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Visualising Electromagnetic Fields: An Approach to Visual Data Representation and the Discussion of Invisible Phenomena

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This paper presents the process, approach and results for *Visualising Electromagnetic Fields*. A project that produced a toolkit and visual vocabulary for technological exploration – through light-painting and long-exposure photography – to capture, visualize and communicate invisible electromagnetic fields that surround everyday objects. The project acts as a case-study to answer a need for work that combines scientific and artistic practices. To create a open dialogue between the public, scientists, designers, and engineers in a way that provides a visual language for understanding and critical discussion.

1 Introduction

In 2013 when the project was first created and published there were (and still are) many different tools, techniques, platforms, sensors and processes for the capture, recording, visualisation and quantification of data. Especially 'invisible' data, which is defined in this paper as statistical information than can be measured scientifically, but where the data describes an invisible phenomena that cannot be seen by the human eye.

Long before interaction design existed as a discipline, Manzini argued that materials, including digital and interface technologies, are under such rapid change that there is a widening gap between them and their cultural understandings. (Manzini & Cau 1989)

The project developed from a need to address a growing concern. As designers, scientists and engineers we often use and talk about invisible technologies, but how can we be sure our own mental model of these technologies is 1) accurate and 2) is a mental model shared by others, primarily our target-audience? The project was presented as an example of discursive design whereby the aim was to provide a visual vocabulary that could allow for *dialogue* (Bohm 1990) around an area of technology with limited public understanding but wide public usage – electromagnetic fields.

2 Invisible phenomena

Electromagnetic fields (EMF) are an ideal example of a phenomena that are used and produced by most everyday technologies, but most documentation and information remains in the scientific and engineering domain. Information and explanation is not usually designed for use by the general public. In recent years the design industry – who work primarily in the consumer market, producing products, services and systems for public – have actively promoted the use of *seamlessness* (Ratto 2007) in design proposals and creative solutions. Deliberately 'making invisible' many of the technologies that make a system or product function in a desired way.

An electromagnetic field, as the name suggests, is made of 2 components, the electric field and the magnetic field. The magnetic field can be understood using Ampère's Law, which is an electromagnetism law that relates the magnetic field in a closed loop or surface with the electric current circulating through that same loop:

$$\int \vec{B} \cdot d\vec{l} = \mu_0 \cdot i$$

Fig. 1 Ampère's Law (Duarte 2014)

The electric field can be understood using Gauss's Law, that describes the relation between the electric field flowing through a closed surface, the Gaussian surface, and the sum of the electric charges inside a volume, limited by that same surface:

Fig. 2 Gauss's Law (Duarte 2014)

$$\int \vec{E} \cdot d\vec{A} = \frac{Q_{int}}{\epsilon_0}$$

The project combined both, using the built-in magnetometer-sensor inside the iPhone 4 and LG Nexus 4 smartphones. These sensors are capable of measuring both the magnetization of a magnetic material like a ferromagnet, and the strength and direction of a magnetic field at a point in space.

2.1 Previous approaches to electromagnetic visualisation

Electromagnetic fields have been the focus of scientific and artistic study and material-exploration for several decades. From the 1820's scientists such as André-Marie Ampère and Hans Christian Ørsted[1] were demonstrating their scientific and mathematical discoveries through the design of scientific instruments that could visualise the unseen magnetic forces around objects with an electrical charge.

In recent years within the field of Design, the fascination with invisible phenomena has developed beyond data visualisation, to allow provocation and a critique of previous modes of explanation and aesthetic methods of representation. In his book *Hertzien Tales*, Anthony Dunne dedicates a chapter to the "radio space", although this is not an attempt to visualize the invisible, but to "explore new aesthetic possibilities for life in an electromagnetic environment".

> Whereas cyberspace is a metaphor that spatialises what happens in computers distributed around the world, radio space is actual and physical, even though our senses detect only a tiny part of it. (Dunne 1999)

3 Photographic approach

There is a history of using photographic techniques in the sciences and Human-Computer Interaction (HCI) research to capture and understand complex or invisible interactions with the physical world. To use photography as a visualisation tool that can be used to track and display information.

1 Oersted's law. April 21, 1820. Accessed at (http://en.wikipedia.org/wiki/Oersted%27s_law)

Light painting is a photographic technique that has a history of being used to track motion and changes in space, over time. One of the earliest examples of this photographic technique is *Pathological walk from in front, made visible by incandescent bulbs fixed to the joints* by Étienne-Jules Marey and Georges Demeny (see Fig 3). The motivation is often because of the power of the photograph to engage with an audience without a requirement for technological understanding, in contrast to a diagram or statistical information that requires mental processing and 'reading' of information.

