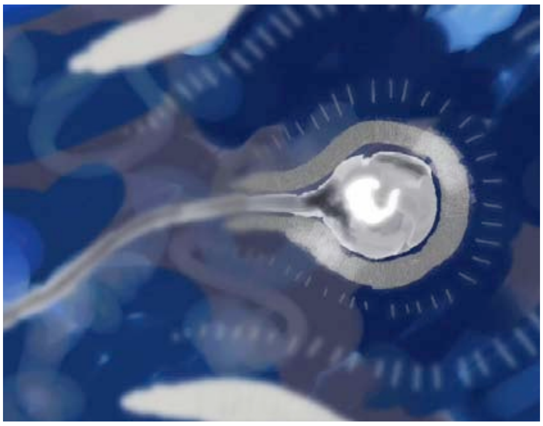

Figure 5 Tessa's synaesthetic reaction to the sound of a balloon deflating

If the animation was going to claim to be able to translate unique perceptual processing into external images then there had to be a robust system of feedback. Thus at every stage of the film's production; static images, moving animation, composited animation and final film, the participants were given an opportunity to change or improve the correctness of the images made.

Evidencing the veracity of the material was key to the film's integrity. In order to claim any substance for the authenticity of the images we had to endeavour to make the animated representation of the synaesthetic reaction as close as possible to the original experience. Ultimately the representation is just that, not an exact replica of the experience but an approximation given the limitations of the medium and the humans using it.

There were several practical problems encountered when collecting and verifying material for this project. As discussed, in the role of facilitator/interpreter of their subjective interior experience I had to completely sublimate my own ideas and opinions about the clips as an artist and repress any desires to alter, smooth over or re-interpret the imagery being described. An example of this was Tessa's reaction to the sound of a balloon deflating, which she saw as a huge metallic silver sperm shape. Her reaction to the sound of a loon call was what looked to me like a set of midnight blue ovaries. I would not have chosen those images for the film since they have a very different resonance for most of the rest of us, but they had to be retained as the 'truth' of what she saw. I was on one side of the boundary between imagining and seeing and she was on the other.

All the synaesthetic people we interviewed found it easier to react to sound when it was part of a more complex piece of music, rather than individual sounds. We only discovered this when we went back to play them the rough cut with sound and image together. This was unexpected and made it trickier to review which bit of visual information went with which sound, they however found this easier than single sounds. Related to this, the layering of sounds on top of

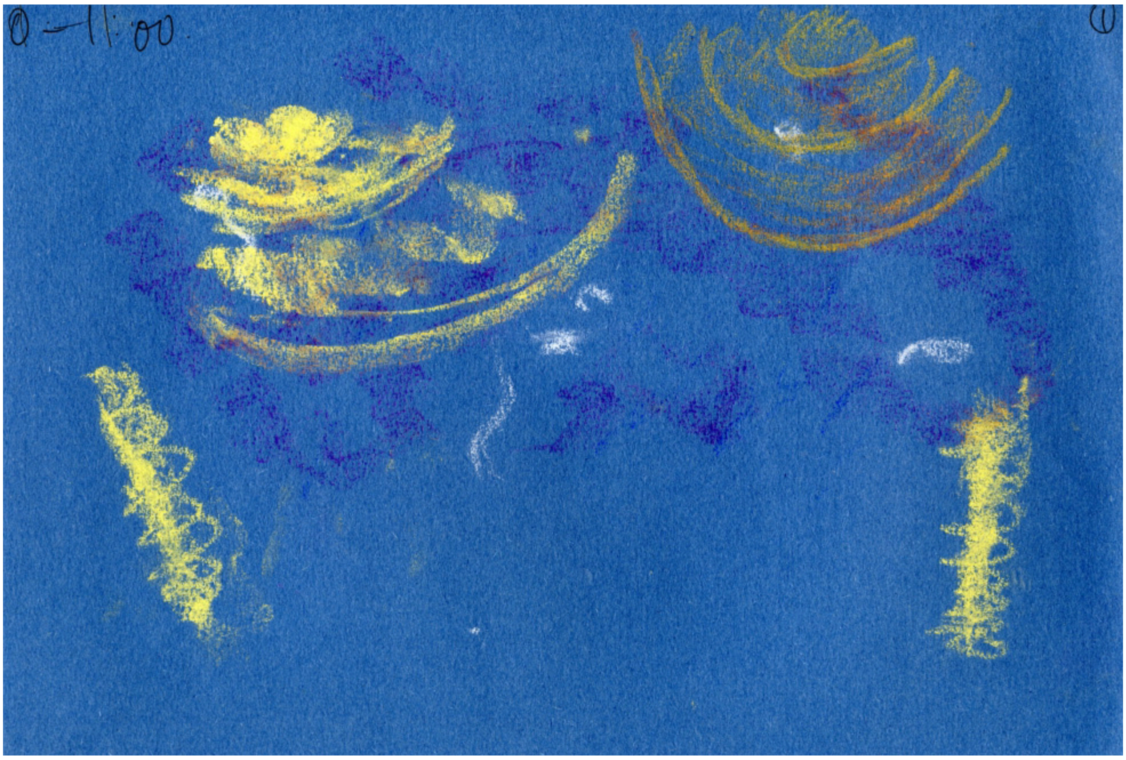

Figure 6 Emma's drawing of a minute of the mixed sound track

each other could produce a different reaction to the sound individually, so I often found myself sitting in front of a computer screen trying to translate what looked like a Kandinsky painting into individually animated clips.

Working with the sound designer and composer we layered different synaesthetes' sound/visuals together during the sound track, making artistic decisions about what worked better or what would be more visually interesting (connecting sound and synaesthetic image). For example there may have been a sound which we had more than one visual reaction for, in which case the reaction was chosen that was more visually stimulating, interesting to look at or that fitted in best with the flow of the film. This artistic/directorial overview was the point where the shared collaborative process had to end, ultimately the film did have a director and that role afforded the opportunity to have the final word on (and ultimate power over) the material via the sound and image editing. However we tried to make this as transparent a process to the collaborators as possible.

