

THE AESTHETICS OF INFORMATION

The significance of data visualisation as a design
tool in art, design and architecture

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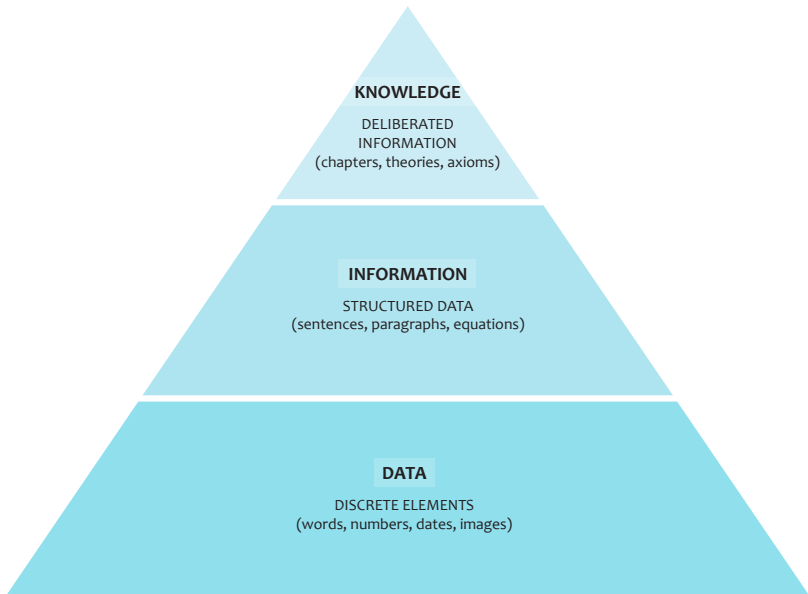
The world we live in today is increasingly described and governed by the vast quantity of data that we, as humans, generate on a daily basis. “We are living in a new ‘information society’” (Manovich, 2005, p. 1), where an incomprehensible quantity of data is endlessly being generated and collected for a multitude of purposes. In the past, it was used for the understanding of the physical and social sciences that govern our everyday lives. Whilst this is still largely the case today, it is also being used for the understanding of the virtual world of numbers and figures that is constantly being created by our ‘information society’.

This is all done with the help of data visualisation, a field being transformed with technological progression. The evolution of data visualisation is what, over the centuries, has taken the data we have generated and collected, transforming it from something abstract into something concrete. Data visualisation is slowly progressing from two-dimensional outputs to three-dimensional, spatial experiences. This is what Lev Manovich, the forerunner in these ideologies, has termed ‘info-aesthetics’; data can be used as an adaptive design tool to respond to the new cultural requirements created by our ever-changing ‘information society’. Arguably, data visualisation has affected every aesthetic domain (art, design, fashion, cinema) except that of architecture, something which is often overlooked. Over the last two decades, artists and designers have seen the diverse potential of developing data visualisation into an art form which provides multi-medium immersive experiences as a means of understanding the virtual world we are building. However, architecture mostly uses data for the practical, problem-solving approach of designing responsive and automated buildings. It is important for architecture to embrace data as an adaptive design tool and medium in order to bring the virtual into the realm of the physical.

0.1 Contextualisation

Since the creation of the computer, an ideology has been established linking data, information and knowledge (Figure 0.1). *Data* are discrete elements without any context (words, numbers, dates, images); *information* is the structuring and contextualisation of data (sentences, paragraphs, equations); *knowledge* is the organisation and deliberation of information (chapters, theories, axioms). Today, we are generating exponential amounts of data due to the combination of computation and connectivity, rendering it impossible to structure all of this data into information to extract knowledge from.¹ The prominent Spanish sociologist, Manuel Castells, has

Figure 0.1: Explanation of data-information-knowledge hierarchy



termed this phenomenon ‘information society’, which can be defined as a “post-industrial society in which information technology is transforming every aspect of cultural, political, and social life and which is based on the production and distribution of information” (Business Dictionary, 2017). As a result of this ‘information society’ and the vast amounts of data driving it, the need to visualise the information we are producing as a means of understanding it is ever-important. Thus, the field of data visualisation, and its shift from two-dimensional outputs to three-dimensional, multi-medium spatial experiences, becomes the foreground of this thesis; and

the question of how it can be used as an aesthetic design tool in art and architecture arises.

Furthermore, this thesis will expand on Lev Manovich's idea of the aesthetics of information and the ideology of using the vast amount of data generated and collected in today's society as a unique design tool. A historical exploration of data visualisation will be provided as an overview, before presenting three case studies ranging from 2D artistic visualisations to 3D architectural installations and buildings. These case studies will highlight the fact that art and design are excelling in the creation of 'info-aesthetic' data visualisations, whereas architecture is not achieving its full potential. Ultimately, this will be done as a method of investigative research to determine and draw conclusions about the importance and the methods of quantifying and visualising the intangibility of data as a way of truly understanding and experiencing the uncontrollable and immeasurable 'information society' we live in today.

0.2 Data Generation and Collection

The world we live in today is increasingly described and governed by the vast quantity of data that we, as humans, generate on a daily basis. From our social media profiles to contactless card payments, virtually everyone in the developed world now has a digital footprint. From as early as the 10th century, humans have been collecting all types of information to form an understanding of the physical and social sciences that govern our everyday lives. As Lev Manovich, one of the leading theorists of digital culture, explains:

"we are living in a new 'information society'... All kinds of work become reduced to handling data on one's computer screen... And when we leave work, we don't leave information society. In our everyday life, we use search engines and retrieve data from databases; we rely on 'personal information appliances' and 'personal information managers'... We turn our lives into an information archive" (Manovich, 2005, p. 1).

Here, Manovich points to the fact that there is a vast, incomprehensible quantity of data endlessly being generated by humans; data which is readily available to be used by anyone, for anything.

Art, design and architecture have all benefitted from the use of this endless data generation which is being utilised as a tool for delving deeper into the inner workings of particular points of interest and, in turn, helping to make more informed designs. More specifically, the evolution of data visualisation, a discipline which falls somewhere in between art, design and architecture (and works in tandem with all three), is what, over the centuries, has taken our generated and collected virtual data and transformed it from something abstract into something concrete.

0.3 Data Visualisation

In broad terms, data visualisation can be defined as "the graphical display of abstract information for two purposes: sense-making (also known as data analysis) and communication" (Few, 2006). Typically, quantitative data sets are presented in a visual context as a means of revealing the patterns, correlations and structures that are formed by abstract information. The precise definition of data visualisation, however, is ever changing; it transforms as technology progresses. When it was first being introduced in the 16th century, data visualisation was a form of map-making to aid the navigation and exploration of the physical world. When William Playfair, a British political economist, revolutionised data visualisation in the 18th century (with the invention of the line, area and bar charts), it became a form of graphical statistical diagramming which aided in the understanding of society. Today, data visualisation is a multiform medium heavily reliant on computers and, as will be shown herein, is used for anything from basic two-dimensional infographic diagrams to complex three-dimensional artistic and architectural creations.

Arguably, data visualisation in the 21st century has come full circle: it is a new form of map-making. Rather than aiding in the navigation and exploration of the *physical* world, however, it helps us navigate, explore and ultimately decipher the *virtual* world of numbers and figures that is constantly being created by our 'information society'.

0.4 Aesthetics of Information

Until relatively recently, data visualisation has always been focused on the output of quantitative visuals such as bar charts, pie charts, line

graphs, contour graphs, scatter plots. The rapid growth of computer software and hardware has undoubtedly standardised the use of the aforementioned. However, data visualisation is slowly beginning to shift from these two-dimensional outputs to three-dimensional, multi-medium spatial experiences. Over the last two decades, artists and designers have imagined the diverse potential of developing data visualisation into a multi-dimensional art form which provides immersive experiences as a means of understanding the virtual world we are building. Hence, data can be used as an adaptive design tool to respond to the new cultural requirements created by our emerging 'information society'. This is what Lev Manovich has termed 'info-aesthetics' and defines it as the scanning of "contemporary culture to detect emerging aesthetics and cultural forms specific to a global information society" (Manovich, 2008, p. 6).

However, where art is excelling in this, architecture, although has the potential to, is not. In architecture, data collection, for the most part, is being utilised for the practical, problem-solving approach of designing 'smart buildings'² and 'smart cities'³. Naturally, it is important to use data collection to inform the design of responsive, technologically-advanced buildings. Yet, it is also important to let the data shape the architectural form itself; firstly, because this allows architects and designers to produce creative, bespoke and unique designs with meaning; and secondly, because it facilitates data representation in a physical setting which renders "...the phenomena that are beyond the scale of human senses into something that is within our reach, something visible and tangible" (Manovich, 2002, p. 8).

SECTION 1.0

A BRIEF HISTORY OF DATA
VISUALISATION

In order to understand the development of data visualisation into the three-dimensional form it is becoming today, it is important to first take a look at the key historical moments which paved the way for this significant transformation. Naturally, the rise of technological advancements over time has “contributed to the widespread use of data visualization today. These include technologies for drawing and reproducing images, advances in mathematics and statistics, and new developments in data collection, empirical observation and recording” (Friendly, 2007, p. 15). All of these developments not only enabled the standardised, everyday use of graphic representation, but also facilitated in advancing its form and content.

Due to its dependent relationship with the advancement of technology, the precise definition of data visualisation is ever changing. Hence, the historical account, detailed in this chapter, will be presented thematically according to this changing definition. This particular thematic categorisation has been done exclusively by the author in order to recount the history of data visualisation in a more focused way which highlights its progression from two-dimensional diagrams to three-dimensional spatial experiences. Firstly, data visualisation will be briefly introduced as a form of *geographic* cartography aiding in the navigation and exploration of the physical world. Secondly, it will be presented as a form of *thematic* cartography aiding in the understanding of the social world. Thirdly, it will be presented as a form of graphical statistical diagramming aiding in the visual interpretation of numbers. Finally, data visualisation will be presented as the dynamic infographics dominating our present and aiding in the understanding of the virtual world we are building.

1.1 [Data Visualisation as:] CARTOGRAPHY OF THE PHYSICAL WORLD

The cartography of the physical world is an extensive subject matter; hence, it will only be briefly discussed here in order to provide a basic platform for the true beginnings of visual thinking of collected information.

The origins of visualisation date back to as early as 200 BC, when ancient Egyptian surveyors developed a coordinate system for their town planning requirements. More specifically, it was in the fields of astronomy and cartography that visualisation truly surfaced and played a revolutionary role in providing a visual representation of the physical world. There are examples of mathematically accurate cartographical studies as early as the 2nd century, however they were not globally accessible, thus visual

representations of these ideas were not produced until the 15th and 16th centuries (Figures 1.1-1.2). These maps represent the strong desire for discovery and understanding of our world’s physical composition in a visual, yet scientifically accurate, form. It is this desire which caused the rapid development of different “techniques and instruments for precise observation and measurement of physical quantities, and geographical and celestial positions” (Friendly, 2007, p. 18). This can be observed in

Figure 1.1: Ptolemy’s World Map, 1482



Figure 1.2: Representation of Ptolemy’s geocentric model, Peter Apian, Cosmographia, 1524





the creation of the first modern cartographic atlas which was produced in 1570 (Figure 1.3) and was a result of the introduction of triangulation in surveying. Arguably, these early cartographic examples and methodologies form the foundations of data visualisation and what it would become in the coming centuries.

