Weather Bracelet and *Measuring Cup:* Case studies in data sculpture

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Abstract

This paper describes two practice-led research projects in the tangible representation of environmental time-series data. *Weather Bracelet* (2009) and *Measuring Cup* (2010) compress fine grained data sets into small, tactile objects realised using 3d printing. Here these works are examined as case studies in the context of a nascent practice of "data sculpture". After discussing technical, conceptual and creative considerations in these works, the paper addresses challenges for the interpretation of data sculptures, especially their claim of veracity. Finally the paper questions "sculpture" as a framing term for these objects, proposing a broader category ("dataform") that better reflects the potential cultural value of this practice.

Keywords

Data visualisation, sculpture, climate, tangible, fabrication

1. Introduction

This paper describes two practice-led research projects in the tangible representation of environmental time-series data. *Weather Bracelet* (2009) represents one year of Canberra temperature and rainfall data in the form of a small wearable object. *Measuring Cup* (2010) is a small, cylindrical form derived from a 150-year time series of monthly average temperatures for Sydney. These two projects provide case studies in an emerging genre that Zhao and Vande Moere (2008) have termed "data sculpture": objects that are part artwork and part functional visualisation. This paper demonstrates how these forms arise from an interplay of technical, functional, conceptual and poetic factors, and discusses the rewards and challenges of the process. It also considers issues in the context and interpretation of data sculpture.
Transformation is at the core of this practice: the mapping of relationships in one domain (the weather, or the stock market) into another (the tangible form). As these projects demonstrate, this transformation is easier than ever to accomplish; but how is it to be understood? Can data sculpture move past the digital "trick" of transformation, to provoke a deeper understanding or engagement? These works often rest on a claim of veracity or "truth to data"; but how might an audience interrogate or understand that claim?

2. Context and Background

These projects are informed by a context spanning media arts, computational approaches to

design, and data visualisation. They emerge from a field of creative practice in which code and data are deployed in a range of cultural genres and venues: commercial and non-commercial, poetic and prosaic, art and design. This work is an example of “artistic visualisation”, a practice which Viegas and Wattenberg (2007) argue is informed both by the increasing accessibility of computational tools, and by the increasing cultural currency (and availability) of data itself.

In focusing on the physical embodiment of data, and in seeking to balance the legible communication of data structure with the aesthetic engagement of an art object, these works can be situated more specifically as “data sculpture.” Zhao and Vande Moere (2008) define a data sculpture as “a data-based physical artifact, possessing both artistic and functional qualities.” This neat definition conceals the diversity of approaches, materials and intents at work in practice. Examples range from the handmade sculptures of Nathalie Miebauch (2011) , derived from tide and weather data from her native New England; to Maassen and Verbruggen’s digitally milled *Brainwave Sofa* (2009), derived from three seconds of the designer’s own EEG data. Much work makes use of increasingly accessible digital fabrication; both 3d printing, such as Loh and Fiedler’s *~IDENTITÄT* (2009), and computer-controlled cutting and milling, such as Miska Knapek’s *Windcuts* (2009). On the other hand Thomas Traxler’s *The Idea of a Tree* (2008) offers an elegant example of “direct fabrication” — this is a data sculpture without data, where fluctuations in solar energy drive variation in a mechanically fabricated form.

Within this context, *Weather Bracelet* and *Measuring Cup* focus on a specific set of concerns. These works reflect an ongoing interest in time-series data, especially drawn from everyday environment and experience. In a previous work, *Watching the Sky* (Whitelaw, 2008), large image time series are gathered and “revisualised”, recording subtle patterns of environmental variation. *Watching the Sky* addresses the disjunction between the moment-by-moment time of experience, and the intangible long-term trends and time-scales that require increasingly urgent attention. Put another way: when does weather become climate? These projects address the same question, using an “open” workflow assembled from readily available data, tools and services. Like the works of Miebauch, Knapek and Traxler cited above, *Weather Bracelet* and *Measuring Cup* treat data not as a rarefied, abstract essence, but as a trace of a complex environment; and data sculpture offers a means to make those traces available in a rich, compact form — to return them, transformed, to experience.

