From abstract to actual: Art and designer-like enquiries into data visualisation

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Category: Viewpoint, Case study

Structured Abstract

Purpose
The purpose of this paper is to suggest that physical experience can contribute to the comprehension of scientific data, especially through artistic approaches.

Design/methodology/approach
A number of relevant case studies is presented to make the case.

Findings
‘Objective’ or neutral data-visualisation does not exist. Every visualisation process relies on human definitions or mediation. Based on this premise, interdisciplinary collaborators can use methods from design and art to actively design the usability of data visualisations together (with their-aesthetic, ambiguous and imaginative dimensions) in order to create a multi-layered human experience of data.

Research limitations/implications (if applicable)
Physical engagement in combination with rich, ambiguous experiences are not a substitute for scientific data visualization, but can nonetheless be an evocative medium for the public communication of science such as at science centres or science museums.

Practical implications (if applicable)
This paper presents clear reasons to support of interdisciplinary collaborations and systematic applications of methods to create aesthetic experiences from scientific data.

Social implications (if applicable)
Potentially novel, engaging and evocative sensual experiences can be designed for data visualisations around themes such as climate change, sustainability and ecology.

Originality/value
Systematically applying methods from art and design in order to add a sensual component to intellectual experiences could be considered an unorthodox yet highly effective-approach.

Over the past decades a significant number of works exhibited in art contexts have emerged from interdisciplinary collaborations between artists and collaborators from other disciplines, for example astrophysicists or software engineers. Often these works make use of sophisticated technical setups that transform abstract data into evocative sensual experiences, such as software applications that transform solar wind data into sound. For laymen and experts such experiences may facilitate a more direct and immediate engagement with scientific “data” than graphs, charts or diagrams. During the process of making, individual members of the
interdisciplinary team learn about each other’s fields, for example physicists learn about music, while musicians get deeper insights into physics and astronomy. Through their collaborative efforts they also effect public perception, by transporting “science” out of the laboratory into the art gallery.

While this paper focusses upon the distinctive difference with which art and design approach data visualisation, it argues that artistic methods in combination with design research methods may allow the visualisation of complex data in more evocative ways. This is especially significant regarding audience interactions and the aesthetic quality of that experience.

The paper introduces relevant case-studies that emerged from interdisciplinary collaborations in which artists, designers and scientists created work that was either inspired by scientific principles or that involves scientific instruments or data.

The debates surrounding climate change, sustainability and ecology will create further public interest in complex – yet aesthetically rich and comprehensible – installations that visualise (scientific) data. Multi-disciplinary collaboration may be key to find such a balance between complexity of data, clarity of conveyance and ambiguous-aesthetic qualities which stimulate individuals’ imaginations and allow them to make the experience their own. These will hopefully allow trans-disciplinary perspectives to emerge.

1.0 A discussion of ‘data visualisation’

The New Oxford American Dictionary defines “Visualization” as ”1. form a mental image of; imagine 2. make (something) visible to the eye.” (New Oxford American Dictionary, 2005) If we disregard mental images for now, a telescope or a microscope can be seen as visualisation technologies as they make objects visible that were not visible to the naked eye. What are other examples of indiscernible natural processes becoming materialised and actual?

The roots of present-day scientific data visualisation lie in graph theory, where mathematical principles are depicted graphically. ”From the seventeenth century on, the style of European mathematics had gradually shifted from geometry, the mathematics of visual shapes, to algebra, the mathematics of formulas. Laplace […] boasted that his Analytical Mechanics contained no pictures. Poincaré […] turn [ed] once again to visual patterns.” (Capra, 1996, p. 125) These visualisations of mathematical equations were qualitative in the sense that the depiction would give viewers a more direct access to knowledge then an abstract formula did.
Another approach to capture and visualise data is evident in the history of instruments that measure weather conditions such as the Barometer. Measuring and subsequently recording barometric pressure with a Barograph made possible a written record of the imperceptible changes of air pressure over time. This allowed an invisible and ephemeral process to be visualised in a concrete material record. In the device a clockwork rotated a cylinder covered with paper upon which a pen attached to the pressure-sensing device would mechanically record barometric pressure as the cylinder moved beneath it. Another example is Charles Thomas Rees Wilson’s “cloud chamber” in which invisible radioactive particles write their trail in form of visible contrails inside a vapour filled chamber. These visualisations were direct in the sense that the entire process was obvious and open to scrutiny as it evolved over time. They functioned as "transparent" tools that helped to make visible and understand otherwise-hidden processes.

Since then the visualisation of data has undergone a radical change. The ubiquitous personal computer with its sophisticated software applications has allowed us to depict data with unprecedented accuracy and visual richness, yet this came with the loss of the earlier direct access. The visualisation process has become hidden within a blackbox of hardware and software which only experts can fully comprehend. An ubiquitous example for such a visualisation would be a ‘visualiser’ plug-in for a computer-based music player. Here images on the computer screen respond in real-time to properties of music such as beat and pitch, while their immediate cause, highly sophisticated algorithms, are hidden from view. Reduced to the role of ‘users’ we may enjoy the results, but we rarely understand how these are created. Though frustrating, this may not matter much in a music visualiser. Yet in a scientific instrument it is crucial to have full scrutiny of the process that leads to certain results.