The synaesthetic subjects of the film found the external visualising of their internal idiosyncratic synaesthetic reactions exciting. Two of them reported using the DVDs I sent them of their animated reactions as explanatory tools for their partners, families and friends.[10] When they saw the final film screened in a cinema[11] they spent some time picking out 'their' reactions on screen. Even though there was a selection of different people's synaesthesia being represented, Emma said that the film was 'made very synaesthetically' and Tessa reported that her husband now really understood what synaesthesia was after seeing the documentary. This was a challenging project which went into territory far removed from the popular concept of the animated cartoon. Like synaesthesia, animated non-fiction is an area which has slowly gathered credibility as an area for study and interest after languishing for some years. The conceptual and the perceptual, the telling and the showing, the imagining and the seeing are all areas that non-fiction animation can simultaneously inhabit and that develop the scope of what the form is able to do. The film discussed may be perceived as realistic to the subjects of the film and abstracted and dreamlike to a non-synaesthetic audience; visualisation and art work at the same time. This duality is at the root of animated non-fiction and part of what makes this genre such an interesting one to me as a filmmaker and researcher. My intent in bringing these two areas together is to investigate what is unique about animated documentary as a form, what is it for and what it does. By answering this question I am not seeking to prove that animated documentary is the best vehicle by which to represent a brain state such as synaesthesia. Instead I am using the arena of representing subjectively experienced brain states through theory and practice as a way to interrogate the boundaries and definitions of 'animated documentary' and the codes that inform it.

Notes

1. Julie Roxburgh, synaesthete, *An Eyeful of Sound* (2010).
2. See Duffy (2001: 7–15) for an autobiographical description of the author's developing childhood awareness of her synaesthesia.
3. See Ward (2008) for a discussion of synaesthete James Wannerton's taste-word synaesthesia.
4. Dixon et al., 2000: 335–343.
5. For example Alexander Shiryaev's recently discovered films from 1906 to 1909 documenting his choreography for the Russian Ballet (Robinson, 2009).
6. Paul Wells (1997: 3) talks about Disney's stranglehold over the form 'by overshadowing its history and creating an orthodox style' during this period.
7. The first animated documentary conference 'Animated Realities' was held at the University of Edinburgh in 2011.
8. John Grierson, famously defining the new genre in his review of *Moana*, in the *New York Sun*, 1926.
9. Julie Roxburgh, *An Eyeful of Sound* [e-mail] Personal communication, June 2009.
10. See http://vimeo.com/20011009 for an example of this.
11. London Short Film Festival 2010.

References

Dixon MJ, Smilek D and Merikle PM (2000) Not all synaesthetes are created equal: Projector vs. associator synaesthetes. *Cognitive, Affective and Behavioral Neuroscience* 4.

Duffy P (2001) *Blue Cats and Chartreuse Kittens: How Synesthetes Color their Worlds*. New York: Henry Holt.

Harrison J (2001) *Synaesthesia: The Strangest Thing*. Oxford: Oxford University Press.

Honess Roe B (2010) Inadequate indexes: Epistemology and medium-specificity in animated documentaries. In: *Visible Evidence Documentary Studies Conference XVII*, Bogazici University, 9–12 August, Istanbul (unpublished).

Nichols B (1991) *Representing Reality*. Bloomington: Indiana University Press.

Ramachandran VS (2011) *The Tell Tale Brain: A Neuroscientist's Quest for What Makes Us Human*. New York: Norton.

Robinson D (2009) Alexander Shiryaev: Dance to film. *Film History* 21(4): 301–310.

Ward J (2008) *The Frog Who Croaked Blue: Synaesthesia and the Mixing of the Senses*. Hove: Routledge.

Ward P (2005) *Documentary – the Margins of Reality*. London: Wallflower Press.

Wells P (1997) *Understanding Animation*. London: Routledge.

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Interdisciplinary engagement through artistic visualisation

Process and practice

Abstract
In the following paper I will examine what insights the information visualisation community could draw from studying how artists and other creative practitioners use visualisation as part of their work. After a brief overview of Viégas and Wattenberg's analysis of artistic experiments with visual methods and tools, the paper attempts to resolve some of the problematic assumptions that underpin their analysis in the hopes of providing a more inclusive framework for understanding how visualisation can be used in other disciplinary contexts. In order to accomplish this, I argue that visualisation should be understood as both process and practice. The last section of the paper applies this framework to a case study in order to show how it might enable the information visualisation community to work with other disciplines.

Keywords
art, interdisciplinary, practice, process, visualisation methods

Introduction
There is a growing recognition of the value of interdisciplinary collaboration between art and science in the field of information visualisation (Diamond, 2010; Kemp, 2005; Wilson, 2010). Frenanda B. Viégas and Martin Wattenberg (2007), for example, argue that the information visualisation community could learn to better communicate 'a particular point of view' by studying how contemporary artists experiment with visualisation tools and methods. The two are careful to point out that the resulting artworks do not constitute information visualisation, arguing that artists commit 'various sins of visual analytics' (Viégas and Wattenberg, 2007: 190) in the process of producing works of art. But their analysis leads them to recognise how information visualisation processes can be adapted to disciplines outside the field of information visualisation to communicate points of view. Their overview of a number of recent artistic projects leads the authors to ask: 'Should data visualization researchers investigate ways to support making a point, as well as disinterested analysis?' (Viégas and Wattenberg, 2007: 191). This paper makes the argument for another insight, that an examination of artistic appropriations of visualisation tools and methods could bring the visualisation community beyond visual analytics: how these tools and methods can be used to engage with the situated meaning of different disciplinary contexts. Such an insight depends on an understanding of visualisation as both *process and practice*. The first section will further develop the distinction and interdependence between process and practice for the artistic use of visualisation methods followed by a case study that provides a more

detailed illustration of how this distinction can be applied.