However, these events also strongly emphasise the dependency of data visualisation's evolution on new technological innovations to be able to create more complex visual representations of information. If it wasn't for developments and inventions such as triangulation, the camera obscura⁴, the Cartesian coordinate system and many more, cartographical theories and methodologies would never have been represented and understood visually. In addition, a key factor for creating new and unique visualisations is the dataset itself. As can be seen from the various cartographic examples mentioned here, the only data that could be collected in these early stages, was that of "physical measurement – of time, distance, and space – for astronomy, surveying, map making, navigation and territorial expansion"

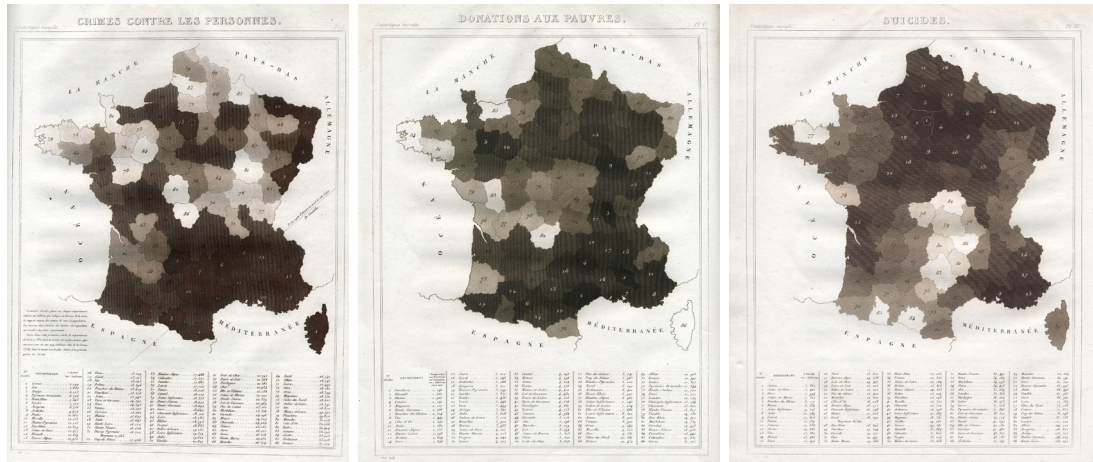
Figure 1.3: Theatrum Orbis Terrarum, Abraham Ortelius, 1570

(Friendly, 2007, p. 18). These were the predominant interests of the time, hence, it is this type of information that was readily available and any advancements in technology served this type of information as well.

1.2 [Data Visualisation as:] **THEMATIC CARTOGRAPHY OF THE SOCIAL WORLD**

In the late 17th century, interests in the type of information that could be collected began to shift from the physical measurements of geodetic data mentioned previously to social, economic and political data. Having understood the physical and natural world to the best of the available technology's abilities, the importance of people-centric data increased significantly in the following centuries because there was a new curiosity to understand the man-made world. This curiosity arose from pivotal societal transformations such as industrialisation, capitalism and the rise of bureaucracy. The Industrial Revolution was a key milestone in history because it influenced every aspect of daily life from changing marriage patterns to growths in average income to new manufacturing inventions. Due to the fast-paced nature of these widespread developments, the need for an official central system of management – bureaucracy – arose. Bureaucracy would facilitate in efficiently managing and structuring the growth of industrialisation, paving the way for increased quantitative thinking. Hence, there was a desire to decipher and understand the new path society was taking by finding ways to quantify it. This is supported by Friendly who explains that "the systematic collection and study of social data began... under the rubric of 'political arithmetic'... with the goals of informing the state about matters related to wealth, population, agricultural land, taxes... as well as for commercial purposes" (Friendly, 2007, p. 21).

Thus, the method of combining data of significant interest with the geographic maps of the physical world was invented and was known as thematic cartography because each geographic map portrayed a different set of data. Thematic cartography flourished during the 19th century, and it led to new ways in which social quantitative information could be portrayed on maps. One notable individual who revolutionised this methodology was André-Michel Guerry, a French lawyer and amateur statistician. He produced ground-breaking visual work of the moral statistics of France, where he displayed collected data on crime, poverty and suicides on maps of the country (Figures 1.4-1.6). By creating multiple maps focusing on



different datasets, Guerry was able to present a visual comparison of varying statistics in the same regions, thus revealing the shape of the data in a clear and refined form. Taking this methodology further, and into an even more graphic domain, was Dr. John Snow with his dot map showing the deaths caused by cholera in London's Soho in 1854 (Figure 1.7). This “landmark graphic discovery” (Friendly, 2007, p. 26) signifies a climax in the application of thematic cartography to social subjects and results in an aesthetic visual representation which will become the foundation of modern infographics⁵.

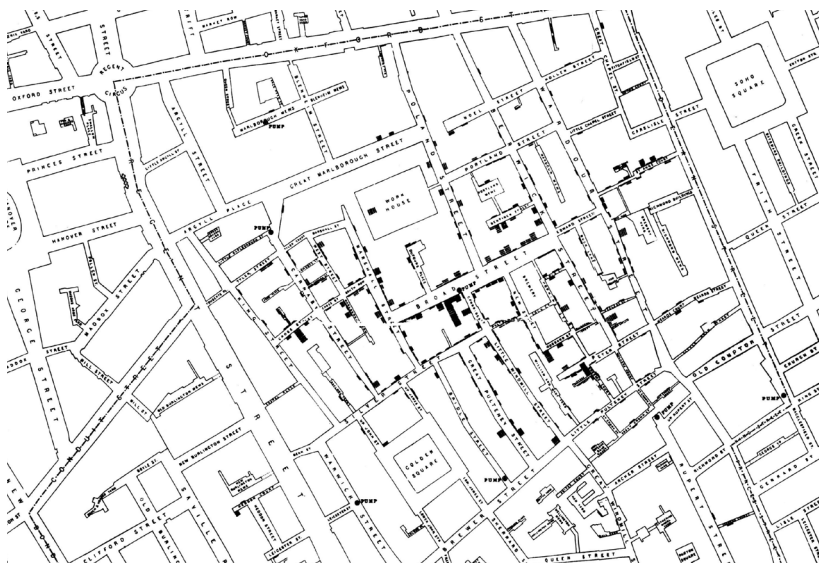


Figure 1.4: Crimes Against People, André-Michel Guerry, 1833

Figure 1.5: Donations to the Poor, André-Michel Guerry, 1833

Figure 1.6: Suicides, André-Michel Guerry, 1833

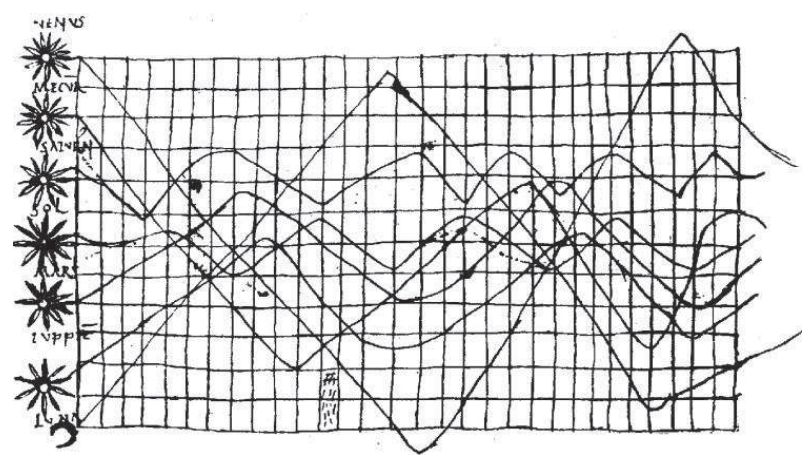
Figure 1.7: Cholera Map of Soho showing cholera clusters around the Broad Street water pump, Dr John Snow, 1854

1.3 [Data Visualisation as:] GRAPHICAL STATISTICAL DIAGRAMS

Arguably, the development of thematic cartography led to the sudden growth of statistical graphics – data visualisations such as graphs and charts which are used to visualise quantitative data based on statistics – in the first half of the 19th century. This is due to the now widespread “collection, organization and dissemination of official government statistics on population, trade and commerce, social, moral and political issues” (Friendly, 2007, p. 30). Suddenly, new graphical methods and applications were required in order to keep up with the complexity and the quantity of this publicly- available data.

Before exploring the graphical innovations of the 19th century, it is important to look at one of the earliest depictions of quantitative information: a multiple time-series graph⁶ of planetary movements (Figure 1.8). This graph dates back to the 10th century and “appears as a mysterious and isolated wonder in the history of data graphics” (Tuft, 1983, p. 28) because nothing similar is produced for the next 900 years. It is a significant image because it highlights the aspiration to display information in a visually graphical format, but its development is inhibited by stagnant technologies and inaccessibility to a variety of data. With technological advancements and data availability on the rise, the 19th century was a breeding ground for this type of graphical visualisation. Friendly states that “all of the modern forms of data display were invented: bar and pie charts, histograms, line graphs and time-series plots, contour plots, scatterplots” (Friendly, 2007, p. 23).

Figure 1.8: Planetary movements shown as cyclic inclinations over time by an unknown astronomer, 10th century



Minard was a pioneer in the use of graphics in engineering and statistics at a time when graphs were becoming popular in economic and state planning. This is illustrated well in his *Tableau Graphique* (Figure 1.12) which shows

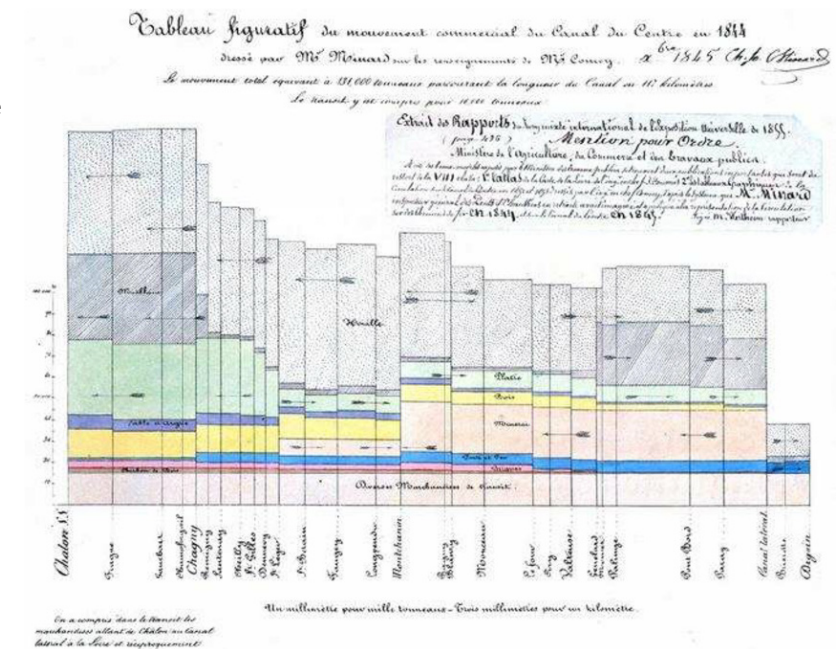
Figure 1.10: Trade balance time-series chart, William Playfair, 1786



Figure 1.11: Pie-circle-line chart comparing population and taxes in several nations, William Playfair, 1805

This was the highpoint of creativity in data visualisation, which fell dormant until the mid-20th century. Friendly argues that the reason for this was that “graphic innovation was... awaiting new ideas and technology: the development of the machinery of modern statistical methodology, and the advent of the computational power and display devices which would support the next wave of developments in data visualization” (Friendly, 2007, p. 36).