> Marey wanted to give a visible expression to the continuity of movement [...] and to do so within a single image. Only this, he believed would give him quantifiable results – photographs from which measurements could be taken. (Braun 1994)

In addition to quantifiable information that could be stored within a single photograph using the light-painting technique, artistic expression and human emotion could be expressed and shared. The photograph acting as a discussion point between the author and the audience. Artists such as Marey & Demeny, Gilbreth , Man Ray and Pablo Picasso (in collaboration with Gjon Mili) used light-painting as creative tool for expression and storytelling in their practice between 1930–1950 (see Fig 3).

Fig. 3 Light-painting works (Marey & Demeny 1889), Cyclegraph (Gilbreth 1914), and "Picasso draws a Centaur" (Picasso 1945)

3.1 Light-painting technique

The photographic technique used for the project is exactly the same process as used by artists such as Picasso et al. to produce their light-paintings of the 30s and 40s. A camera with a small aperture size is placed on a tripod and the shutter is released for a long period of time. Between 60 and 90 seconds were used for the creation of all photographs in the project, but it is most likely that Picasso and Mili would use a much longer time period, given the capabilities of the camera equipment that was available to them at that time. While the shutter is open, a strong light such as a candle, led, or mobile phone screen can be moved in front of the lens, creating a trail of light that is capture by the cameras digital sensor (or photographic film).

When the shutter is finally closed, the remaining image will be the result of all the light that travelled through the lens during the entire exposure period. Both the bright light used for light-painting and any ambient or stage lighting that was also present.

4 Everyday objects

A key motivation for the project was to capture and communicate invisible phenomena surrounding technology, to an audience without any prior technical knowledge or experience. We chose everyday devices and household items as the central objects for investigation, so that the widest number of viewers could identify and relate to the project. Everyday objects such as an Apple MacBook Pro, Radio alarm, iPhone and Google Nexus 4 were photographed. The purpose was the engage with a wider audience and provide a visual language and toolkit that can enable conversation and discussion across multiple disciplines, experiences and understandings.

> It is only through a process of exploration and revelation that we are able to develop our 'object-world' understandings as designers, in order to assemble new perspectives on, and meanings around, emerging technology. (Arnall 2013)

Through experimentation we developed an understanding of both the photographic principles and limitations of light-painting, and the technical specifications of the magnetometer sensor inside an LG Nexus 4. Using the open-source programming language *Processing*[2] and the open-source *Ketai*[3] software library to access information from the phone's sensors we created our own simplistic real-time data visualisation application that could run on any Android enabled device.

4.1 Data communication

After the creation of a very simple software tool, the next step was to experiment with different visual languages that might help us communicate and visualise the material qualities of the EMF that can be detected around everyday objects.

Shape, size, colour, speed, depth, resolution and time were all parameters that could be adjusted for each image. Through experimentation we arrived at a limited palette that could be successfully and repeatedly used to visualise and compare the EMF field of any object.

2 Processing programming language. Accessed at https://processing.org/

3 Ketai Library for Processing. Accessed at https://code.google.com/p/ketai/

4.2 Artistic expression

Understanding and clear communication was always a primary consideration for each aesthetic decision when creating the images. But the success of the project relied on how engaged the public would be with the images and videos that were published. Therefore a careful balance was made between data representation and the generation of an attractive visual language that would intrigue viewers and provoke conversation and discussion.

This artistic expression is present within every single photograph, from the lighting and composition to the crop of the product and the resolution of the light-painting inside the photograph. Most obvious is the affect that the movement of the hand will have on the final photographic image. To avoid the further removal of information from the photographic image we constructed systems and methods of rigor, so that we could repeat the same movements and gestures to generate similar subsequent photographic images that could be used to contrast and compare electromagnetic fields. Still photography was used to identify areas of EMF that could be detected and visualised, then the gestures were repeated – sometimes more than two-hundred times – to create a photographic sequence that could produce an understandable moving image.

Fig. 8 Final visual language through photography

5 Conclusion

The project set out to identify and communicate an invisible aspect of our technological lives to a wider audience. To engage with the public as well as design, academic, scientific and engineering communities who might also find the research and approach valuable. Upon completing the project a two minute

video was created and uploaded to Vimeo.com and the majority of photographs (both successful and failed) were uploaded to a dedicated album on Flickr.[4]

The toolkit that was created for the purpose of the project has been shared as open-source code.[5] Allowing anyone with programming experience to download, modify, improve, and ideally share their own learnings. To teach others and contribute to a wider public conversation. An iPhone and Android version of the mobile applications are available to download for free from the respective app stores.