Adapting information visualisation processes to situated practice

One of the key issues that Viégas and Wattenberg's analysis must resolve is the interdisciplinary challenge of selecting and interpreting the results of work in a discipline that is not their own (Strathern, 2006). Their solution is to devise two selection criteria that artworks must meet in order to be considered. The first is that the works must be based on 'actual data' (Viégas and Wattenberg, 2007: 189) in order to qualify as drawing inspiration from visualisation processes. For their second criteria, the authors avoid the tricky (and centuries old) challenge of determining what is or isn't art by drawing on a rather institutionalist definition (Dickie, 1969) based on intent and recognition rather than aesthetic criteria: 'our working definition in this paper is that artistic visualizations are visualizations of data done by artists with the intent of making art' (Viégas and Wattenberg, 2007: 184–185).

The limitation of this institutionalist approach appears if we shed the assumption that using visualisation processes for the purposes of communicating a point of view necessarily requires a particular field of expertise (a theme which is explored by Viégas and Wattenberg in non-art related disciplines, see Viégas, Wattenberg and Dave, 2004). By taking the institutionalist view of art, one runs the risk of replicating the disciplinary biases of those who determine who is and who isn't an artist. Scholars of culture and media including Henry Jenkins (1992) and Chris Atton (2001) provide a continually growing body of evidence that making meaningful cultural artefacts is not limited to experts of culture. An example of how to apply a broader conceptualisation of creative uses for visual methods is David Gauntlett's research into audience engagement with media. Rather than using visual methods to represent data, Gauntlett's research participants are invited to respond to his questions by creating visual representations. His research not only recognises how people are already familiar with processes of visual representation as a means of communication, but also that how people choose to represent something can provide valuable insights into social phenomena like identity formation (Gauntlett and Holzwarth, 2006) and how they engage with the media (Gauntlett, 2005).

According to the criteria set by Viégas and Wattenberg, the results of Gauntlett's approach cannot be considered information visualisation because the works do not draw from actual data nor are the creators artists. However, Gauntlett's work may provide an insight for information visualisation researchers through his understanding of how the situated use of visual methods can generate meaning from the act of making rather than simply from its resulting artefacts. In order to explore this distinction in greater detail, I will use the term 'practice' as defined by Brown and Duguid (2002: 91–115) as a way to refer to shared situated meanings that stem from and enable process.

An understanding of the importance of practice is well-established in some artistic circles including community arts (Kuppers, 2007) and Do-It-Yourself (DIY) movements in digital media (Lievrouw, 2008) in which artists collaborate with individuals or groups of individuals to produce works of art. In the field of artistic appropriation of visualisation processes, Tom Corby (2008: 464–466) points to Christian Nold's *Bio Mapping* project and Lucy Kimbell's *Pindices* as examples of how soliciting public participation in artworks can generate visualisation data from the 'bottom-up'. For Corby, these two projects:

> … produce a visualization practice that models a role for the artist/visualizer as an enabling agent, rather than a top-down interlocutor insofar as contexts for participation in information visualization processes are designed that provide ordinary members of the public with ways of grasping, accounting for and investing in their lives. (2008: 466)

In this quote, Corby addresses the overlapping relationship between process and practice: the artist's role is meaningfully transformed by adapting visualisation processes that engage participants in the context of specific artistic performances. In this sense, one of the things that the information visualisation community can take away from these cultural and creative practitioners is not simply an 'artistic' way of visually representing a point of view, but understanding how one can adapt visualisation processes and apply them to contextualised, meaningful practices that elicit points of view. The following case study attempts to further elaborate this insight.

Case study – Proboscis' *bookleteer* platform

In 2008 I began working with Proboscis, a non-profit artists' group whose interests included collaborative exchanges with various disciplines. As their website stated: 'Collaboration is at the core of our creative practice and ethos: involving innovative collaborations in fields as diverse as medical research, music, community development, housing and urban regeneration, pervasive computing, mapping and sensor technologies' (Lane, 2011a).

One of their projects – *bookleteer* – was a digital platform designed for participants interested in collecting, publishing and disseminating stories. The idea originally stemmed from a series of commissioned artworks known as *Performance Notations* in 2000 in which members of Proboscis developed an imposition system for folding and cutting regular sheets of paper into a small notebook. The project developed into a process for generating and printing what Proboscis subsequently referred to as *Diffusion Shareables*: notebooks and paper cubes (StoryCubes – see Figure 1) that could be inexpensively designed and used in a number of different contexts to make and share stories. (Videos demonstrating part of the process for making one of these shareable are available at: http://vimeo.com/channels/bookleteer.)

In 2003 a digital platform was developed in order to allow people to remotely access the software to design and print these Shareables. According to their website (http://diffusion.org.uk/ Lane, 2011b), Proboscis directly collaborated with over a hundred different contributors over the next 10 years. By 2010, over 225,000 Diffusion Shareables were downloaded from the platform. The most recent iteration of the platform, *bookleteer* (Lane, 2011c), was a web application developed through a Technology Strategy Board grant awarded in 2009.

While Proboscis did use the platform to produce their own material, including drawings and photographic documents, most of its iterations involved collaborations with other practitioners

Figure 1
An example of Diffusion Shareables – StoryCubes

to develop new ways in which the Diffusion Shareables could be used. These collaborative relationships took many forms: Proboscis commissioned projects, invited people to participate in workshops, or maintained online relationships with users.

According to the criteria set by Viégas and Wattenberg, most individual Diffusion Shareables produced by participants would not qualify as information visualisations because they did not draw on data to produce visualisations. However, Proboscis have collaborated with a number of people who have used the Shareable as part of visual methods to engage respondents in order to produce visual material. In the following section, I will briefly discuss three different ways in which Shareables were used. These examples are only a sample of the kinds of ways in which *bookleteer* has been used and in no way cover the full range of uses.

Example 1 – Articulating futures

While completing a Masters in 'Creative Practice for Narrative Environments' from Central Saint Martins in London, Niharika Hariharan worked as an intern with Proboscis in 2008. She subsequently continued to collaborate with them as an associate, learning how to use the *bookleteer* platform.

After returning home to India, Niharika took an interest in pedagogical methods in Indian classrooms. She started developing a series of workshops in November 2009 with the objective of challenging how Indian elementary school students learned in class (Hariharan, 2009). Part of the problem Niharika identified was that students were asked to transcribe verbatim lessons in generic workbooks. She felt that this process involved little opportunity for students to creatively and critically engage with the material covered. To address this issue, Niharika designed a set of Shareables as part of workshops that would encourage students to reflexively engage with taught material in class. In an interview with her, she summarised how the Shareables were presented to students as follows: '… this is just like your classroom book that allows you to do what you want and actually develop your own point of view by recording information that you feel is relevant not what is taught'.