Figure 1.12: Tableau Graphique, showing the transportation of commercial goods along the Canal du Centre (Chalon-Dijon), Charles Joseph Minard, 1844



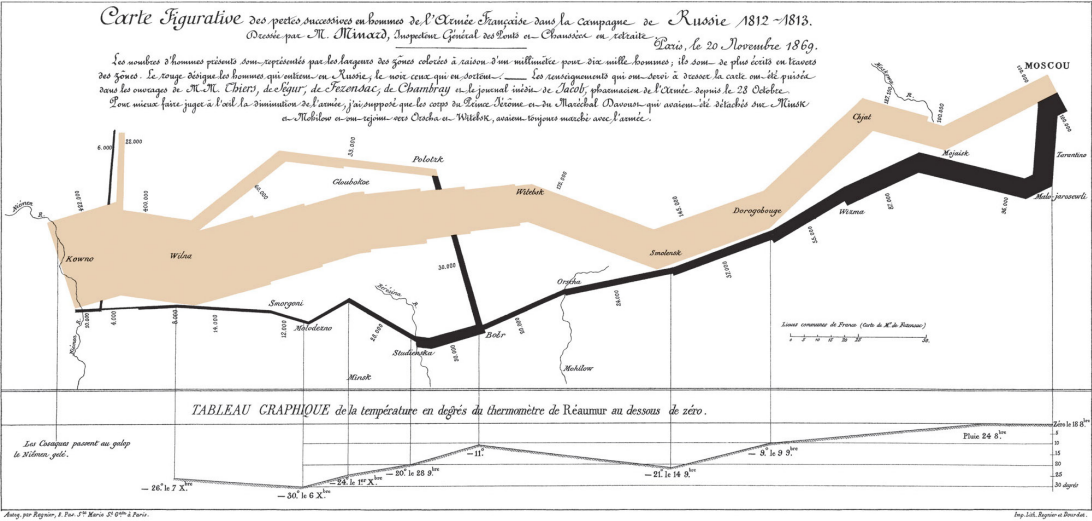


Figure 1.13: Flow map of Napoleon’s disastrous Russian campaign of 1812. The graphic is notable for its representation in two dimensions of six types of data: the number of Napoleon’s troops; distance; temperature; the latitude and longitude; direction of travel; and location relative to specific dates; Charles Joseph Minard, 1861

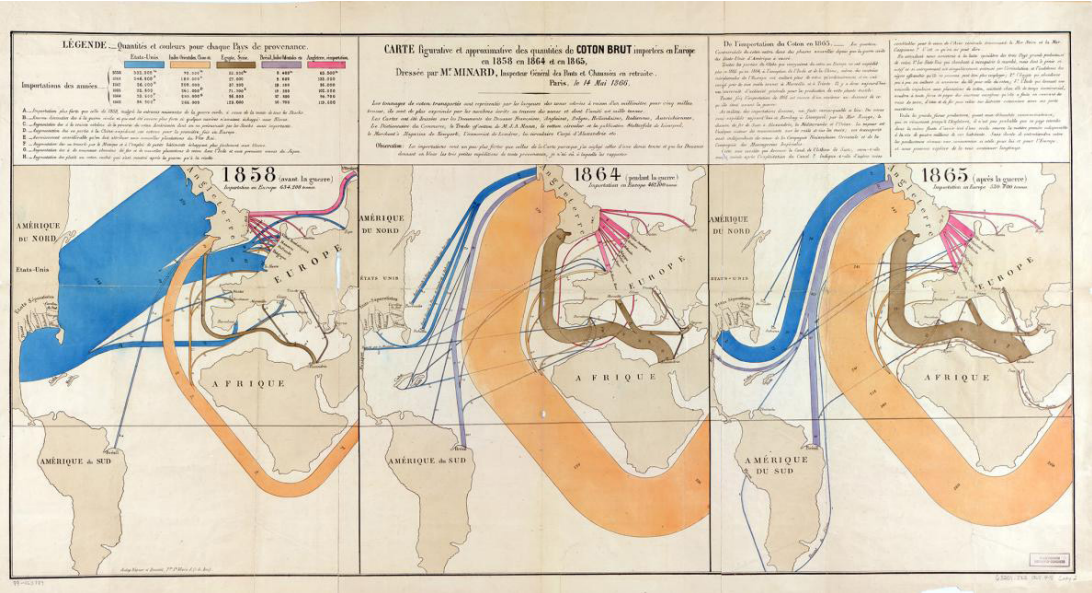


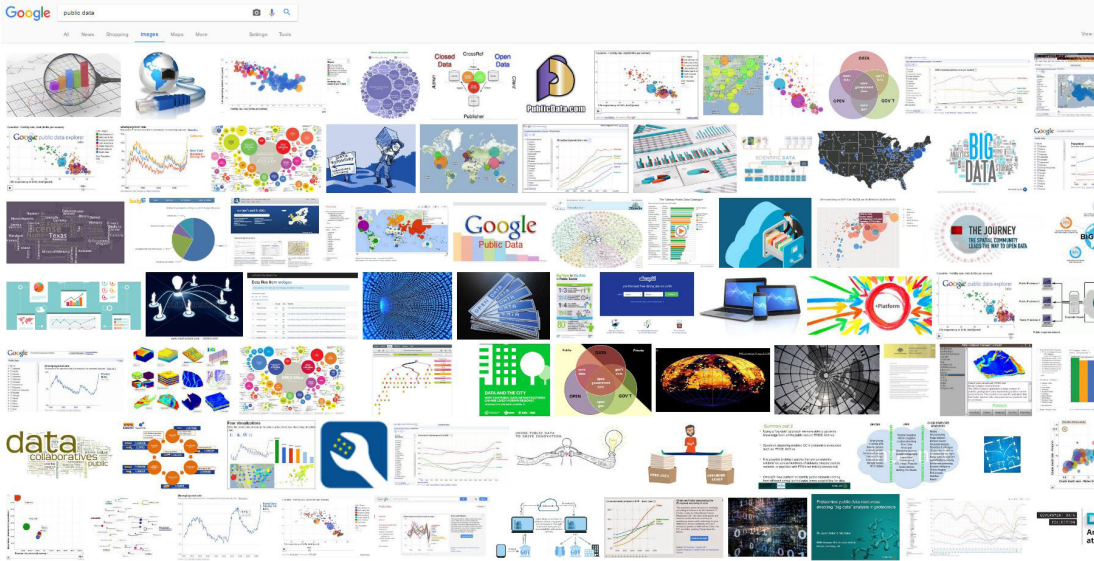
Figure 1.14: Thematic graphical maps showing the origin and amount of cotton imported into Europe in 1858, 1864, and 1865; Charles Minard

1.4 [Data Visualisation as:] DYNAMIC INFOGRAPHICS

As mentioned from the very start, the evolution of data visualisation has always been heavily dependent on advancements in technology. The invention of the modern computer during the Second World War was the landmark invention that, combined with the invention of monitors, not only helped data visualisation rise from dormancy in the mid-1960s, but also played a pivotal role in its transformation into an entirely new medium, still progressing in the present day.

The widespread installation of mainframe university computers in the late 1960s offered people the possibility to construct old and new graphic forms with the use of computer software. In the last few decades, a vast increase in computer processing speed and capacity has facilitated computationally-intensive methods and access to data problems of increasing difficulty. This huge leap in technological advancement combined with the abundance and accessibility of data, as a direct result of the Internet, has led to a new era of dynamic infographic representations. As Manovich points out, and as can be seen in Figure 1.15, when any public data is searched for online, the resulting website links are automatically created infographic representations of this data (Manovich, 2010, p. 2). Arguably, we are slowly becoming numb to the data visualisations which were so revolutionary in the 19th century, because of their standardised presence in everyday life.

Figure 1.15: Google image search of ‘public data’



As a result, “information visualization is becoming more than a set of tools, technologies and techniques for large data sets. It is emerging as a medium in its own right, with a wide range of expressive potential” (Manovich, 2010, p. 1). This new medium takes the form of 2D and 3D artwork, interactive installations and some architecture. Visualisation projects are now created by scientists, designers and artists alike, with the aim of exploring the virtuality and intangibility of data in a visual and physical form. Naturally, by “using software, we can visualize much larger data sets than it was previously possible; create animated visualization; show how processes unfold in time; and, most importantly, manipulate visualizations interactively” (Manovich, 2010, p. 5). A good example of this is the Museum of Modern Art’s large online survey exhibition *Design and the Elastic Mind* (MoMA, 2008). The website interface becomes a dynamic and interactive infographic in itself (Figure 1.16), whilst simultaneously displaying a catalogue of numerous data visualisation projects. One of these projects, is Brendan Dawes’ *Cinema Redux* of the film *Vertigo* (Figures 1.17-1.18). As described by the artist himself, “Cinema Redux creates a single visual distillation of an entire movie; each row represents one minute of film time, comprised of 60 frames, each taken at one second intervals. The result is a unique fingerprint of an entire movie, born from taking many moments spread across time and bringing all of them together in one single moment to create something new” (Dawes, 2016).

Figure 1.16: Design of the Elastic Mind, MoMA, 2008

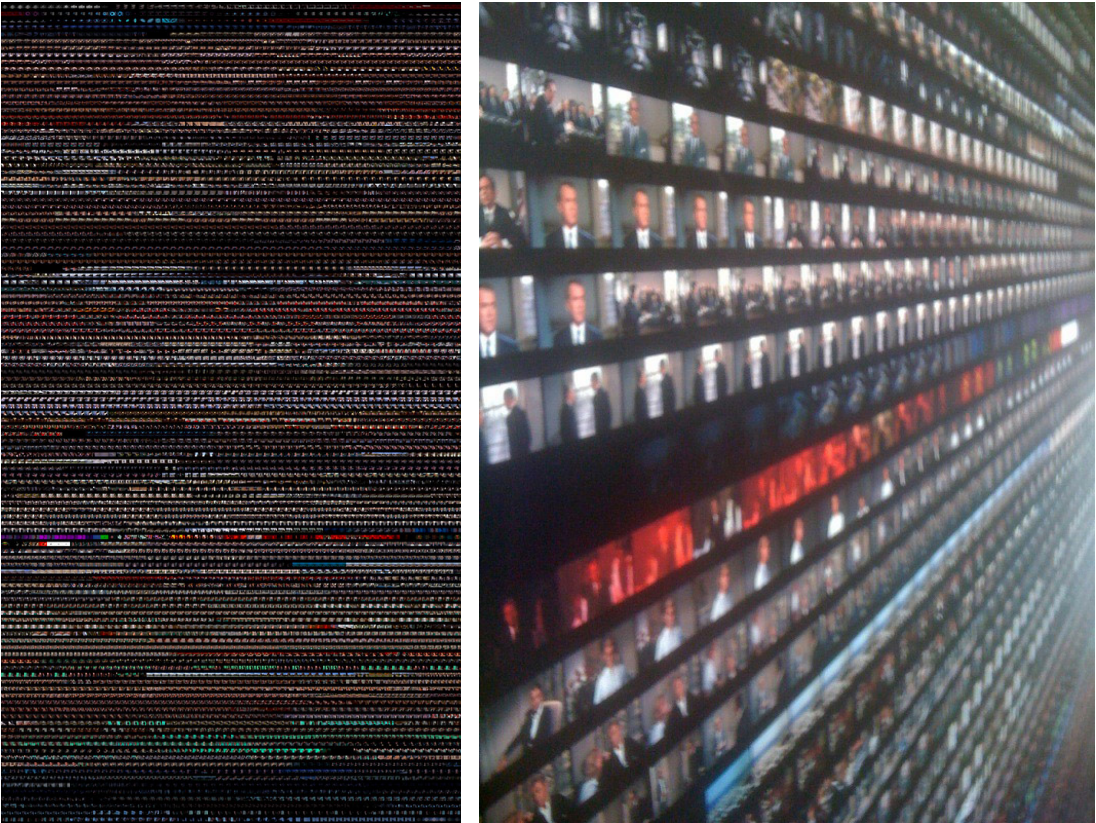
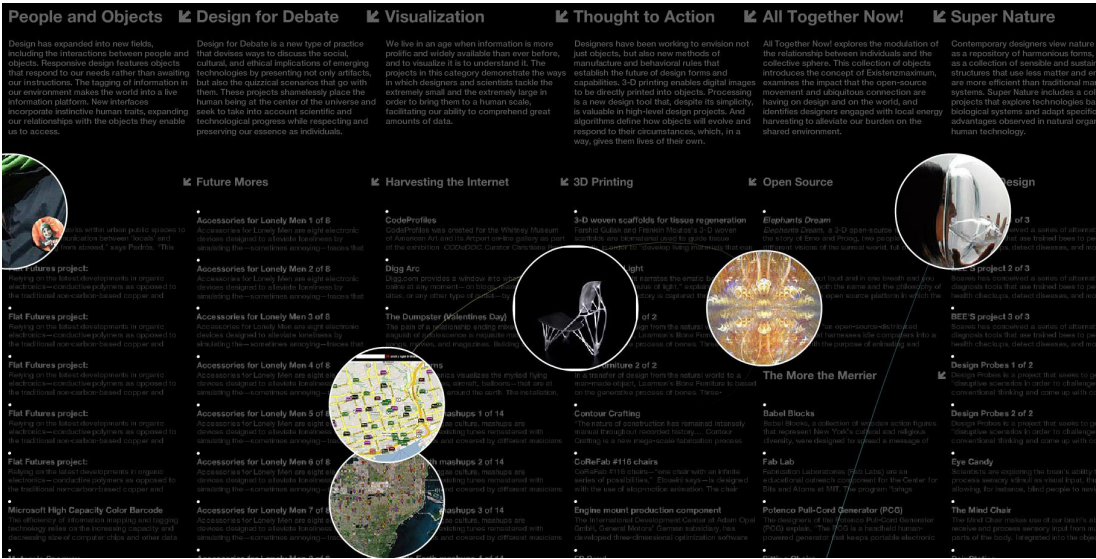