3. Weather Bracelet

Weather Bracelet represents 365 days of local (Canberra) weather data, in the form of a small wearable object. The project arises from interests in the materiality of data, the technical and cultural potential of 3d-printing and digital design, and the charged context of time series weather and climate data. While the resulting object has been exhibited as a visual art work, it is intended as an experimental artefact that may be interpreted through fields including visualisation, product design, fine art, craft, and tangible computing.

The data for this object consists of 365 days of weather data: daily maximum, daily minimum,

and daily rainfall for the period July 2008 to June 2009. These statistics were chosen because they inform key aspects of our everyday experience: they are the headline numbers by which we typically frame and interpret our experience of the weather. We typically encounter these figures (as forecasts and observations) in chunks of three to seven days. At longer time scales (months and years), we are most often presented with decimated statistical descriptions: minima, maxima and averages. A key principle informing this project was the preservation of fine-grained (daily) detail in a large (annual) dataset. Drawing on the “show everything” approach of Stamen Design (see Jones, 2009) this principle seeks to enable those encountering the data to navigate, summarise and analyse it independently. Rather than assume a given query or focus, and provide specific “information” on that point, the object aims to provide rich “data” in a tangible form.

The choice of the bracelet as a typology or formal template was informed by a convergence of factors. The data itself traces the annual cycle of the seasons, and in turn the Earth’s solar orbit, suggesting a circular form. Treating this form as a bracelet gives it scale and context, positioning the object in a tactile, personal and social setting. Zhao and Vande Moere identify *affordances* — physical attributes that invite specific uses or interactions — as a key feature of data sculpture. In this case the bracelet form brings with it a set of potential affordances that the sculpture can appropriate: ways of touching, holding, wearing, displaying and discussing the object.

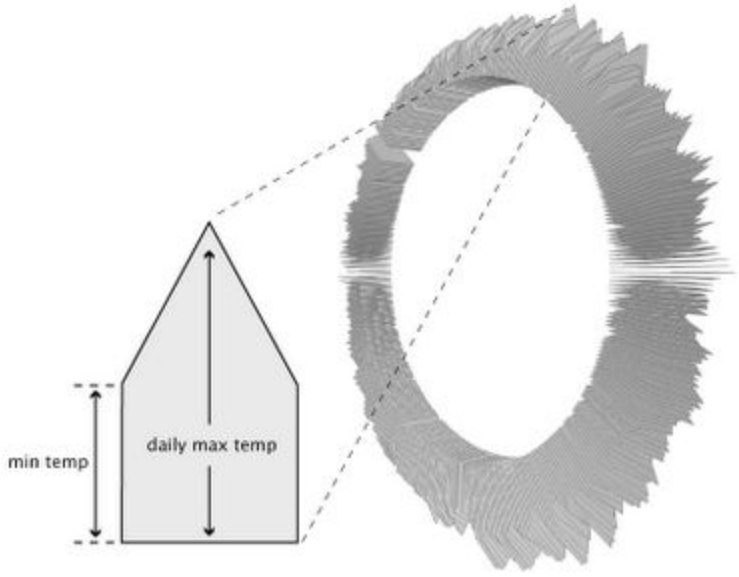

Figure 1: Mapping temperature to radial slices in *Weather Bracelet*

The design of the object involved creating mappings from the fine-grained source data onto this formal template. Here the envelope of the bracelet form is made up of a radial “stack” of two dimensional profiles, with one profile per day of data. As shown in the diagram below, each slice

encodes daily maximum and minimum temperature values into a polygon. The mapping is simple and linear; with the relatively continuous and consistent temperature data, this gives a legible result. The bracelet form is generated by stacking 365 of these slices around a circular path, leaving a small gap to indicate the beginning and end of the sequence (Figure 1). This cross-section is informed by the functional requirements of the bracelet form as well as its tactile affordances.