The Shareables were therefore designed and used in contradistinction to existing workbooks. By producing a set of tools that required a degree

Figure 2. Image of *bookleteer* workshop

of visual representation and creative writing as part of an unconventional process, Niharika developed a situated practice that she hoped would foster a more active participation on the part of students in their learning environment.

Example 2 – Greenhill Digital Storytelling Guide

Gillian Cowell is currently a PhD student in the School of Education at the University of Stirling conducting research into the 'complexities of processes of civic learning of individuals and social groups living together in the same geographic area' (Cowell, 2011). She first encountered the Shareables online while doing research for her Masters degree. At the time, she was seeking online tools that could help her to develop more engaging ways to collect information from residents of the communities she was researching. She also hoped the Shareables would provide an inexpensive and simple solution for feeding the results of her research back to the community.

After ordering a few of the different Diffusion Shareables via the website, she decided to use one set of Shareables known as eBooks as a way to disseminate the results of her research back into the local community; when presenting her research to people who lived in the local communities she studied, she would hand out custom designed eBooks that provided information about her findings, including copies of photographs and artworks produced by members of the community. When I interviewed her on 30 July 2010, she had started exploring with Proboscis how to use new high-quality printing methods and paper for the eBooks as a way of publishing historical accounts of local residents that could also convey the importance and uniqueness of the their stories.

Case 3 – Cambridge Curiosity and Imagination

Cambridge Curiosity and Imagination is made-up of a network of associates who deliver a number of group facilitation events in and around the city of Cambridge. Ruth Sapsed, its director, had initially tinkered with the idea of using Shareables by visiting the website but soon decided that the only way she could determine if and how she could use these tools was to attend one of the workshops organised by Proboscis called *Pitch Up & Publish* (see Figure 2). These workshops were organised by Proboscis as a way of introducing *bookleteer* to new users. Interested individuals were invited to their studio in Clerkenwell where members of Proboscis demonstrated how the platform could be used. In Ruth's case, it was also an opportunity to hear from other attendees about how they hoped to make use of the platform.

For Ruth, Cambridge Curiosity and Imagination's mandate included provoking people who attended their events to think differently about their work. She felt that Diffusion Shareables were well suited for this kind of provocation because they helped the workshop facilitators to generate unfamiliar ways for people to put their ideas down on paper and share them with others. '... this idea of using these kind of very low-tech, simple resources as a way of encouraging people to share and come play and come try things out'.

Synthesis

In each of the three examples above, the individuals who worked with Proboscis' platform not only used it in different contexts but they also learned to use the platform in very different ways. In the first example Niharika learned to use the platform by working with Proboscis, while the other two examples involved learning about the materials online and testing ideas independently or in workshops. These different learning approaches, in combination with each of the examples' different disciplinary backgrounds and working environments goes some way to explaining why the process for printing and making Diffusion Shareables as initially designed by Proboscis were adapted is such distinct ways.

But in all of the cases encountered over the course of the research including the three above, people used the Shareables as a way of disrupting or challenging what they believed to be an established routine. These disruptions were not designed to improve the routines –most interventions were temporary and ephemeral – nor did the resulting works convey Proboscis' particular point of view. However, the way in which people designed and applied processes for using Diffusion Shareables in different contexts served at once to highlight the implicit constraints of the established processes and also enabled the participants to reflexively develop and represent their point of view in a way that was not previously available to them. While in many cases the visualisation methods used were limited, the very act of using a different process challenged tacit expectations of how these activities should take place. One could therefore argue that the *bookleteer* platform has developed through a collaboration between its artist-creators and various communities of practice as a process for instigating reflection and analysis by interrupting established processes within these communities through creative methods including visualisation.

Artistic platforms and collaborative processes like the one developed by Proboscis might therefore be of use to the information visualisation community in contexts where simply communicating the results of visual analytics or a particular person's point of view is insufficient, and a more open-ended dialogue with other communities is required. Although the particular processes presented in this paper emphasised disruption, one could certainly imagine other forms of meaningful engagement that would be helpful.

Conclusion

This paper set out to examine how the information visualisation community could gain insights from the way in which its methods and tools are used in different disciplinary contexts with a particular emphasis on artistic collaborations. It stressed that future research in this field must be careful to avoid disciplinary assumptions of who is able and who is unable to appropriate visualisation for purposes other than visual analytics, particularly in terms of expressing a particular point of view. The paper argued that one way in which this would be possible is by understanding visualisation as both a process and a practice.

References

Atton C (2001) *Alternative Media*. London: Sage.

Brown JS and Duguid P (2002) *The Social Life of Information*. Boston: Harvard Business School Press.

Corby T (2008) Landscapes of feeling, arenas of action: Information visualization as art practice. *Leonardo* 41: 460–467.

Cowell G (2011) *School of Education Research Student: Gillian Cowell* [online]. Stirling: University of Stirling. Available at: http://www.ioe.stir.ac.uk/research/Students/GillianCowell.php (accessed 20 January 2011).

Diamond S (2010) Lenticular galaxies: The polyvalent aesthetics of data visualization [online]. *CTheory* cds002. Available at: http://www.ctheory.net/articles.aspx?id=651 (accessed 1 March 2011).

Dickie G (1969) Defining art. *American Philosophical Quarterly* 6: 253–256.

Gauntlett D (2005) Using creative visual research methods to understand media audiences. *MedienPadagogik*. Available at: http://www.medienpaed.com/04-1/gauntlett04-1.pdf

Gauntlett D and Holzwarth P (2006) Creative and visual methods for exploring identities. *Visual Studies*, 21: 82–91.

Hariharan N (2009) *Articulating Futures* [online]. Available at: http://articulatingfutures.wordpress.com/ (accessed 20 January 2011).

Jenkins H (1992) *Textual Poachers: Television Fans & Participatory Culture. Studies in Culture and Communication*. New York: Routledge.