Figure 1.17 & 1.8: Cinema Redux: Vertigo, Brendan Dawes, 2004

It is this type of abstracted data visualisation as art that is emerging presently. Infographics are becoming standard practice and “informationalization’ puts pressure on society to invent new ways to interact with information, new ways to make sense of it, and new ways to represent it” (Manovich, 2008, p. 5). Data visualisation artists now have the opportunity “to map such [intangible] phenomena into a representation whose scale is comparable to the scales of human perception and cognition” (Manovich, 2002, p. 8). In this way, they facilitate in the understanding of the virtual world we are building today.

As a conclusion to this brief history of data visualisation, Michael Friendly’s observations are the most applicable:

“...most of the innovations in data visualization arose from

concrete, often practical goals: the need or desire to see phenomena and relationships in new or different ways. It is also clear that the development of graphic methods depended fundamentally on parallel advances in technology, data collection and statistical theory.” (Friendly, 2007, p. 44)

SECTION 2.0

INFO-AESTHETICS

The brief history of data visualisation detailed in Chapter 1, highlights the desire to visualise quantitative data as a means of understanding our social and physical worlds. However, with the emergence of dynamic infographics in the last few decades, a new ideology for identifying the cultural changes that have arisen from our ‘information society’ has also surfaced. This new ideology is more focused on the aesthetic exploration of generated data as a means of deciphering the raw data itself, rather than the social and physical aspects of the world. However, in doing so, the understanding of the new-evolving virtual world is also revealed as a consequence. Lev Manovich has termed this ideology ‘info-aesthetics’ and defines it as follows:

“‘info-aesthetics’ refers to those contemporary cultural practices that can be best understood as responses to the new priorities of information society: making sense of information, working with information, producing knowledge from information” (Manovich, 2008, p. 6).

In essence, ‘info-aesthetics’ is the convergence of the digital and the physical, the former being a manifestation of the latter. This ‘convergence’ can take the physical form of a variety of aesthetic media such as cinema, fashion, art, design and architecture. It is the evolution of data *visualisation* into data *materialisation*, because as Manovich points out “in order to be useful to us, information always has to be wrapped up in some external form” (Manovich, 2008, p. 2). There is a critical relationship between information and its material support, a concept which dates back to ancient Greek and Roman philosophers’ explanations of the meanings of knowledge and information. The likes of Plato, Aristotle, Cicero, Descartes all used the paradigm of manipulating a piece of wax (deforming it, imprinting in it, writing characters in it) as an early philosophical analysis of knowledge (Adriaans, 2012). By manipulating wax, which is a physical material, visual outputs of intangible ideas/information can be produced to form knowledge about a particular subject. In a similar way, this is happening with ‘info-aesthetics’ and data materialisation today. Instead of wax, however, the external form of information is now a type of monitor (computer screen, television, tablet, smartphone), which provides a clear visual representation of the digital, facilitating in the representation of abstract data through the use of interactive visual interfaces. The interfaces designed and displayed on these monitors – folders, icons, menus, voice recognition – act as navigational tools to explore the virtual realm of data. In the last two decades, however, interface design has become well developed

and as a result, there has been a shift in visual representations of data on flat monitors to the exploration of new, three-dimensional ways with which to materialise data and navigate through it (see Chapter 3).

Since antiquity, information has usually been strongly linked to numerical and mathematical principles because, in their pure form, numbers have the power to reveal a form of truth, making visible laws that are otherwise hidden. Hence, data visualisation sought to visually represent quantitative data in a clear, methodical way which would lead to its absolute understanding. Above all else, it aimed to inform. In contrast, ‘info-aesthetics’ and data materialisation strive to primarily create aesthetically physical experiences of data with secondary thought to its understanding. Despite being derived from data, they do not necessarily provide a clear understanding of the individual data values themselves; instead, through the physical and visual representation of a selected dataset, they expose the vast quantity of data generated today. Arguably, data, in these instances, can be seen as cultural artefacts rather than as purely functional elements. They exist as supporting, rather than leading, components in the creation of immersive physical experiences.

Thus, ‘info-aesthetics’ is the result of the powerful combination of computational power, monitors and the Internet, and is becoming progressively more prominent in everyday life: the Internet easily connects all corners of the world, makes data readily available and accessible, and generates vast amounts of data itself; computers act as the tool with which all this generated data can be collected, organised and analysed, as well as aiding in its aesthetic output; and finally, monitors are the all-important device which translate data into a visual output for us to understand. Virtually everything is being collected nowadays: culture, asteroids, DNA patterns, credit records, telephone conversations. Thus, “the world appears to us as an endless unstructured collection of images, texts, and other data records. It is only appropriate that we... would want to develop poetics, aesthetics, and ethics [for its representation]” (Manovich, 1998, p. 2). It is the responsibility of ‘info-aesthetics’, therefore, to inspire the creation of new visual and tangible ways to structure our experience of the world through data visualisations.

The forms we create as artists, designers and architects become hugely important in bringing the ‘info-aesthetics’ ideology to life. We may be developing into an information-processing species, but we will always remain a form-creating one as well. The increasing overlap of the two allows

data to become a unique type of design tool where it can shape the physical forms we design. Through the material forms of art, design and architecture, we can begin to shape intangible data structures into concrete creations as a means of rendering them useful and meaningful for human perception. In this way, we come one step closer to visualising the vast, complex network of the virtual. Manovich poses some interesting questions about this:

“What is the ‘shape of information’? ...Has the arrival of information society been accompanied by a new vocabulary of forms, new design aesthetics, new iconologies? ...How can the superhuman scale of information structures... be translated to the scale of human perception and cognition?”
(Manovich, 2008, p. 6)

There is a multitude of design projects which begin to answer some of these questions, a few of which are discussed in Chapter 3. Firstly, to address the second question, the simple answer is yes. Our ‘information society’ has resulted in the digital gradually infiltrating the majority of aesthetic domains. Art is now turning to the digital, from Brendan Dawes cataloguing film stills to David Hockney using an iPad to create digital paintings, as a way of showcasing the many different ways in which data can be represented visually, physically and aesthetically. Consequently, these new methods generate new types of design toolkits. Secondly, to address the third question, the aforementioned digitalisation of art provides new methods to translate the intangible, superhuman scale of data into concrete and immersive 2D and 3D visualisations. These have the ability to form a wider image of the complex data structures that govern our world.

Finally, it is important to discuss these questions in relation to architecture independently of art, because the former is not as developed as the latter when it comes to using data as a formative design tool. Architecture uses data in a pragmatic, problem-solving manner rather than an aesthetic one. The development of ‘smart’ buildings is, of course, desirable as we strive for an automated and sustainable lifestyle. However, architecture also has a responsibility to bring the ‘info-aesthetics’ ideology into a three-dimensional realm. As Antoine Picon states, “architectural space [is] neither the Cartesian geometric space [too concrete] nor the space of sensorial perception [too abstract] ... [it is a] compromise between these two extreme conceptions of space in order to stimulate thought as well as sensation” (Picon & Ponte, 2003, p. 299). This highlights how architectural space, under the ideology of ‘info-aesthetics’, needs to be designed to create a link between “the abstract

and the concrete, [between] geometrical measurements and sensorial experience” (Picon & Ponte, 2003, p. 299). It is important to let data shape architectural forms and elements in order to give buildings unique designs, whilst simultaneously creating sensorial experiences of that data. In this way, by using data both pragmatically and aesthetically, architecture can expose the much larger picture of ‘information society’. Only by giving a physical, three-dimensional form to data – an abstract entity humans have created – can we truly understand the quantity of that data being produced, and in turn form a comprehensive view of the current status of the world.

SECTION 3.0

CASE STUDIES

In order to form a better understanding of the ideology behind ‘info-aesthetics’, it is important to look at its application in a selection of case study examples in the fields of art and architecture. The chosen case studies are Lisa Jevbratt’s *1:1* project and Ryoji Ikeda’s *supersymmetry* exhibition, for the former, and Daniel Libeskind’s Jewish Museum in Berlin, for the latter. All three will be described and critically analysed on their use of data as a design tool.

The aforementioned projects have been chosen specifically because they offer a wide range of media explorations of data visualisation in the last two decades. *Computer* art has existed since the 1960s; however, it is only until relatively recently that *data* art has emerged as a result of the development of new media and the abundance of information available. Data art is the conversion of collected data into visualisations which aim to create aesthetic and immersive experiences as a means of understanding the scale of data we generate in today’s ‘information society’. Hence, we can argue that data art is a form of ‘info-aesthetics’. Until recently, the visualisation of data in the cultural sphere “has been used on a much more limited scale, being confined to 2D graphs and charts... or an occasional 3D visualization” (Manovich, 2002, p. 2). However, data art not only allows for an abundance of aesthetic data visualisations as cultural artefacts, but also creates an outlet for multi-dimensional projects.