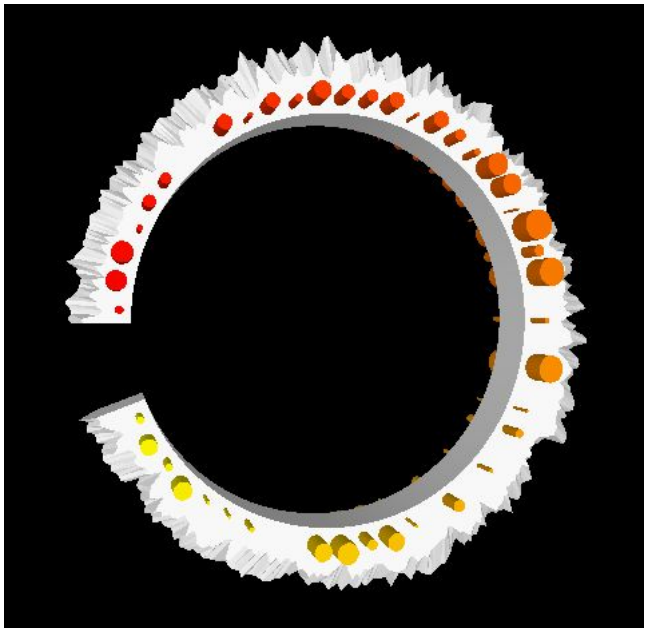

Figure 2: *Weather Bracelet* mesh showing rainfall volumes

Adding rainfall data to the form posed some challenges. Rainfall data was gathered as daily values, but these have a very uneven distribution: most days have a value of zero; many days show less than 1 mm of rain; but on the wettest day in the dataset (13 December 2008) 55.4mm of rain fell on Canberra. Eventually the principle of preserving granularity was compromised slightly, and rainfall was aggregated up into weekly totals, with each week represented as a cylindrical volume piercing the bracelet envelope (shown in Figure 2 as positive volumes). In this case the area of the circular face (and thus the volume of the cylindrical void) is proportional to the rainfall value. As well as a perceptually appropriate mapping of quantity to area, this relationship helps compress the high variability in rainfall values into a feasible and legible range of forms.

The final 3d model is simply a result of subtracting the rainfall volumes from the positive bracelet envelope. The geometry was created using code written in Processing; MeshLab was used to clean, scale and convert the resulting meshes, with final boolean modelling step undertaken in Blender. The bracelet was realised as two 3d prints produced by online fabrication service Shapeways. One print is laser-sintered nylon (Shapeways' "strong white and flexible" material) (Figure 3) and one is an acrylic photopolymer ("transparent detail") (Figure 4).