Kemp M (2005) From science in art to the art of science. *Nature* 434: 308–309.

Kuppers P (ed.) (2007) *Community Performance: An Introduction.* London: Routledge.

Lane G (2011a) *Proboscis* [online]. London: Proboscis. Available at: http://proboscis.org.uk/ (accessed 20 January 2011).

Lane G (2011b) *Diffusion* [online]. London: Proboscis. Available at: http://diffusion.org.uk/ (accessed 20 January 2011).

Lane G (2011c) *bookleteer* [online]. London: Proboscis. Available at: http://bookleteer.com/ (accessed 20 January 2011).

Lievrouw L (2008) Oppositional new media, ownership, and access: From consumption to reconfiguration and remediation. In: Rice RE (ed.) *Media Ownership: Research and Regulation*. Cresskill, NJ: Hampton Press.

Strathern M (2006) A community of critics? Thoughts on new knowledge. *Royal Anthropological Institute* 12: 191–209.

Viégas FB and Wattenberg M (2007) Artistic data visualization: Beyond visual analytics. *Proc. of HCII '07*: 182–191.

Viégas FB, Wattenberg M and Dave K (2004) Studying cooperation and conflict between authors with history flow visualizations. *CHI 2004* 6(1): 575–582.

Wenger E (2000) Communities of practice and social learning systems. *Organization* 7: 225–246.

Wilson S (2010) *Art + Science Now*. London: Thames & Hudson.

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Listening to the invisible
Sonification as a tool for astronomical discovery

Abstract
Sound has been used for scientific investigation for many years; the stethoscope and the Geiger counter are just two examples. Sonification is a method of transforming data into sound. The listener can then explore the data sonically, which can reveal hidden structures and relationships not apparent through visualisation. This paper discusses the advantages of sonification and introduces the reader to techniques such as audification, parameter mapping and model-based sonification. It provides case studies of astronomy-based sonification and concludes with a brief discussion of current work on the sonification of radio astronomy data as part of the Search for Extra-Terrestrial Intelligence (SETI).

Keywords
astronomy, audification, interdisciplinary, parameter mapping, science, sonification

Introduction
Just for one moment, close your eyes and listen.

What cues about your environment can you establish just by listening? Are you sat in large reverberant hall or a small-enclosed room? Can you hear a clock ticking? In what direction is the clock? We are often unaware of the richness of information sound can portray to us. For example, if we pour water into a vessel it will resonate with increasing pitch, providing an acoustic indication of its fullness. When driving a car we often use the sound of the engine to anticipate changing gear.

Sonification describes a process where raw data is analysed or explored through the medium of sound. In Greg Kramer's 'Sonification report' this is defined as 'The transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation' (Kramer et al., 1999).

Sonification is a series of techniques that take data as an input and generate sound as an output. Generally the input data is a numeric series such as a column of a spreadsheet, and it can be multidimensional. The sonification algorithm is a computer program that transforms data into sound. This algorithm can be implemented in a traditional programming language, such as C++/Java, or a graphical based environment such as MAX/MSP. The output is a synthesised sound, an audio file or a MIDI file that is later played through a synthesiser.

The phrase 'sonification' has parallels with the term 'visualisation'. Whereas visualisation is a process of representing data in a graphical format, sonification is a process where data is represented sonically. Listening to data can reveal patterns and structures that may not be apparent through visual methods. Hermann (2010) identifies several areas where sonification techniques could be utilized within a scientific context. Process monitoring, rapid summary of large datasets, searching for patterns in data, and exploratory data analysis. Sonification techniques have been applied in many scientific disciplines, including astronomy, particle physics, chemistry, mechanical engineering, medicine, seismology and meteorology.

Many scientific investigations involve the analysis and exploration of large multidimensional datasets that have traditionally been perceived by visualisation techniques. There are limitations to visual perception, such as temporal resolution and difficulties in representing multiple dimensions of data. Sonification can provide an alternative to visualisation techniques or used in conjunction to enhance analysis.

Multidisciplinary aspects of sonification

Sonification combines skills found in many areas such as music technology, computer science, sound design, composition and performance, data mining, acoustics and physics. An excellent example of multidisciplinary sonification is the *sonEnvir* project (Campo et al., 2006), which investigated implementing sonification techniques in a range of scientific disciplines including neurology, theoretical physics, signal processing and sociology. The project produced a series of tools based around the Supercollider programming language (Cycling74, n.d.).

Why use sound?

There are several characteristics of auditory perception that sonification exploits (Kramer, 1994: 7). The ear is excellent at perceiving time based information, such as rhythm and pitch. The highest pitch we can theoretically perceive is 20Khz (in practice it is often much lower) – that is we can detect acoustic vibrations that oscillate over 20,000 times a second. If such a frequency rate was to be presented visually – much of the information would be blurred or lost completely. The ear is better at detecting rapid or transient changes than the eye.

We are capable of perceiving several sounds simultaneously. Whilst listening to a classical music performance, you will be able to distinguish the individual components of the orchestra concurrently. This ability means that we can listen to several sonified streams in parallel, which is advantageous when dealing with multidimensional information.

Backgrounding is the ability of our auditory system to relegate sounds to a lower priority. Although we are constantly surrounded by sound, we are not aware of most sounds until our attention is drawn to them. For example, you may not be aware of road traffic outside until a passing motorist sounds their horn.

Our hearing is multidimensional; we have the ability to localise sound. If a tiger snaps a twig behind us, we are alerted to this danger that we didn't see because it was not in our field of vision. Unlike a visualisation system, we do not have to be orientated in the direction of the sonification. An example of this is the Geiger counter. As it provides its information in clicks we do not have to constantly observer the meter, so we can safely walk around taking measurements.

A sonification can be 'eyes free' – enabling the user to listen to the data while occupied with another task. So the addition of sound can increase the amount of data presented without increasing visual overload. Our hearing is constant; we do not have the ability to stop listening. This can be useful when monitoring data because if the data was visual we could miss an event if we blinked or looked away momentarily.