3.1 ART: 1:1 and 1:1(2) (Lisa Jevbratt, 1999 and 2001)

Two-dimensional art, as well as three-dimensional art in the form of installations (discussed in Chapter 3.2), are the most prominent media of data art which portray the ideology of ‘info-aesthetics’. Starting with the two-dimensional are Lisa Jevbratt’s projects entitled *1:1* (Figure 3.1) and *1:1(2)* (Figure 3.2), which is a continuation of the former. The initial concept of the project was to create a database that would search for websites at a specific numerical address (IP address) and store them if they existed. The aim was for the database to eventually contain the addresses of every website in the world, as well as provide different interfaces for the navigation of the database itself. Jevbratt designed five interfaces to provide a visual representation of the database as well as a means of using it to access the Web, much like a search engine. She eloquently explains:

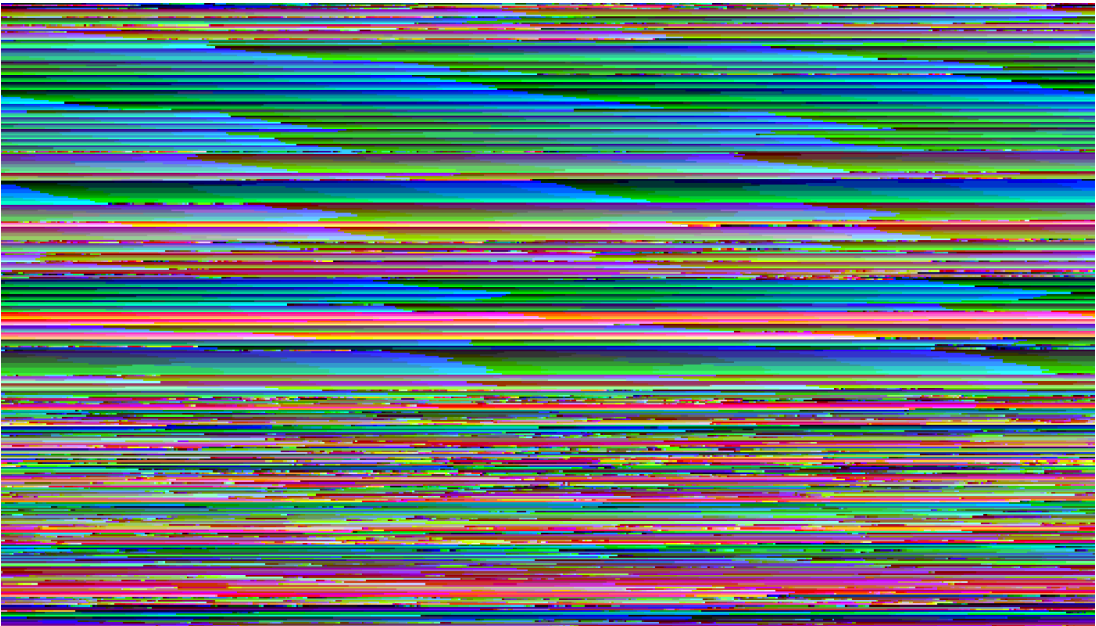


Figure 3.1: 1:1 (every IP address in 1999), Lisa Jevbratt, 1999

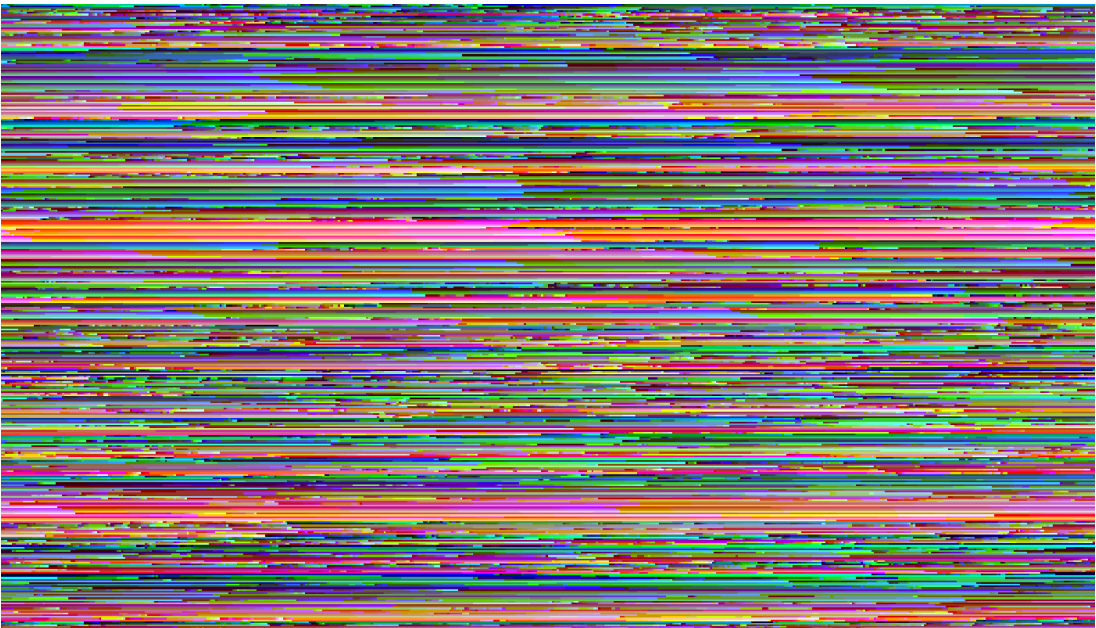


Figure 3.2: 1:1(2) (every IP address in 1999), Lisa Jevbratt, 2001

“when navigating the Web through the databases, via the five interfaces, one experiences a very different Web than when navigating it with the “road maps” provided by search engines... this Web is an abundance of inaccessible information, undeveloped sites and cryptic messages... Search-engines... deliver only a thin slice of the Web to us.... The interfaces/visualizations are not maps of the Web but are, in some sense, the Web... They are a new kind of image of the Web, and they are a new kind of image” (Jevbratt, 1999-2002).

The images shown in Figures 3.1 and 3.2 best display these observations. They are part of the ‘Every’ interface of the database which collectively depicts all the IP addresses found on the Web in a visually powerful format. The way the data is displayed, as thousands of pixels of various colours, creates an aesthetically rich image which essentially resembles abstract art. At the same time, however, it creates an overwhelming and chaotic feeling in the observer, acting as a metaphor for the vast amount of incomprehensible data which exists virtually. Ultimately, Jevbratt succeeds in giving a virtual set of numerical data a visual and concrete structure. Although seemingly 2D, the artwork, in actual fact, has an additional dimension to it: interactivity. It allows the user to click on the different pixels which are linked to the IP addresses they represent. Hence, the image is not just a visual representation of data, but also the data itself. Numerical data has been used as the initial design tool for the pixel image which has been strengthened by the resultant interface design, thus creating an aesthetic and immersive experience of the structure of the Web.

The artwork is presented in two different media: one is the database in its pure form displayed online and seen through a monitor, and the other is a physical billboard print-out of the ‘Every’ interface. Both offer a different visual experience: the former allows for the interactive experience of the database itself, and in turn creates a very personal exploration of the artwork as each person will navigate it differently; the latter creates a more physical experience, particularly when printed at a large size, as it appeals to the viewer on a visual as well as a somatic level. Both of these representations highlight the importance of media in the visualisation and materialisation of data.

3.2 INSTALLATION: *supersymmetry*, London (Ryoji Ikeda, 2015)

As exhibited by Lisa Jevbratt’s projects, the multi-dimensionality of data art is significant as each additional dimension acts as another layer of information, thus resulting in well-rounded and experimental visualisations of data. Another example of this type of multi-dimensional art is the work of Japanese data artist, Ryoji Ikeda, who held an exhibition in London in 2015 which I was fortunate to have visited. The exhibition, entitled *supersymmetry*, was influenced by Ikeda’s residency at the European Organisation for Nuclear Research (CERN) in Switzerland where ‘supersymmetry’, a theoretical mathematical model which helps explain why particles have mass, was being tested. The installations “attempt to transform the complexity of quantum information theory into an immersive aesthetic experience, meshing sound, visual data and high-speed light displays” (Culpan, 2015), thus acting as the perfect example of a multi-media and multi-dimensional data visualisation.

The exhibition area itself was divided into two dark spaces, each of which housed a different installation. The first space, entitled *[experiment]*, had three light boxes at its centre, where tiny ball bearings moved around on a glowing white backdrop forming unique and unpredictable patterns (Figures 3.3-3.4). The second, and most engaging, space, entitled *[experience]*, had two twenty-metre-long screens facing each other on opposite ends, blinking with forty monitors, all displaying how the data from the *[experiment]* installation had been analysed and translated (Figures 3.5-3.6). The experience is aptly described by the following account:

“The synchronized monitors pulse with high-speed analyses and typed text, while the electronic soundscape -- a symphony of bleeps, buzzes and droning hums -- adds to the charged atmosphere. The overall effect, as you glance at the mutating text and the rapid-fire bombardment of data, is both hypnotic and hallucinatory, and yet there’s also something strangely oppressive about being caught in this endless loop of sound and information.” (Culpan, 2015)

The described effect can be seen on a basic level in Figure 3.7, which shows eight video stills of the *[experiment]* installation taken in the space of eight seconds. Each still is significantly different from its neighbour, highlighting the fast-paced nature of the installation. Furthermore, the installations illustrate one of Manovich’s key observations, that “data visualization moves from the concrete to the abstract, and then again to the concrete.

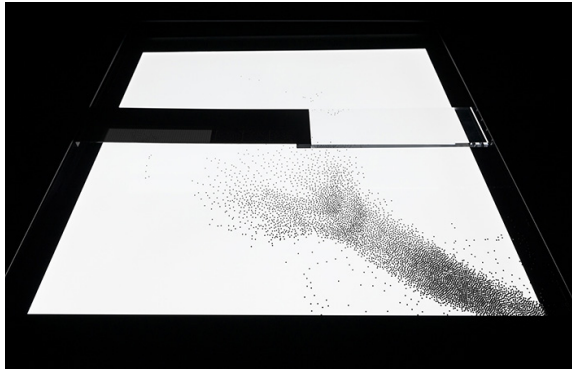


Figure 3.3: *[experiment]*, *supersymmetry*, Ryoji Ikeda, 2014

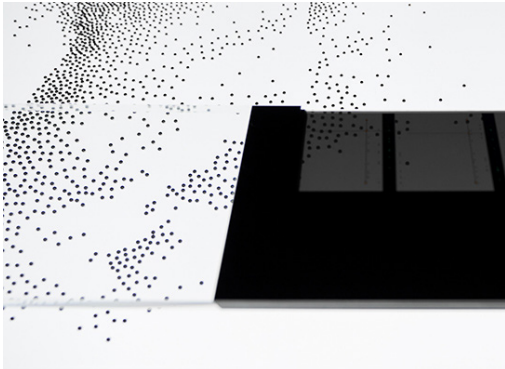


Figure 3.4: *[experiment]*, *supersymmetry*, Ryoji Ikeda, 2014



Figure 3.5: *[experience]*, *supersymmetry*, Ryoji Ikeda, 2014

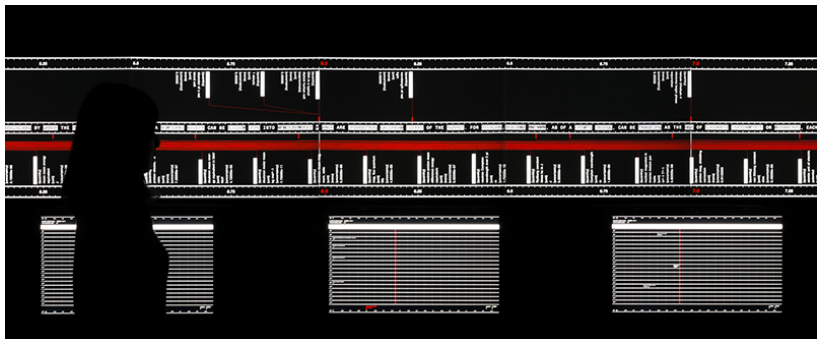


Figure 3.6: *[experience]*, *supersymmetry*, Ryoji Ikeda, 2014

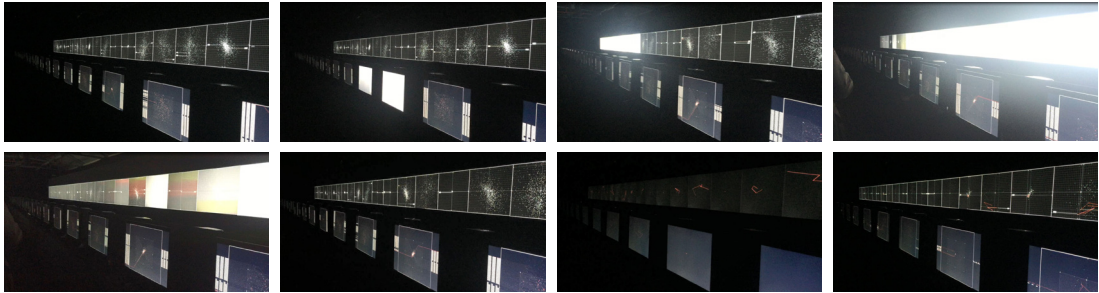


Figure 3.7: *Sequence of video stills from the [experience] installation, London, 2015*

The quantitative data is reduced to its patterns and structures that are then exploded into many rich concrete visual images” (Manovich, 2002, p. 7). As seen particularly in the *[experiment]* installation, the virtual structure of selected particle physics data is deciphered by Ikeda and re-imagined as the concrete visuals displayed on the various monitors. Taking this one step further, Ikeda’s chosen representational form for these concrete visuals actually shows the sequence of decoding the dataset. In this way, data is being used as a type of design tool where the virtual process of decoding data into a set of understandable structures and patterns creates an aesthetically immersive and multi-sensory work of three-dimensional art.