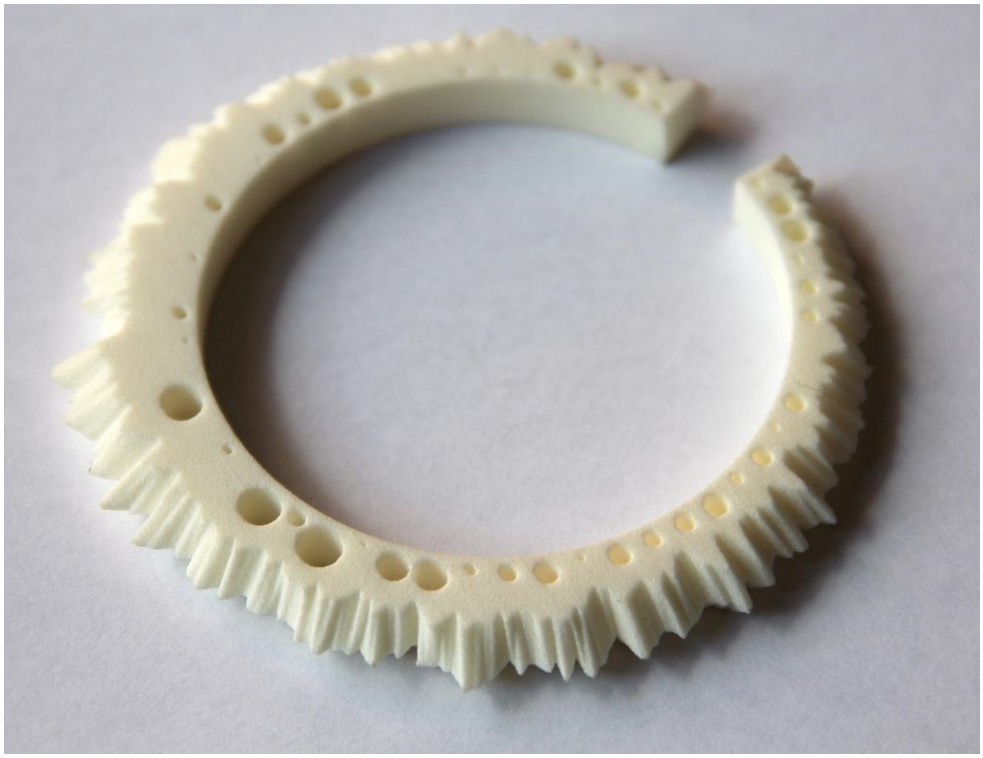

Figure 3: Weather Bracelet 3d printed in laser-sintered nylon

Figure 4: Detail of Weather Bracelet print in photopolymer

Informal feedback and reflection suggests that as a data representation, the *Bracelet* is successful. Once familiar with the mappings, most people who encounter the form can interpret patterns and variations within the data. Observers typically begin with macro level (seasonal) variation, before focusing on dramatic local features such as the rapid cooling at the end of summer. This functional or “prosaic” aspect was one key aim of the piece; but more striking was the impact of its tangible presentation. The scale of the object and its level of detail seems to engage touch in a powerful way, and many are struck by the affect, as well as the concept, of literally feeling the complex variations of our lived environment in this form.

4. Measuring Cup

In working with a year of daily weather data, *Weather Bracelet* alludes to a context in which long-term changes in the environment are a highly charged topic, but where at the same time, our everyday perception and experience remain dominated by short-term variations; that is, by the weather, rather than the climate. In compressing a year into a hand-sized object, *Weather Bracelet* suggests the potential of working with longer-term patterns. *Measuring Cup* is an experiment investigating that potential directly.

This project was made possible by the 2009 release of a large climate change research dataset. The HadCRUT3 data set consists of monthly average temperatures for over 3000 land based weather stations, with some time series extending back over 300 years (see Brohan et al, 2006). Like the short-term weather data we encounter, long term temperature data is almost universally discussed using statistical aggregates such as averages. Similarly location is often generalised or aggregated up into national or global “bottom lines”. The fine grain of the HadCRUT3 data provided an opportunity to work more specifically, and again, close to home; this work is based on a 150-year time series of Sydney temperature data extracted from the global dataset.

The data structure here consists of monthly average temperature values, for a total of around 1800 data points. Building on the mapping of annual cycle to radial form used in *Weather Bracelet*, this series can be imagined as 150 radial graphs stacked along a vertical time axis, creating a roughly cylindrical form. In the interests of intimacy and tactility, the form became a small cup — an object to be grasped, but also an object that operates in a social or domestic context, a sort of data-curio.