Other applications expand the strict meaning of visualisation to other, non-visual sensory modalities (also described as “non-visual multi-modal visualisation”). One such process is sonification, which is often used on astrophysical data of various origins. Here properties of the data are transformed into sound or even music, allowing us to listen to cosmic radiation with devices such as the Kosmophone (Chamkis, 2005), a star’s magnetic field (Kurtz, 2009) or solar wind (Semiconductor, 2009). The history of this practice is long and reaches at least back to Johannes Kepler’s “Harmony of the Spheres” (Koestler, 1984). Kepler tried to assign sound to planetary motion by calculating the orbits and sizes of the known planets of the solar system and relating them to distances on the taught wire of a monochord whose vibrating lengths he adjusted with a moveable bridge. In recent
years many astrophysicists have begun to sonify the data they receive from their instruments with the help of computers and sophisticated software. Scientists regularly use classical music for these types of applications while artists tend to use electronic sounds. A reason for this could be that scientists want to create something of aesthetic appeal that conveys the ‘beauty’ they see within the data (Stanford Solar Center, 2010). Artists on the other hand may feel that a conventional aesthetic form distracts from the origin of the data and as a result emphasise disharmony and glitch (sonic artefacts) (Semiconductor, 2009). Both result in very different experiences.

In astronomy, electromagnetic radiation outside the range of visible light is regularly transposed into the range of visible light. As a result some popular images of interstellar nebulae actually are composite images from multiple space telescopes combining x-ray, infrared and optical images (Butcher, 2010). This process requires active human intervention in order to attribute visual properties such as colour to phenomena that would otherwise remain invisible to the human eye, not as a result of their distance but because the light they emit is outside the visible range. During this last optical visualisation process a new and crucial element exists that was not present in Kepler’s or Wilson’s transformation of data: an active decision of subjective human taste that determines the aesthetics of an apparently “objective” depiction. Of comparable significance would be the decision of how to display “smog” on a televised weather report: From what concentration upwards shall air pollution be called smog? Shall the colour be neutral grey or a lurid green?

In these examples it becomes apparent that in visualisation the degree of mediation is fluid, progressing from the optical microscope and telescope to the cloud chamber to entirely computer-processed digital satellite imagery. Astronomical satellites capture wavelengths beyond visible light such as radio waves, micro waves, infrared and near-infrared (Butcher, 2010). Data from the optical Hubble telescope is digital and composed of three individual images covering different wavelengths of light. It becomes apparent that there is no objective measure to distinguish between ‘unmediated’ and ‘mediated’ results. “It’s like “seeing” with a camera, night-vision goggles, and x-ray vision all at once” (Butcher, 2010, 9). All of these involve certain degrees of human intervention. The raw images require human processing on a computer screen. And perceiving, for example, is an active process, not the passive reception of objective reality. What can be perceived is influenced by knowledge, past experiences and psychological factors and deeply engrained in culture. For example, to competently ‘read’ a chest
x-ray image may require up to six years of experience (K. Sirvana, personal communication, 27 December 2010). When Anton van Leeuwenhoek used an early microscope to study spermatozoa in the late 17th century, he documented what he perceived with accurate drawings. When he studied human spermatozoa he clearly distinguished a “little human” figure, when examining spermatozoa of dogs he distinguished a little dog (Cody, 1995). That is, the unsatisfying quality of the device’s optical properties were compensated for by van Leeuwenhoek’s knowledge of the origin of the sperm and his active imagination. He saw what he wanted to see, or to quote Heinz von Foerster, “Believing is seeing” (Von Foerster, 1984). To a certain extent, such a process could also take place during the processing of satellite images. While scientists must strive for accuracy in their data visualizations, artists have more creative freedom. How would an interdisciplinary team led by an artist ‘visualise’ data in the form of an installation that had instrument-like accuracy but fostered imagination, and the individual construction of meaning?

2.0 From abstract to actual and the construction of meaning: two examples of reflective insights through data visualisation

Luke Jerram’s installation “Tide” (Jerram, 2002) visualises the effect of the moon’s gravity upon sea levels in the English town of Bristol. While the moon and earth change their position a gravimeter measures minute changes in gravity and controls the water levels in three large rotating glass spheres, which represent the sun, moon and earth. On the rim of each sphere sits a friction device that makes each glass ‘sing,’ not unlike an oversized wine glass, in vibrant resonating overtones that fill the exhibition space. In a felicitous conceptual mapping, the water inside the spheres is used as a medium to visualise rising and sinking tide levels and also as the medium that effects the sound quality. Here, technology produces a visceral sensual experience otherwise imperceptible to the human senses: minute changes of gravity.