Unlike Jevbratt’s artwork which primarily exists on a monitor, Ikeda’s installation takes on a multi-medium, three-dimensional form causing it to progress more towards architecture than art. Spatial experiences in architecture tend to rely on all five senses; Ikeda’s use of monitors, lights and sounds is a step in this direction because by engaging multiple senses, he creates an exploration of physical space as well as the virtual data driving it. Furthermore, the installation is presented at an architectural scale, unlike Jevbratt’s which is dependent on the user’s monitor size. By allowing visitors to walk around an open room surrounded by screens, Ikeda is essentially creating an architectural space, which he has carefully curated to formulate an all-encompassing, immersive experience. Arguably, the installations are engaging works of art which are both conceptual in their visual output and strongly material in their information input. They appear to do exactly what ‘info-aesthetics’ expects of artwork of this type: they take a complex and unimaginable mathematical dataset and create an immersive, physical experience of it.



3.3 ARCHITECTURE: The Jewish Museum, Berlin (Daniel Libeskind, 1999)

In contrast, the field of architecture is trailing behind that of art in terms of the possibilities of using data visualisation as an aesthetic design tool. Lev Manovich points out that “many architects... record, analyse, and map information flows, and then utilize resulting records and diagrams to drive the design of architectural forms and spaces” (Manovich, 2005, p. 3). This is a key observation as it highlights the fact that data collection in architecture is primarily being used for the creation of practical, technologically responsive designs, when it could also be used for bespoke and aesthetically meaningful ones. There are few examples which showcase this ideology in practice, and even those only scratch the surface of it. One of these examples is the Jewish Museum in Berlin designed by Daniel Libeskind in 1999 (Figure 3.8). Although it is “one of the most outstanding architectural buildings of the last decade” (Manovich, 2002, p. 9) in terms of its design, its concept, and the sensory experience it provides within, it lacks a deeper representation of symbolic data used for the design of its façade.

It is important to firstly take a brief look at the four different concepts surrounding the overall design and form of the building. As explained by Libeskind himself,

Figure 3.8: Aerial view of Jewish Museum, Berlin

“the first aspect is the invisible and irrationally connected star which shines with the absent light of individual addresses. The second one is the cut through Act II of Moses and Aaron which has to do with the not-musical fulfilment of the work. The third aspect is that of the deported or missing Berliners; the fourth aspect is Walter Benjamin’s urban apocalypse along the One Way Street.” (Dogan & Nersessian, 2012, p. 16)

The first and third aspects are the most relevant in this study because they involve the collection and mapping of data, which, in this case, is the linking up of specific people and places around Berlin. Libeskind explains further:

“I started by trying to plot a hexagonal figure... the star of David... Around the site on Lindenstrasse there lived so many famous Germans, and many famous Jews... I went about trying to find out the addresses of Berliners like Kleist⁷, Heine⁸, Rahel Varnhagen⁹, E. T. A. Hoffmann¹⁰, and Mies van der Rohe¹¹, but also of more contemporary Berliners like Schönberg¹², Paul Celan¹³, Walter Benjamin¹⁴... I ended up with a kind of distorted hexagonal set of lines... This rather irrational set of lines forms a nexus that links up certain anonymous places in Berlin, both East and West. But it is also a series of connections between unreal places and real people.” (Libeskind, 1992, p. 83)

Here, Libeskind lists a number of historical figures as well as a selection of buildings on a separate occasion (“Berlin Museum, Erich Mendelsohn’s Metal Workers Union Building, Libeskind’s own City Edge Project, Oranienstrasse, and Mehringplatz” (Dogan & Nersessian, 2012, p. 25)), all of which are interconnected and, essentially, form his starting dataset. The choice of people and places and the connections between them, aims to unite Jewish and German cultures as well as Jewish-German history by placing them all under one contextual roof: the city of Berlin.

Libeskind also mentions the star of David as his initial concept for the building form which, as can be seen in some of his early exploratory sketches (Figure 3.17), he tries to manipulate and abstract its shape so as to generate a more open and fluid form to incorporate his dataset of selected historical figures and their addresses. In the final and more developed drawing of the star diagram (Figure 3.18), we can see the star extending across the whole city of

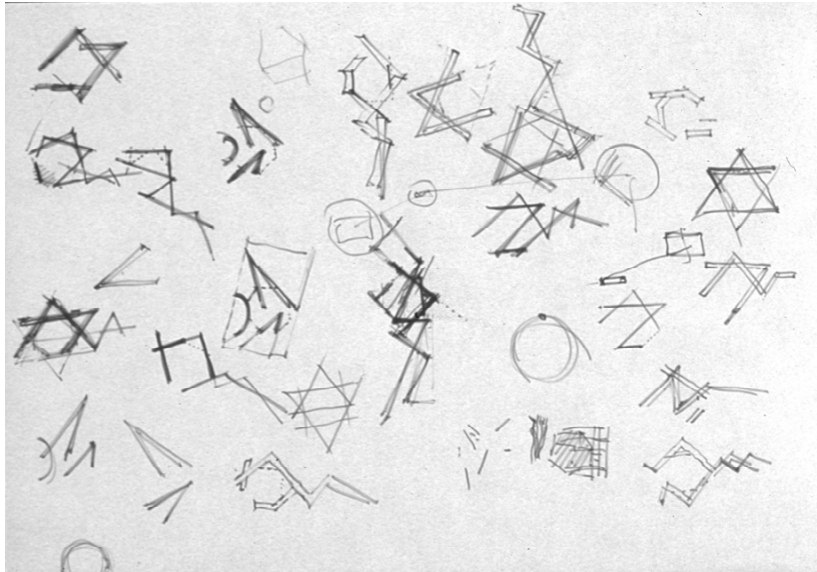


Figure 3.17: Initial sketches showing the manipulation of the star of David for the form of the building, Daniel Libeskind

Figure 3.18: Final star diagram concept drawing, Daniel Libeskind

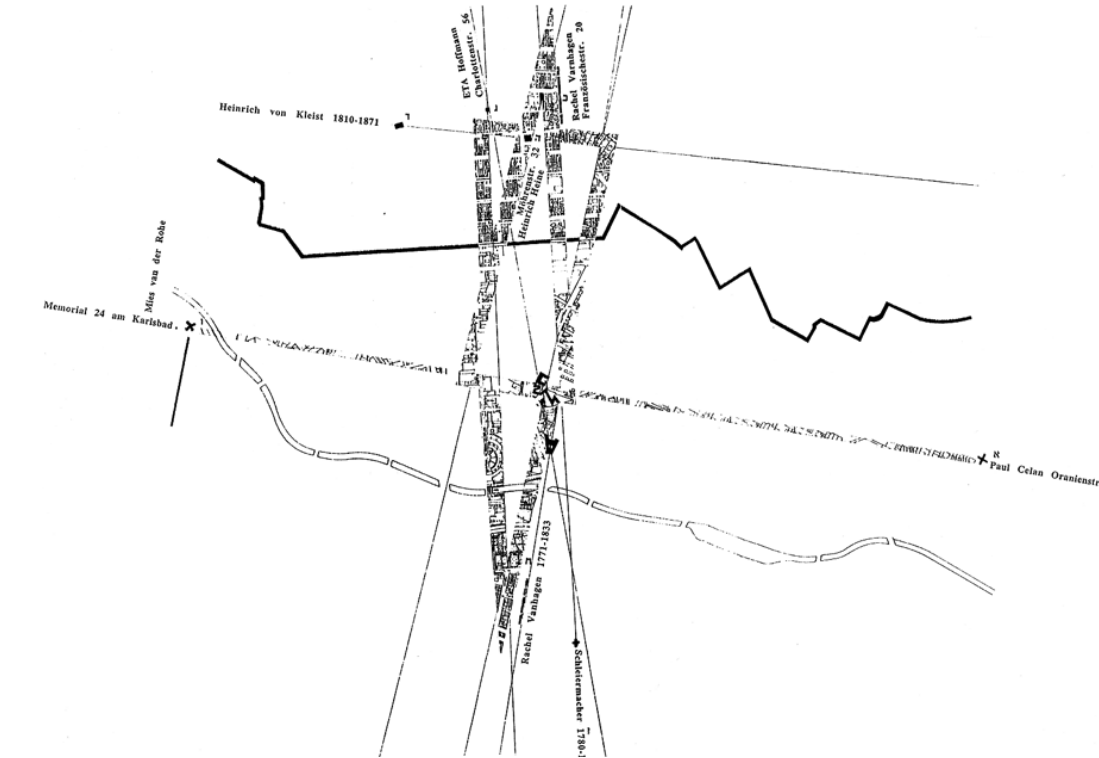


Figure 3.19: Sketches showing the connection of historical places, Daniel Libeskind

Figure 3.20: Sketches showing the connection of people using a partial star of David, Daniel Libeskind

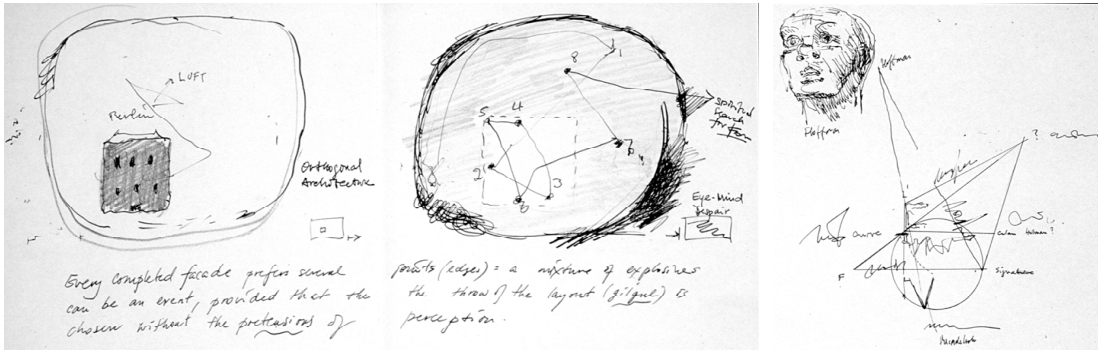
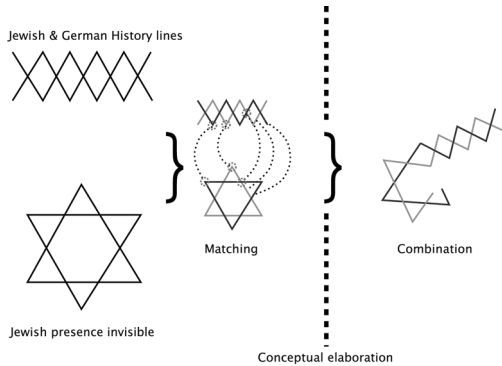


Figure 3.21: Diagram showing the deconstruction of the star as two unfolded lines of the original star, Fehmi Dogan and Nancy J. Nersessian

Berlin as an imaginary projection, with the locations of the aforementioned historical figures marked on. The scale of the star was adapted to cover a large area of the city in order to display the network of historical figure connections as corresponding points to the edges of the star itself.