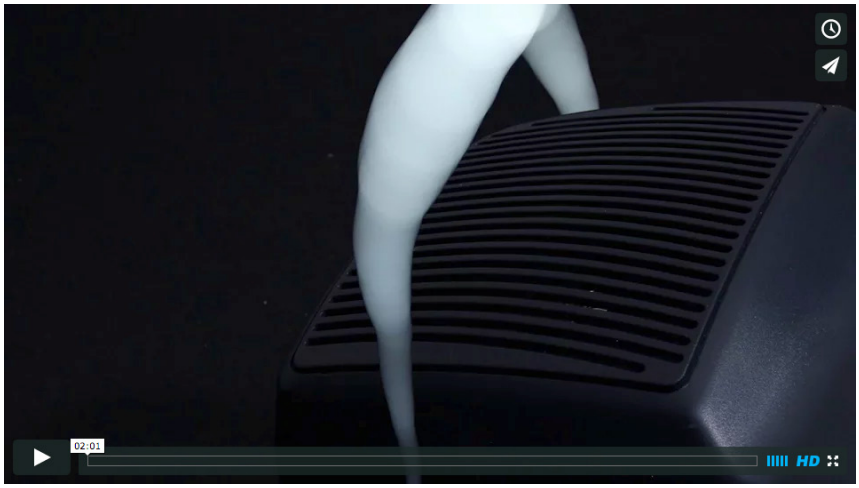


Fig. 9 Visualising electromagnetic fields video (https://vimeo.com/65321968)

5.1 Digital sharing platforms

As well as documentation, both these platforms allow image and video content to be easily shared across the globe instantly. Using the internet, email, blogs and social media to share links and images that all link back to one another, provide a content loop that connects and maintains a link between the produced content, the research, written text, articles and press releases and perhaps most importantly, a digital record of the comments and discussion that took place online.

5.2 Creating dialogue

After only two months of being published online, the project was featured on the technology and lifestyle blog the *Creators Project*.[6] The article was titled *Light Painting The Electromagnetic Field* and was written in response to the project, featuring the video, a selection of eight photographs and links to other 'related' projects and art; continuing the discussion and EMF and invisible technologies.

4 https://www.flickr.com/photos/luke_sturgeon/sets/72157633310156013/

5 https://github.com/lukesturgeon/iOS_EMF_Sensor

6 http://thecreatorsproject.vice.com/blog/light-painting-the-electromagnetic-field

> We're surrounded by things we can't see. In a recent project the pair decided to make visible the electromagnetic field (EMF) that surrounds many of the devices we use in our daily lives. To do this they used long exposure photography and stop-frame animation to produce light paintings that show the EMFs that surrounds laptops and a old school tape deck. (Holmes 2013)

The first article was discovered by several other technology[7], lifestyle[8], news[9], fashion[10], design[11] and business websites[12] and since being uploaded to Vimeo on April 2013 the video has been played more than three-hundred thousand times and shown at film festivals and design events around the globe.

> The phone was used as a kind of light brush, which reacted to the changing strength of the EMF, and long exposures allowed them to capture the whole field. Amusingly, the EMF from the laptop's hard drive was strong enough to stall the phone's magnetic sensor – so there's still room for improvement – but the result is pretty cool nonetheless. (Condliffe, 2013)

The conversation and discussion that was provoked by the decision to publish the work on digital sharing platforms was one of the largest success points for the project. The aesthetic and technical decisions that led the the creation of images and stop-frame animations provided visual content that could be shared easily, and were used alongside provocative article titles such as "Your MacBook Has a Force Field. This Is What It Looks Like". This led to a series of conversations about technologies and phenomena that we can and cannot see, how we measure these things and how we visualise and express them. The conversations were provoked by the original work.

> You might view your laptop as a nice, neatly contained unit – but there's more bursting out of it than meets the eye. In fact, all of its electrical components create complex magnetic and electric fields that spread far and wide, and this video shows you their reach. (Condliffe 2013)

> Though the images are beautiful, the information we can glean from them is still abstract. (Stinson 2013)

> The phone was used as a kind of light brush, which reacted to the changing strength of the EMF, and long exposures allowed them to capture the whole field. [...] there's still room for improvement – but the result is pretty cool nonetheless. (Condliffe 2013)

The images from the project focused on provocation and engagement instead of the accurate reading of numeric and

7 https://www.prote.in/en/feed/2013/07/visualising-electromagnetic-fields

8 http://www.wired.com/2013/07/the-invisible-images-coming-from-our-favorite-devices/

9 http://www.huffingtonpost.co.uk/2013/07/03/laptop-invisible-force-field_n_3541122.html

10 http://www.esquire.co.uk/gear/gadgets/4279/laptop-electromagnetic-forcefields/

11 http://www.creativereview.co.uk/feed/july-2013/06/visualising-electromagnetic-fields

12 http://www.businessinsider.com/designers-make-force-fields-from-laptop-and-iphones-visible-2013-7?IR=T

statistical information. They exist as a way to excite and provoke conversation.