There are of course some disadvantages of using sound. Auditory perception is relative. When comparing two stimuli we can only state if they are the same or if one is larger than the other; we cannot give an absolute value. Many characteristics of hearing are co-independent upon others, so a change in one will change how we perceive another – for example our perception of loudness changes with pitch.

Some individuals may find the use of sound to be an irritation. Consideration should be given to environmental issues of sound; someone quietly working in the next office may not appreciate hearing your sonification. The hearing capabilities of the listener may also be a consideration. Some may have noise-induced hearing loss or even amusia (tone deafness).

Sonification techniques

There are several algorithmic techniques used to transform data to sound, in this section we discuss these processes and provide examples within a science.

Auditory graphs

Most readers will be familiar with the concept of a graph, having an x and y axis and a series of data points plotted between. Auditory graphs are a sonic representation of graphical data. Each data point on the graph is mapped to a note on a synthesizer. The pitch of the note depends upon where the point falls upon the Y axis. Starting at the XY origin each point is played from left to right – so that the output is a series of notes that corresponds to the input sequence. Multidimensional graphs can be represented by converting each dimension into a different instrument, for example piano, guitar and violin. This form of sonification can be beneficial for presenting graphical data to both visually impaired and sighted users.

Audification

Audification is where data is directly converted to sound. Techniques are based around converting the data to digital audio samples, which can then be saved in an audio file. This practice is beneficial for working with large datasets. One second of CD quality audio requires 44,100 data points. If the playback length is too short the listener may not be able to distinguish any sonic features or recognize patterns.

Audification has been applied to seismology with relative success. Speeth (1961) found that it was difficult to differentiate atomic bomb explosions from earthquakes just by visual observation of seismograph data. By audification, listeners were able to distinguish between the two types of events.

In an engineering context, audification was used by Pauletto and Hunt (2004) in collaboration with Westland Helicopters to analyse flight data. There are numerous flight sensors on a helicopter, which the Westland engineers would print out in graph form and place on the floor so that they could examine all the data visually at once. Sonifying the data was found to accelerate the diagnostic process.

Audification was utilised by Pereverzev et al. in their research on weakly coupled super fluids. Presenting data visually demonstrated no useful information, but when the data was directly audified Pereverzev was able to hear frequency components that led to a discovery.

> If the electrical output of the displacement transducer is amplified and connected to audio headphones, the listener makes a most remarkable observation. As the pressure across the array relaxes to zero there is a clearly distinguishable tone smoothly drifting from high to low frequency during the transient, which lasts for several seconds. This simple observation marks the discovery of coherent quantum oscillations between weakly coupled superfluids. (Pereverzev et al., 1979)

Parameter mapping

Parameter mapping is a sonification technique where input data is used to control a characteristic of a synthesised sound such as pitch, loudness, timbre, rhythm and melody. This is perhaps the most common form of sonification. In 'sinification' the data is mapped to the frequency of a sine wave oscillator. Midification describes a process where the data is converted to MIDI note values that can then be 'played' on a MIDI synthesizer. As there are numerous acoustic characteristics of sound, parameter mapping can be used for sonifying multidimensional datasets.

An early example of parameter mapping was demonstrated by Sara Bly (1982) who showed that sound could be used to distinguish between three species of Iris flowers. She mapped characteristics such as sepal length and width to pitch, volume and timbre. When this was played back each variety of iris had its own characteristic 'sound'. Bly found that most listeners had the ability to accurately identify each species through sound alone.

An audio-visual browser was developed by Grond et al. (2010) to explore the structure of RNA. The software developed provides a visualisation of RNA structure that the user can interact with, that is, focus upon a particular section or expand out. The software maps RNA shape information to parameters of sound such as loudness, phase and timbre. This is a good example of how sonification can enhance visualisation techniques.

Model-based sonification

Developed by Thomas Hermann (2002), this moderately new technique data is used to form points in a multidimensional space. Each point of data has physical laws imposed upon it, which dictate how the data points relate to each other and the modelled space. The user then excites the data points by stimulating the system and the reaction of the points is sonified. In model-based sonification the data forms an instrument that is played by applying a stimulus. The prepared piano is a good analogy for model-based sonification. This instrument has physical objects inserted between its strings and dampers with the purpose of altering timbre. For example, a composer may attach ping pong balls, paper clips or spoons. In this analogy the objects are data, and the piano is the data space. The presence of objects on the strings changes the sound of the piano when the instrument is played, very much how the data points interact with the model space when excited by an input.

Interactive sonification

Interactive sonification is an area that focuses on the importance of interaction between the listener and the sonification (Hermann and Hunt, 2005). Rather than passive listening, the user interacts with the data. They may have a controller that allows them to navigate the sound, replaying a section, and adjusting playback speed and position.

Sonification toolkits

Several authors have developed open source sonification toolkits. A toolkit is a set of off-the-peg software that provides sonification functionality. The toolkit can be an entire application or a library of functions that can be incorporated into other tools. These applications make sonification more accessible to those new to the area, providing a quick and easy introduction to sonification techniques.

The *sonification sandbox* (Walker and Cothran, 2003) is a standalone Java application developed to facilitate the creation of auditory graphs. The user can upload vector data in a comma separated values (CSV) format and control many parameters to the graph output such as voice, note length, etc.

MAX/MSP is a visual programming language for sound, which is popular with music composers. Instead of text the user manipulates graphical elements to build a program. *aeSon Toolkit* is a framework that adds sonification functionality to MAX/MSP's impressive set of audio objects. This toolkit includes objects to extract data from files, to transform the data and to map to synthesisers.

Some toolkits have been developed to extend the functionality of existing programming environments. The use of these tools enables users to rapidly incorporate sonification into their existing research. *SKDtools* (Miele, 2003) is a library that extends the MATLAB (MathWorks, n.d.) numerical computing environment, and *Sonipy* (Sonipy, n.d.) is a set of modules that add sonification modules to the Python computer programming language.

Case study of sonification within astronomy

Exploring the vacuum of deep space with sound may seem to be counter-intuitive, but there are some interesting examples of sonification within an astronomical context.