Ultimately, the deconstructed star was conceived as an “underlying pattern or structure over the city of Berlin which, though not visible might be traceable through plotting points and connecting them to one another” (Dogan & Nersessian, 2012, p. 24). It is initially used as the base structure for two separate notions, connecting places with each other and connecting people with each other, before combining the two to form a single interconnected piece of visual data. Figures 3.19 and 3.20 show the deconstructed star being used in different ways to bring out different sets of information. The former shows the star as a result of the plotted points of the geographical locations mentioned previously, and the latter shows a partially plotted star formed by the connection of some of the historical figures mentioned earlier. When the two ideas are combined, the shape of the star is deconstructed completely into a set of unfolded lines of the



original star (Figure 3.21) representing the relationship between Jews and Germany in the historical context of Berlin.

The final layer of information is the addition of historically significant dates which correspond to the internal exhibition spaces. As can be seen in Figure 3.22, “the historical succession of events is plotted along a horizontal and a vertical axis, where the horizontal axis is linear and continuous [representing the Jewish history] and the vertical [representing Berlin’s history] tends to zigzag around the linear horizontal axis. Historical events or dates are plotted along both axes” (Dogan & Nersessian, 2012, pp. 28-29).

All these layers of collected data (people, places, dates) are connected to each other linearly, culminating in the iconic façade which is, effectively, a map of Jewish history in Berlin. By projecting the topographical lines joining the addresses, which bisect the site, onto the skin of the building, 365 irregular windows are hacked out of the zinc-panelled façade making it a tangible data visualisation diagram of the city’s past (Figure 3.23). The form

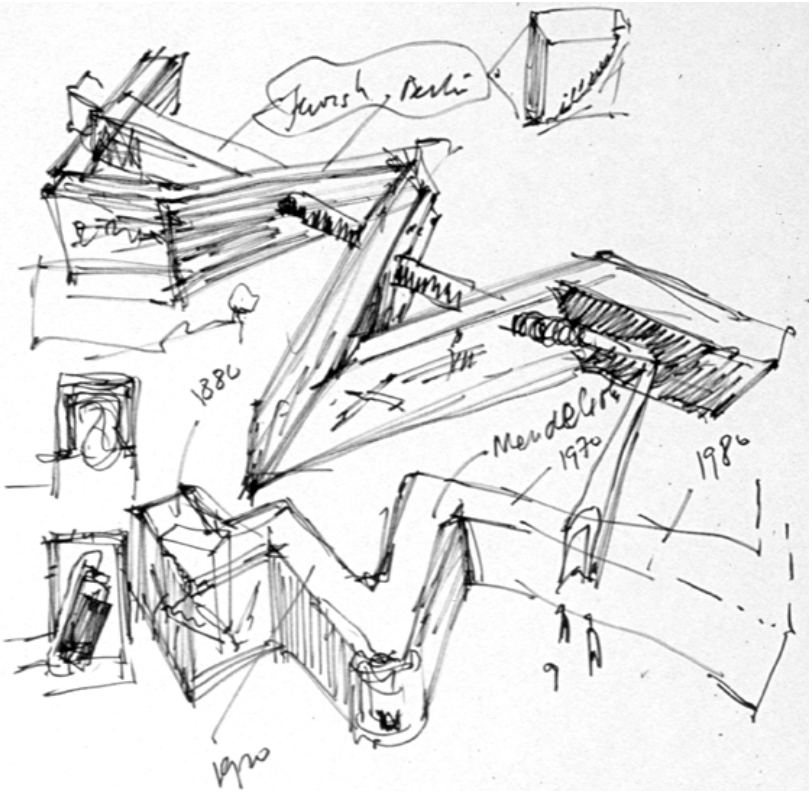
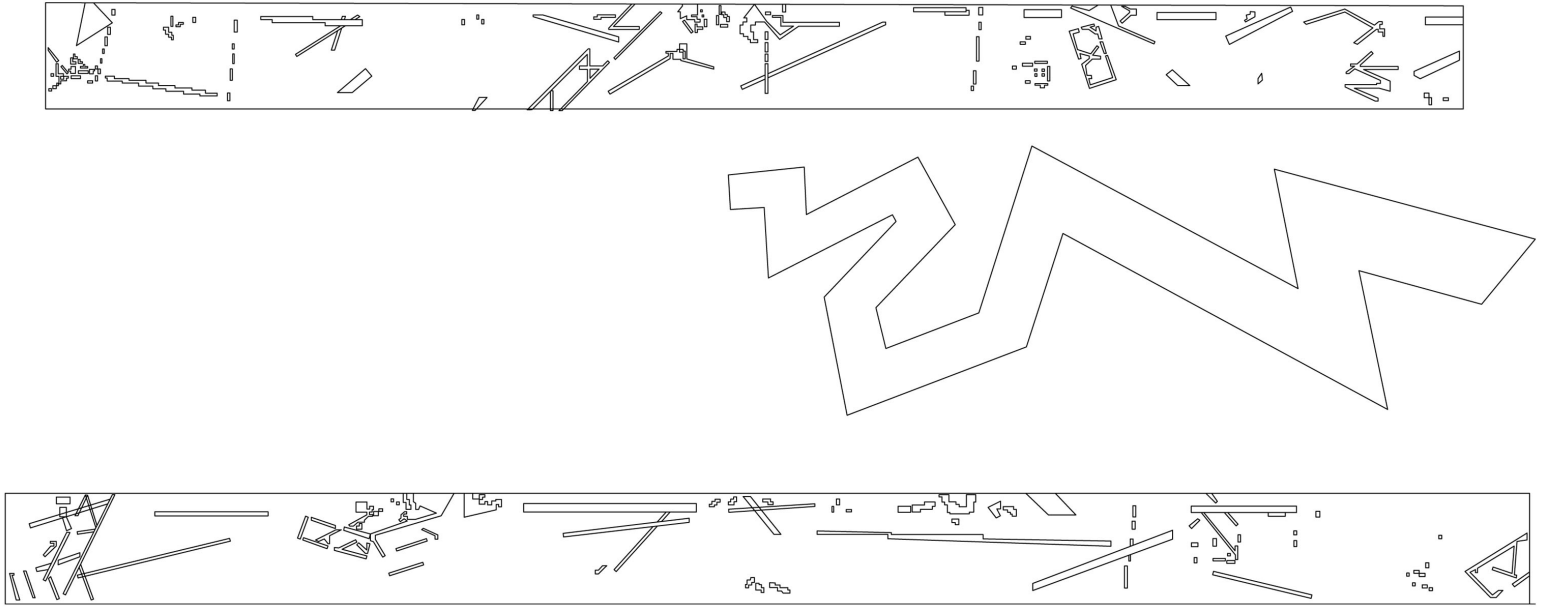


Figure 3.22: Sketch showing historical dates marked onto the form of the building, Daniel Libeskind

Figure 3.23: Facade Elevation as a continuous form to highlight its design as a historical diagrammatic map of Berlin, Victoria Shingleton



and location of the windows are physical manifestations of the intangible data they are derived from. Libeskind himself, describes the building as being “based on the invisible figures whose traces constitute the geometry of the building” (Giannachi, 2016, p. 65). Thus, we can see the intangible data of the past literally cutting into the present form of the tangible building (Figures 3.24-3.26). On some level, the ‘info-aesthetics’ ideology is showcased successfully in the façade design of the Jewish Museum because, on a very basic level, virtual information has been translated into a physical form. This is supported by Manovich’s noteworthy observation that “the virtual becomes a powerful force that re-shapes the physical... Rather than something ephemeral, here data space is materialized, becoming a sort of monumental sculpture” (Manovich, 2002, p. 9). It is the physical realisation of the virtual into a visual and aesthetic form which creates a tangible experience and, in turn, aids in the true understanding of the virtual on a human scale.

When assessing the project in relation to the historic definitions of data visualisation detailed in Chapter 1, we can argue that it falls under a subcategory of thematic cartography because it utilises a unique type of information mapping which links geographical locations with historical figures and events. However, despite this creative collection and mapping



Figure 3.24: External view of building showing the cuts on the facade

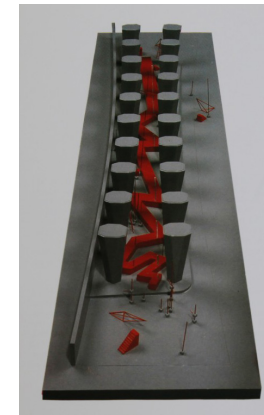


Figures 3.25 & 3.26: Internal views of the building showing the way the facade cuts translate on the interior walls

of data and the relative ‘info-aesthetic’ nature of the project, the full scope of opportunities has not been explored. This is partly due to the fact that the museum was built when the ‘info-aesthetic’ ideology was not fully developed, but also because architecture has preoccupied itself with developing ‘smart’ building technologies for responsive rather than aesthetic designs. In the case of the Jewish Museum, an aesthetic design developed from collected data is achieved to a certain extent, however, the systematic and rational procedure of linking this data (time, place and people) across the city of Berlin is not mirrored in the physical projection of it onto the building form. Instead, it appears like a somewhat arbitrary method of cutting parts out of the façade. This is supported by Manovich who states that, “since usually there are endless ways to map one data set onto another, the particular mapping chosen by the artist often is not motivated, and as a result the work feels arbitrary” (Manovich, 2002, p. 10). There is no indication by Libeskind to the reasons for choosing this particular way of projecting data as opposed to any other way.