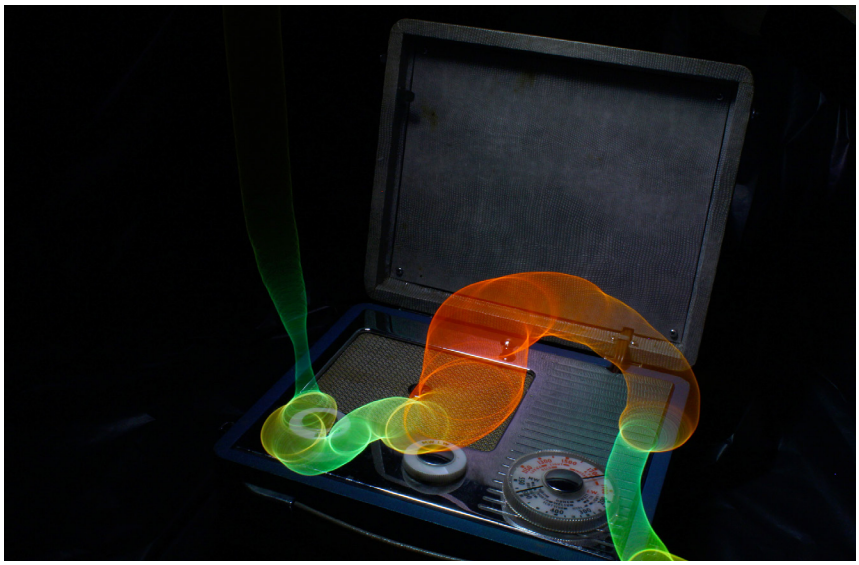
5.3 Education

Fig. 10 Science Museum workshop participants

In September 2014 the Science Museum[13] in London requested a participatory workshop building on the original concept in collaboration with the museums own collection of everyday electronic objects that span decades of human invention and scientific discovery. The 1-day workshop provided hands-on experience for participants who were introduced to the photographic techniques and given access to an improved version of the EMF application that was created for the original project.

Participants of the workshop had backgrounds that ranged from photography, design and art to software engineering, social sciences and business strategy. They were paired and each given a camera, tripod, and photography station. Through hands-on learning and discussion they were about to develop thorough understanding of light-painting and electromagnetic fields within a few hours, producing over 300 photographs there were presented by each pair at the end of the day.

Fig. 12 Workshop participant results



In comparison to the original images, the photographic results from the workshop demonstrate a preference for playful expression rather than comparison and communication of invisible electromagnetic fields. However the participants were able to understand and then explore the material qualities of EMF, in order to achieve the expressive images they created.

The workshop concluded with a late-night public event held at the Science Museum. The results from the workshop were displayed alongside the electronic objects from the workshop and

13 http://www.sciencemuseum.org.uk/visitmuseum/Plan_your_visit/events/media_space_events/field_life_of_electronic_objects.aspx

14 https://www.flickr.com/groups/secretlifeofeverydayobjects/pool

a working camera setup, so that visitors could learn through hands-on demonstrations.

For us, the queue of visitors during the late night event was the measurement of success for the overall project. Through composed photography and careful consideration to the visual language and presentation of scientific phenomena we created intrigue, then understanding and dialogue. As well as facilitating discussion and conversation between visitors, through the presentation and explanation of the original concept, image-making process and motivations for the project.

The final work has been collected in a public Flickr group[14] titled "The Secret Life of Everyday Objects". This approach allows anyone around the globe to contribute their own work and participate in a discussion around invisible phenomena and technology. Using existing photo sharing platforms and social media to engage with a curious audience, regardless of expertise or available tools.

5.4 A new approach to visual data representation

The project has resulted in a better understanding and case-study for the engagement of a wider audience in the conversations around technology, design and science. Through the careful representation of information in an accessible and comprehensible visual vocabulary, open discussions can be achieved across discipline and regardless of technical experience. Provoking conversation and new work, through the collaboration of different disciplines.

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