The Jet Propulsion Laboratory (JPL) has a multimedia presentation called *Spooky Sounds* intended to introduce concepts of sonification of space-based data (Jet Propulsion Laboratory, n.d.). This resource includes a variety of sonifications including Jupiter's radio emissions, Ganymede's magnetosphere, Cassini spacecraft flybys of Enceladus and Saturn, and Voyager 1 recordings of Jupiter's bow shock. This site is an interesting introduction to space-based sonification.

Sonification techniques were used to detect the impact of micrometeoroids upon the Voyager 2 spaceship while investigating Saturn's rings (Scarf et al., 1982). There was a problem with the spacecraft that its controllers were trying to pinpoint using visual methods – but this only resulted in visual noise. By sonifying the data, a 'machine gun' sound was perceived. This machine gun sound was caused by micrometeoroid impacts on the spacecraft.

Selene (Selenological and Engineering Explorer) was a lunar orbiter spacecraft launched by JAXA (Japan Aerospace Exploration Agency) in 2007. Sobue et al. (2010) developed a Geographical Information System based upon laser altimeter data obtained from the mission. The altimeter provides a topographical contour of the surface of the moon. The system developed was a web-based Java application called *Moonbell* (Higashiizumi et al., 2009). This application sonifies the altitude along the route by converting the measured reading into musical notes. The interface is highly configurable, allowing the user to adjust many parameters, such as speed, note range, instrument and volume.

Cosmic Microwave Background Radiation (CMBR) is a nearly uniform space-based radiation that is received in all directions with the majority of its power spectrum contained within the microwave bandwidth. CMBR is a background 'noise' signal that is found all over the universe. It is now considered that this is the faint afterglow of radiation generated by the big bang. The Planck Visualization Project is a NASA education and public outreach initiative to increase public understanding of the CMBR. This project plans to create multimedia displays using CMBR data sourced from the Planck space observatory. Sonification of this data is also being implemented (Van der Veen, n.d.). This team has also sonified the power spectrum of the CMBR (Van der Veen, 2009, 2010).

xSonify is a Java-based sonification toolkit developed to assist in the development of astronomy-based data (Candey et al., 2006). It is designed to implement sonification functionality of NASA's Space Physics Data Facility (SPDF). The SPDF is an online collection of data collated during space-based missions from 1963 onwards. Data is organised by spacecraft and then individual instruments. This resource includes 'heliospheric, magnetospheric, ionospheric and upper-atmospheric data from all NASA and some non-NASA space physics missions' (NASA, 2009).

Finally, audification functionality has been incorporated in relatively new software used to detect the presence of exoplanets (planets orbiting a star other than our own sun) (Systemic, 2011). This approach is experimental but further investigation may be beneficial.

Summary and further work

There are several examples where sonification techniques have proven advantageous in scientific research. The work of Pereverzev, Scarf and Speeth demonstrates that transforming data into sound can provide insights not revealed by visualisation alone. There is a history of sonification within astronomy, from the detection of micro meteors at Saturn, to contemporary research on cosmic microwave background radiation and exoplanet detection. Nevertheless, are there spheres of astronomical research that would warrant investigation using sonification techniques?

Wall (2010) describes the deluge of information that is facing modern astronomers, who are increasingly trying to find a needle in a haystack of data. This data overload has motivated the formation of several citizen science projects such as Galaxy Zoo (2010) and Stardust@Home (n.d.). These projects distribute images to the public so that they can classify them. There is essentially more astronomical data available than there are astronomers to process it. Sonification is a tool that could be utilised for the exploration of large amounts of data.

This paper's authors are currently researching into sonifying radio waves used in the Search for Extra-Terrestrial Intelligence (SETI). SETI is a project initiated in 1961 to search for evidence of intelligent life by the detection of electromagnetic radiation emitted by extra-terrestrial technology (SETI Institute, 2010). If there is intelligent alien life, it *may* use radio waves for communication, much like earth-based television transmission. Radio waves will propagate through the universe, and might be detected as they reach earth. SETI's approach is to selectively position the Allen Telescope Array at a co-ordinate and then take measurements. This process produces a large amount of data that is freely available to researchers through the SetiQuest project (SetiQuest, 2011). We will be investigating how sonification techniques can be implemented in conjunction with a high performance computer cluster to assist in rapid data exploration.

References

Bly S (1982) Sound and computer information presentation. Unpublished doctoral thesis (UCRL-53282), Lawrence Livermore National Laboratory and University of California, Davis, CA, cited in Gaver WW, Auditory interfaces. In: Helander M, Landauer TK and Prabhu PV (eds) (1997) *Handbook of Human–Computer Interaction*, Vol. 1, 1003–1041.

Candey RM, Schertenleib AM and Diaz Merced WL (2006) xSonify: Sonification tool for space physics. In: *Proceedings of the ICAD, 12th International Conference on Auditory Display*, London, UK.

Campo A de, Dayé C, Frauenberger C, Vogt K, Wallisch A and Eckel G (2006) Sonification as an interdisciplinary working process. In: *Proceedings of the 12th International Conference on Auditory Display*, London, UK,

Cycling74 (n.d.) Available at: http://cycling74.com/products/maxmspjitter/ (accessed 4 February 2011).

Galaxy Zoo (2010) Galaxy Zoo Hubble. Available at: http://www.galaxyzoo.org/ (accessed 9 February 2011).

Grond F, Janssen S, Schirmer S and Hermann T (2010) Browsing RNA structures by interactive sonification proceedings of ISon 2010. In: *Proceedings of the 3rd Interactive Sonification Workshop*, KTH, Stockholm, Sweden, 7 April.

Hermann T (2002) Sonification for exploratory data analysis. PhD thesis, Faculty of Technology, Bielefeld University, Germany.

Hermann T (2010) Improving interaction with sonification: Applications from science to smart environments, keynote presentation – DAFx 2010. Available at: http://dafx10.iem.at/proceedings/papers/Hermann_DAFx10_K1_slides.pdf (accessed 26 January 2011).

Hermann T and Hunt A (2005) An introduction to interactive sonification. *IEEE Multimedia* 12(2): 20–24.