More importantly, the question of whether the entire geometric composition of the building could have been created in the same way as the windows, arises. The use of a zigzag shape for the building, although is theoretically a result of two unfolding lines taken from the star of David, was actually initially copied from Libeskind’s *Line of Fire* project some ten years earlier (Figures 3.27-3.28). Donald Bates, a design associate and main liaison between Libeskind and the design team at the time, reports that “the zigzag of the *Line of Fire* project [was used] as the basic plan for the Jewish Museum [because it] ... ‘made sense’ and ‘worked on the site’” (Dogan & Nersessian, 2012, p. 21). Naturally, the zigzag was somewhat developed during the

Figures 3.27 & 3.28: Line of Fire, Daniel Libeskind, 1988, Center for Contemporary Art, Geneva



design process to incorporate Libeskind's design concepts about Jewish-German history in Berlin; however, the final form (Figure 3.29) remained almost the same as that shown in his initial concept sketches (Figure 3.30). Despite creating some exceptionally interesting and atmospheric interior spaces (Figures 3.31-3.33), the exterior of the building appears to be a simple extrusion (Figure 3.34) of this zigzag plan (Figure 3.35). In order to bring it into the full realm of 'info-aesthetics', the façade could have taken on a more direct and complex form of the collected data. Rather than using the data as a basic *cutting* tool for the perforation of the flat-surfaced façade, perhaps the data could have been used as the principal *design* tool to adapt, shape and morph the flat-surfaced façade into something with a more complex

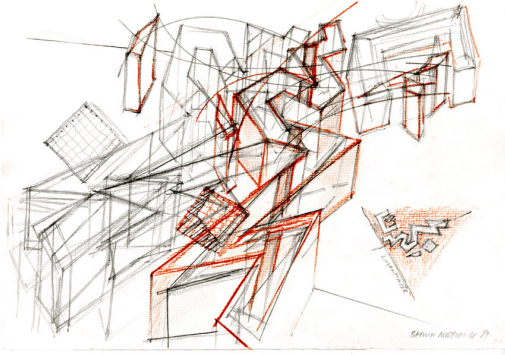
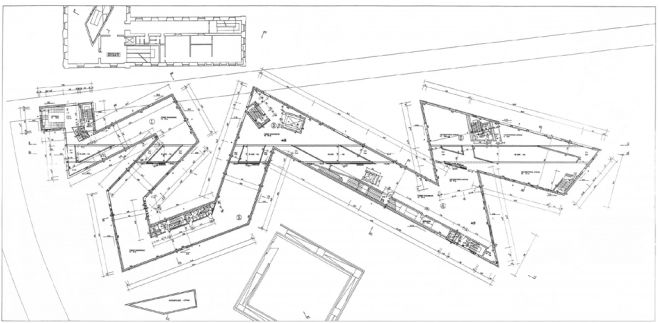
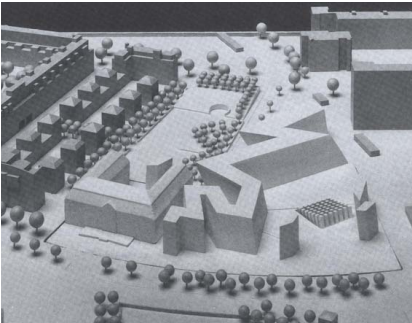


Figure 3.29: Exterior photograph of the museum

Figure 3.30: Initial sketch showing the form of the building, Daniel Libeskind

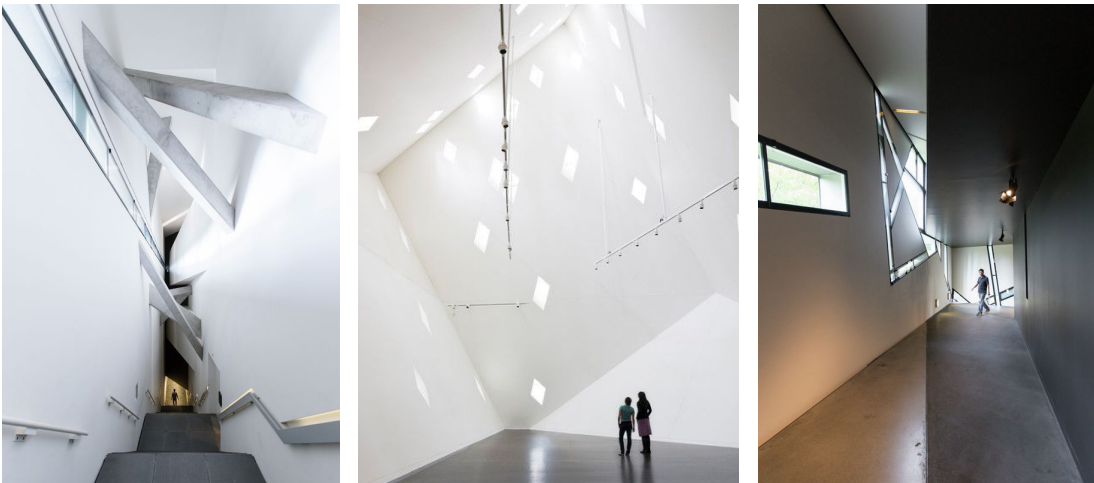
and meaningful form. In this way, the virtual structure of the collected data could be translated visually into physical, three-dimensional geometry with the aim of providing an immersive and exploratory experience of the exterior, to match that of the interior.



Figures 3.34: Massing model for proposal, Daniel Libeskind

Figures 3.35: Final Plan of proposal, Daniel Libeskind

When looking at the visualisation and materialisation of the data, a true variety of media (from conceptual sketches to the zinc-panelled façade) have been used in this instance, somewhat similar to Ikeda's use of media. Where Ikeda's installations slowly move towards the realm of architecture, however, Libeskind's museum is actually architecture. Architecture, by nature, lends itself to multi-media design explorations, where the design process itself is as important as the constructed outcome. This is evident in this project, where Libeskind's numerous conceptual sketches of the deconstructed Star of David, acting as a connector between different people, places and times, become the driving force of the physical end result. Thus, data is represented in two very different ways here: through two-dimensional sketches and through three-dimensional space, both complimenting each other. Through Libeskind's sketches data is displayed in an investigative manner for the formation of physical space and experience. Through architectural space, the projected data creates an immersive, multi-sensory experience, where certain spaces are "neither heated nor air-conditioned and largely lack artificial lighting... and any exterior sounds are heavily muffled by the walls" (Jewish Museum Berlin, 2017). Both media are important as we cannot understand one without the other; together, they form a comprehensive understanding and experience of a particular dataset. The sketches facilitate in deciphering the meaning of the building's façade; they act as maps for the projected data and, arguably, are types of data themselves as they help inform.



Figures 3.31-3.33: Interior photographs of the museum showing the dynamic spaces created as a result of the form

The three examples presented in this Chapter highlight the development of data visualisation as an active design tool in different aesthetic fields. Art, whether 2D or 3D, is the frontrunner because it is more fluid in its multi-dimensional explorations and representations of data, embodying the ideas of 'info-aesthetics'. It is through artistic works like Jevbratt's and Ikeda's projects, that data takes on physical and visual forms, aiding in their understanding as intangible building blocks of a virtual world. On the other hand, architecture, which has the potential to do this more successfully because of its concrete three-dimensionality, is not taking full advantage of using data as an aesthetic design tool. As shown by Libeskind's Jewish Museum, data is often used on a more basic level as an addition to the already designed form of the building, rather than being used to generate the form itself. As a whole, what has been shown here is that the media required to visualise and materialise data is no longer dependent on a monitor; through architecture, it moves away from the two-dimensionality of the screen and into something larger and three-dimensional which can be physically experienced through the senses. Consequently, this also highlights how data always requires material support to be understood.

The shape and aesthetic multi-dimensionality of information are relatively new and unexplored ideologies, with Lev Manovich as the key figure in their investigation and understanding. They are progressively emerging from the constant development of different technologies, and so are ever-changing in their output. As shown in the preceding chapters, the creative development of the aesthetics of information as a form of data visualisation over the centuries has always been highly dependent on the advancement of technology. Without new technological inventions for navigation, surveying, photography and computing, data visualisation would be stuck as a form of geographical cartography. Instead, it has been able to evolve into an entirely new form of cartography, one that could never have been imagined in the 16th century: that of virtual cartography. This form of cartography facilitates the navigation, exploration and decoding of the virtual world of our 'information society', and it comes in many aesthetic forms from art to cinema to architecture. It converges different technologies to combine and create new media, all of which can be grouped under one comprehensive term: 'info-aesthetics'.

Because the emerging 'info-aesthetics' ideology is putting pressure on society to invent new ways to interact with information, make sense of it, and represent it, data visualisation is now becoming dependent on developments in construction tools as much as technological ones. Perhaps this is one of the main reasons why the use of data as an aesthetic design tool in architecture has yet to reach its full potential. Art and design have excelled in this because technological advancements have worked in both their favours; architecture, however, seems to require one step further. Undeniably, new construction technologies are being developed more frequently and have helped in efficient building methods, however, they are slow in allowing architecture to taken on multi-disciplinary forms in the way that Lisa Jevbratt's projects portray. The purpose of 'info-aesthetics' is to imagine realities that do not exist in the physical realm; hence, the representation of projective data is key. Projective data is highly used in 2D and 3D artworks, creating immersive experiences of the complex, invisible structures of data. Architecture, on the other hand, is focused on the use of reactive data and how that can be used to create responsive and automated designs. In order for architecture to produce similar aesthetic outputs as data art, a blending of their boundaries is required. This must be done if architecture is to offer unique spatial experiences representing the data that drives this field.

Ultimately, the evolution of data visualisation into an ‘info-aesthetic’ data materialisation, plays a significant role in revealing the patterns and structures formed by abstract data, and representing them visually as well as physically, because in turn, they reveal the nature of our data-driven world in a way which we can understand. We are slowly getting lost in an endless production of information which is becoming all the more difficult to keep track of and make sense of. This is the reason why the aesthetics of information is so important and why using data as a design tool plays a unique role:

“to show us other realities embedded in our own, to show us the ambiguity always present in our perception and experience, to show us what we normally don’t notice or don’t pay attention to” (Manovich, 2002, p. 11).

¹In this thesis, data and information are used somewhat interchangeably because they both feature in the broader subject of data visualisation

²“Smart buildings... centre on the use of interconnected technologies to make buildings more intelligent and responsive, ultimately improving their performance” [https://www.designingbuildings.co.uk/wiki/Smart_buildings Accessed: 12 March 2017]

³“Smart cities are defined... as the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens” [https://www.designingbuildings.co.uk/wiki/Designing_smart_cities#Definition Accessed: 12 March 2017]

⁴The camera obscura was the ancestor to the photographic camera and is “a darkened enclosure having an aperture usually provided with a lens through which light from external objects enters to form an image of the objects on the opposite surface” [<https://www.merriam-webster.com/dictionary/camera%20obscura> Accessed 4 April 2017]

⁵The term infographic refers to the visual representation of information or data [<https://en.oxforddictionaries.com/definition/infographic> Accessed 4 April 2017]

⁶A time series plot is a graph that can be used to evaluate patterns and behaviour in data over time [<http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/graphs/graphs-of-time-series/time-series-plots/time-series-plot/> Accessed 4 April 2017]

⁷Bernd Heinrich Wilhelm von Kleist (18 October 1777 – 21 November 1811) was a German dramatist [<https://www.britannica.com/biography/Heinrich-von-Kleist> Accessed 6 April 2017]

⁸Christian Johann Heinrich Heine (13 December 1797 – 17 February 1856) was a Jewish German poet [<https://www.britannica.com/biography/Heinrich-Heine-German-author> Accessed 6 April 2017]

⁹Rahel Antonie Friederike Varnhagen (19 May 1771 – 7 March 1833), was a German literary hostess from a wealthy Jewish family [<https://www.britannica.com/biography/Rahel-Varnhagen-von-Ense> Accessed 6 April 2017]

¹⁰Ernst Theodor Amadeus Hoffmann (24 January 1776 – 25 June 1822) was a German writer, composer, and painter [<https://www.britannica.com/biography/E-T-A-Hoffmann> Accessed 6 April 2017]

¹¹Ludwig Mies van der Rohe (27 March 1886 – 17 August 1969) was a German-born American architect [<https://www.britannica.com/biography/Ludwig-Mies-van-der-Rohe> Accessed 6 April 2017]

¹²Arnold Franz Walter Schönberg (13 September 1874 – 13 July 1951) was an Austrian-American composer [<https://www.britannica.com/biography/Arnold-Schoenberg> Accessed 6 April 2017]

¹³Paul Celan (23 November 1920 – c. 20 April 1970) was a Jewish Romanian-born German language poet [<https://www.britannica.com/biography/Paul-Celan> Accessed 6 April 2017]

¹⁴Walter Benjamin (15 July 1892 – 26 September 1940) was a German Jewish man of letters, aesthetician and literary critic [<https://www.britannica.com/biography/Walter-Benjamin> Accessed 6 April 2017]

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WORDCOUNT

Main Body: 8,947
Other: 2,225
Total: 11,172