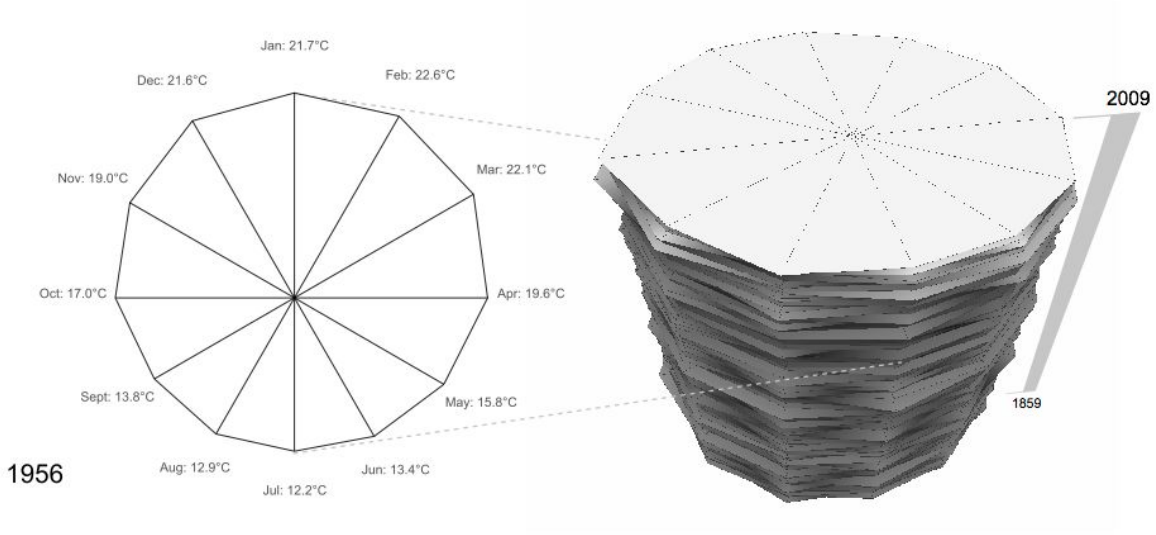

Figure 5: Mapping monthly temperature time series to a cylindrical stack in Measuring Cup. This diagram shows the radial graph of a single year (1956) (left) and the form created from a stack of 150 such slices (right).

The final form was again resolved from a combination of representational and aesthetic aims and pragmatic constraints. As in *Weather Bracelet,* the aim was to map data onto form in a fine-grained and straightforward way. The cylindrical stack provided the starting point, where each “layer” is simply a twelve-sided polygon — a radial graph of the twelve monthly values. The resulting form was angular in the horizontal plane and jittery in the vertical plane, due to short-term variability in the data. This vertical jitter was not only unattractive, it made the form unrealisable, creating walls too thin to be printed. In considering how to smooth the time series, the project crosses into the domain of climate science, and the question of representing trends within “noisy” data. In line with practice in climate science, a simple five-year moving average was used to smooth the time series values. The smoothed form retains a fine-grained texture but shows more legible medium- and long-term patterns of variation.

The work crystallised at the point when the form became a cup, rather than simply a cylinder. Like the bracelet, this emerged from a spatial configuration based on the data structure itself; but also like the bracelet it brings with it a set of potential affordances. A cup has an intrinsic orientation: it invites grasping, and has a specific and intimate relationship to the holder. The time axis of the stack becomes depth, placing the most recent data “on top” (closest to the user). The cup form even affords a pun for the work’s title.