Higashiizumi I, Shimada T, Yamaguchi T, Higa S, Vincent T, Hirokawa J, Kobayashi K and Koike H (2009) Moonbell. Available at: http://wms.selene.jaxa.jp/selene_sok/about_en.html (accessed 15 December 2010).

Jet Propulsion Laboratory (n.d.) Spooky Sounds. Available at: http://www.jpl.nasa.gov/multimedia/sounds/?msource=enews102805&tr=y&auid=1197511%E2%80%9D (accessed 9 December 2010).

Kramer G (1994) An introduction to auditory display. In: Kramer G (ed.) *Auditory Display: Sonification, Audification, and Auditory Interface*. Reading, MA: Addison-Wesley.

Kramer G, Walker B, Bonebright T, Cook P, Flowers J, Miner N and Neuhoff J (1999) Sonification report: Status of the field and research agenda. International Community for Auditory Display. Available at: http://sonify.psych.gatech.edu/publications/pdfs/1999-nsf-report.pdf

MathWorks (n.d.) MATLAB and Simulink for technical computing. Available at: http://www.mathworks.co.uk/ (accessed 4 February 2011).

Miele JA (2003) Smith-Kettlewell display tools: A sonification toolkit for Matlab. In: *Proceedings of the 2003 International Conference on Auditory Display*, Boston, MA, USA, 6–9 July.

NASA (2009) SPDF – information for new users. Available at: http://spdf.gsfc.nasa.gov/new_users.html (accessed 3 December 2010).

Pauletto S and Hunt A (2004) Interactive sonification in two domains: Helicopter flight analysis and physiotherapy movement analysis. In: *Proceedings of the Interactive Sonification Workshop*, Bielefeld, Germany.

Pereverzev SV, Loshak A, Backhaus S, Davies JC and Packard RE (1997) Quantum oscillations between two weakly coupled reservoirs of superfluid 3He. *Nature* 388: 449–451.

Python.org (n.d.) Python programming language – official website. Available at: http://www.python.org/ (accessed 4 February 2011).

Scarf FL, Gurnett DA, Kurth WS and Poynter PL (1982) Voyager 2 plasma wave observations at Saturn. *Science* 215(4532): 587–594.

SETI Institute (2010) Homepage. Available at: http://www.seti.org/ (accessed 4 February 2011).

SetiQuest (2011) SetiQuest homepage. Available at: http://setiquest.org// (accessed 9 February 2011).

Sobue S, Araki H, Tazawa S, Noda H, Kamiya I, Yamamoto A, Fujita T, Higashiizumi I and Okumura H (2010) Proposal of lunar GIS with visualized and auditory data of Japan's lunar explorer 'KAGUYA (SELENE)'. *Journal of Communication and Computer* 7(1) (Serial No. 62).

Sonipy (n.d.) An extensive open-source python framework for data sonification research and auditory display. Available at: http://www.sonification.com.au/sonipy/index.html (accessed 4 February 2011).

Speeth S (1961) Seismometer sounds. *Journal of Acoustical Society of America* 33(7): 909–916.

Stardust@Home (n.d.) Stardust@Home homepage. Available at: http://stardustathome.ssl.berkeley.edu/ (accessed 9 February 2011).

Systemic (2011) Systemic: Characterizing planetary systems. Available at: http://oklo.org/ (accessed 7 February 2011).

Van der Veen J (n.d.) Planck Visualization Project: Seeing and hearing the CMB. Powerpoint presentation. Available at: www.physics.ucsb.edu/~jatila/papers/Planck-for-AAPT-2010.pdf (accessed 16 December 2010).

Van der Veen J (2009) From sound waves to microwaves: 'Listening' to the oldest light of the universe with the Planck Mission. Available at: http://learningcenter.nsta.org/products/symposia_seminars/fall09/NASA/webseminar3.aspx (accessed 21 December 2010).

Van der Veen J (2010) Planck Visualization Project: Seeing and hearing the CMB. In: *Science Education and Outreach: Forging a Path to the Future ASP*. Astronomical Society of the Pacific Conference Series, Vol. 431.

Wall M (2010) Astronomy overload: Scientists shifting from stargazing to data mining. Available at: http://www.space.com/9308-astronomy-overload-scientists-shifting-stargazing-data-mining.html (accessed 2 November 2010).

Walker BN and Cothran JT (2003) Sonification sandbox: A graphical toolkit for auditory graphs. In: *Proceedings of the 2003 International Conference on Auditory Display*, Boston, MA, USA, 6–9 July.


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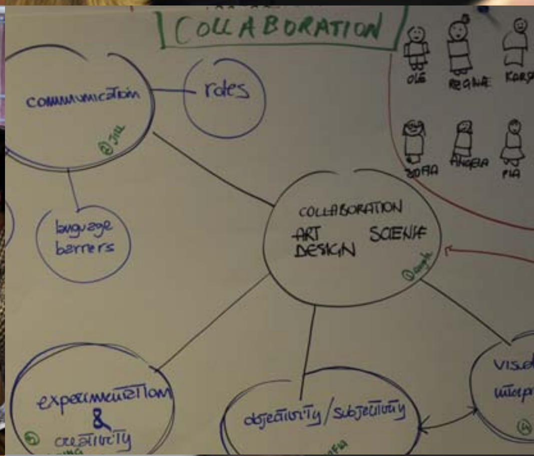
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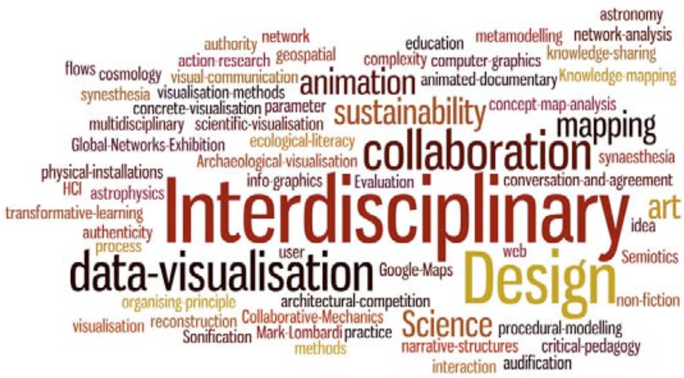

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