In this artistic approach the data is a means to an end: it controls the water levels within three glass spheres. Although the work alludes to the moon there are three glass spheres and little explanation is given. As a result the experience is ambiguous and invites visitors to open speculation, reflection, and construction of their own experience. Why are there three vessels? How is the sound created, physically? In its appearance of glass and steel it is technical and minimalist, contradicting romantic notions associated with the moon. Works of this kind, which transform data of a scientific instrument into visual or embodied experiences, are
also relevant to designers, as follows. Designers traditionally are habitual generalists, as they are regularly exposed to new disciplinary cultures, new knowledge and non-trivial problems. Their speciality is to listen, understand, and integrate other disciplines’ perspectives, along with the differing needs of various stakeholders. This requires the ability to view problems from multiple perspectives, flexibility in adopting new vocabularies used by the disciplines concerned, making sense of complex processes, and often comprehensively communicating those. They also may bring with them an innate awareness of tacit “cultural qualities” and values that cannot easily be communicated. This meta-perspective and critical, evaluative and integrative thinking and communicating can be seen as core strengths of good designers, as a design thinking. They also are solution-focussed and must create, reflect, evaluate, and assess their process of making. This process begins with initial data collection, may involve the creation of mock-ups and methods to capture people’s perception of the design’s strengths and weaknesses. These capabilities are essential in interdisciplinary collaborations.

Let us look at an example of another interdisciplinary collaboration in which the abstract unit of electrical power, ‘watt,’ is visualised through a physical experience. Some science museums employ home-trainer style bicycles to communicate ‘Energy’. One can pedal on such an exhibit and learn from a display the amount of energy generated by this motion. The numerical “watts” on display are accompanied by helpful comparisons such as “You could light a 20 Watt light bulb now.” Through bodily activity, the abstract units of ‘energy’ suddenly become associated with physical exercise. When I used such an exhibit and put all my energy into pedalling to see how many watts I would be able to produce at maximum effort, for a very brief moment I reached a state in which the system read: “If you continue like this for one hour you will bring one litre of water to boil.” This was a valuable insight: The mundane and everyday activity of boiling water set in relation to my own physical experience made me realise that a comparatively large amount of energy is required to bring a litre of water to boil. (From an information design standpoint the installation is inaccurate due to the inefficient energy transmission of the system.) When we think of the ease and effortlessness with which we summon comparable amounts of energy by the simple press of a button (or flip of a switch) on a daily basis, this becomes especially paradoxical. Most people will be unaware of the amounts of energy that their electric appliances use. For me this insight resulted in a lasting change of behaviour, and since then I have been very conscious of how much energy is necessary to bring water to boil.!
Reflecting on the experience, I learned that when the relationship between abstract to actual is clearly mapped and connected to a physical experience, this can result in a fundamental insight that may lead to a change of behaviour.

3.0 Conclusions: Data visualisation, methods and interdisciplinary collaboration

This text has noted that visualisations of data may become memorable and meaningful experiences as a result of inter-disciplinary collaboration. Crucial in this process appears to be the manner of presentation and a combination of intellectual together with embodied experience which also addresses multiple sensorial modalities, such as sound and touch.

People will always create many more and different meanings from artefacts than their makers may have intended. From a designer’s perspective it is seen as good practice to systematically enquire how people attribute meanings to artefacts (Krippendorff, 2006). This process could be combined with artistic methods which are more likely to emphasise aesthetics, ambiguity, multiple layers of meaning, subjectivity, and emotion, and which invite people to open speculation, reflection, and construction of their own meaningful experiences.

The examples I have introduced have been realised by interdisciplinary teams in which engineers, scientists, programmers, artists and designers have collaborated, each contributing their expertise to a project of a scale and originality that could hardly be accomplished by one individual, or through one discipline alone.

Therefore, interdisciplinary collaboration may be the key to creating other evocative visualisations that incorporate the crucial qualities of the disciplines involved, by elegantly combining aesthetics, usability, and conceptual contextualisation within a larger framework of technical function and knowledge. Such works may affect the interdisciplinary team as well as the audience. Members of the teams may have to overcome a constrained perspective of disciplinary reductionism and specialisation. The audience is encouraged by the experience to perceive the world as integrative, and with all sensual faculties involved, beyond a worldview constrained by a single disciplinary perspective. The works also communicate that what they present is not the reality but a reality. Not the truth but a truth. From a second-order cybernetics perspective, they are an offer for interpretation. Every visitor constructs their own experience from the encounter, connected their past, their knowledge, and their interests. Everyone can integrate the insights into their worldview, and modify that view accordingly. That is,
visualisations may help their makers and their users to overcome a reductionist worldview and see the world as an interconnected whole (Irwin, 2003). As the complexity of our world and the interconnectedness of our problems become more apparent, it becomes clear that these insights must be shared with the public. However, we have seen that this may not only be done intellectually but also through embodied experiences that generate insights. This calls for public exhibitions of data-visualisation experiences that use principles and qualities such as those described above and which can only be the result of interdisciplinary collaboration.


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