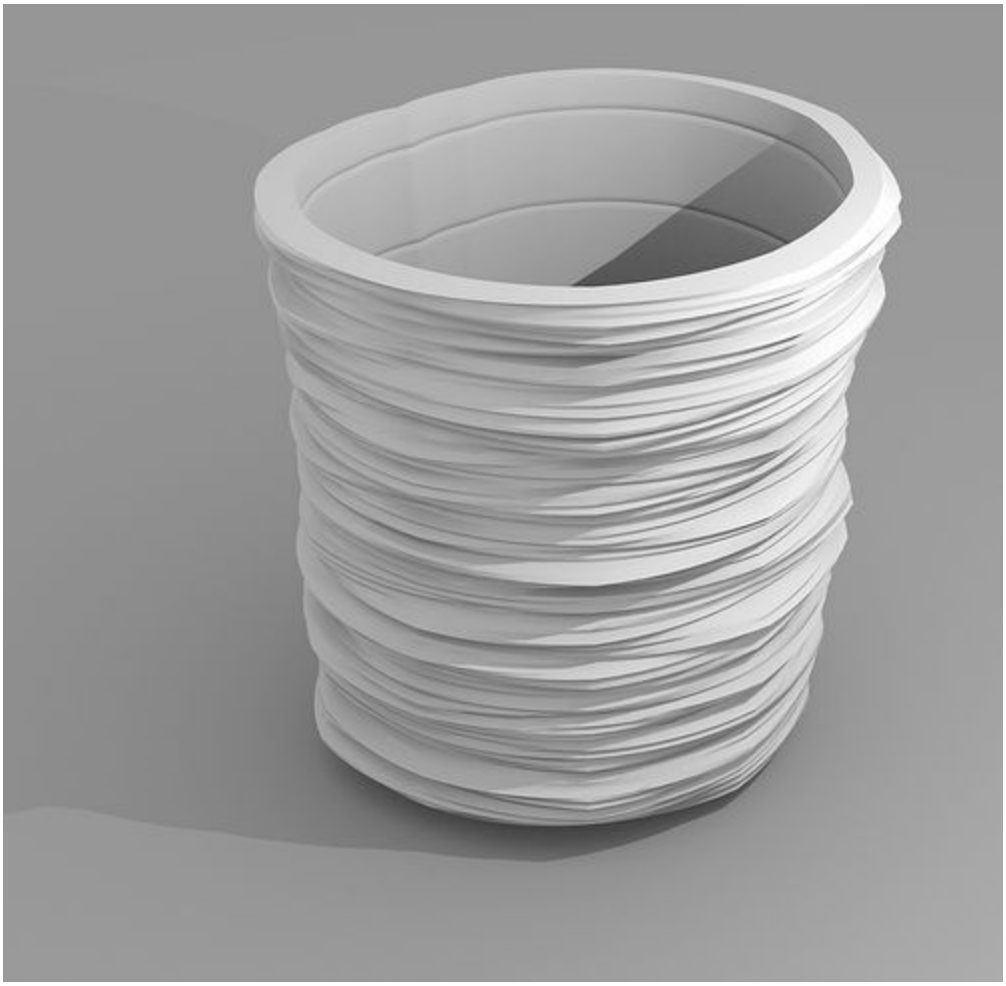

Figure 6: *Measuring Cup* - 3d model showing internal tick marks

Surprises are one of the creative pleasures of working with data as a material; often moments when patterns manifest in unexpected ways. Vander Moere and Patel (2010) identify these phenomena in data sculptures as “emergent forms”. One such surprise here was that the cylindrical layout of the form emerged as an organic, uneven ovoid. Seasonal variation creates a “flat spot” at the winter months, while autumn and spring form asymmetrical bulges. This emergent form plays a strong role in defining the aesthetic character of the form, as well as providing a legible cue to the temporal structure of the data. As a further cue, “tick marks” — shallow grooves on the inside surface of the cup — mark off 25 year intervals between 1875 and 2000.

Figure 7: *Measuring Cup* - 3d print in laser sintered nylon

The work's final surprises are apparent only when the object is held in the hand. The complex undulations of the surface present no clearly visible trend, but in line with its affordances, it fits pleasantly in the grasp. As the cup template would suggest, the form tapers outward towards the lip, but this affordance is not appropriated: it is a product of the data. The warming trend in the data is perceptible only through touch, and then with a sensation that is initially comfortable and familiar. The "rightness" of this fit makes a jarring contrast with the "wrongness" of the long-term trend that it reveals.

5. Metaphor and the Veracity Problem

As case studies in the design of data sculpture, these projects demonstrate some of the creative complexities of the genre. Resolving a form is matter of balancing a number of factors to satisfy aesthetic, functional and conceptual goals. As in a conventional visualisation we seek a form of presentation that suits both the data structure (for example number and type of elements) and its content (for example the range of values). Overlaid on this are the physical affordances offered by the resulting object. These considerations are largely prosaic, but they interact with more poetic criteria. What is the relationship between the data source — the meaning or origin of the data — and the sculptural form? What does it mean to encode weather as a bracelet? This relationship is analysed by Zhao and Vande Moere (2008) as "metaphorical distance": they

use it as a measure by which to compare and analyse data sculptures. However in specific cases this attribute cannot be readily reduced to a single variable; rather like a literary metaphor it is a subtle and multivalent set of associations. In the case of both these objects for example, this relationship involve a deliberate contrast in scale between data source and physical form; the works involve a gesture of condensation of compression.

One creative risk for data sculpture is that this poetic juxtaposition of form and referent becomes too dominant; a trick or gimmick that relies only on the novelty of the transformation for its impact. This is what Tom Moody (2007) terms “XYZ art”: “hey, I did X to Y and now it’s Z!” In these works I have observed how this “trick” plays a role as an initial hook for engagement; the act of transformation in itself is enough to engage the audience. The hope is that it can trigger a more substantial engagement with the object and the data. One challenge to that engagement, here and in other data sculptures, is what might be called veracity: these works assert, and depend on, the integrity of the relationship between data and form. Yet on a casual encounter, that relationship is impossible to verify; we simply cannot tell that this form is “really” a product of the data in question. Both the data source and the mapping process — the intermediate stages between data and form — are inaccessible. With the status of the data itself rendered uncertain, the work can again fall back into a reliance on the assertion of transformation — Moody’s XYZ — as an end in itself.

Weather Bracelet is an attempt to ground data sculpture in localised, firsthand experience: tapping personal recollections, for example, of the sudden cold snap at the end of summer. This is one possible solution to the veracity problem; where data emerges from a shared domain of experience, rather than an abstract outside source. However most datasets are not available to experience in the same way as the local weather. In *Measuring Cup*, where we move from weather to the longer time scale of climate, we cannot validate the data in this way. Instead *Measuring Cup* attempts to address the veracity problem by exposing its data source and documenting the production process, as well as using readily accessible tools and services. This might be termed an “open culture” approach, drawing on the ethos of open source software and open data (Murray-Rust, 2008). However this approach is not a neat or easy guarantee of authenticity. It demands participation, exposing its process to enable others to reproduce and build on it; this in turn demands significant technical skills and literacies. For Zhao and Vande Moere (2008) data sculpture is intended for a “lay audience”, as in a traditional visual arts paradigm; but in an open culture approach the object is an invitation, potentially inducting the user into an active data practice.

6. From Data Sculpture to Dataform

One problem with the term “data sculpture”, as proposed by Vande Moere and Zhao, is its implication of high art and the autonomous, self-sufficient object. As shown above an “open” approach complicates any simple sense of autonomy, but also enriches the cultural context of this practice. Within this field it is clear that visual art is only one of the cultural domains

involved. Data sculpture is equally entangled with design, human-computer interaction, craft, and maker / DIY culture. For entrepreneurs such as Fluid Forms (2012), data sculptures are a new species of customisable product. It's notable that Fluid Forms' objects rely on the personal significance of data (especially geospatial data) for their significance. Projects such as Russell Davies' Datadecs (2010) — data driven Christmas decorations based on social media data — demonstrate the same process in a playful, non-commercial context.

Sculpture is not a useful term to describe these objects; instead they might be products, gifts, curios or conversation pieces, jewellery, ornaments, avatars or talismans. We might call them "dataforms" — a catch-all term to indicate the range of possible roles they play. They are culturally "low" rather than "high", but their life is all the richer for it. Like *Weather Bracelet* and *Measuring Cup*, dataforms will continue to appear in galleries, playing the role of art objects for the sake of convenience. However their most interesting role is as prototypes of something else: ubiquitous, everyday data-objects. These objects fit Pousman et al's definition (2007) of casual information visualisation: often personal, used over long periods of time, and providing insights unlike those promised by traditional visualisation. However where Pousman et al treat casual visualisations as expert-designed artefacts, open culture and commodity-level fabrication suggest the broader potential of a bottom-up, participatory culture drawing data into all manner of tangible forms.

As prototypical dataforms, *Weather Bracelet* and *Measuring Cup* demonstrate the technical viability of the practice, thanks to readily accessible data, software and fabrication tools. They also illustrate some of the creative challenges of the form, especially the resolution of functional, technical, aesthetic and poetic aspects of these objects. The cultural viability of the data sculpture or dataform is a more challenging question however. These objects are emergent hybrids: they cannot be easily located within a single cultural tradition or genre. This gives them the shine of novelty, and the potential to adapt across cultures as required; but novelty is fleeting, especially if this practice depends solely on the cultural currency of the "trick" of digital transformation. More optimistically, the central promise of the dataform — to be revealing, poetic, and tangible — is compelling, especially in our screen-saturated environment. In a culture ever more shaped by data, the question of how we encounter and apprehend it, what data *feels like*, is crucial. This may be the most significant future role for the dataform, not as a simple solution, but part of a developing culture of practice and interpretation.

References

Brohan, P. et al., 2006. Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850. *J. Geophys. Res*, 111(D12), p.D12106.

Davies, R., 2010. datadecs. Available at: http://russelldavies.typepad.com/planning/2010/01/data-decs.html [Accessed April 11, 2012].

Fluid Forms. Available at: http://www.fluid-forms.com/ [Accessed April 11, 2012].

Jones, M., 2009. Data as Seductive Material. Available at: http://www.slideshare.net/blackbeltjones/data-as-seductive-material-spring-summit-ume-march09 [Accessed June 28, 2009].

Knapek, M., 2009. Collection: windcuts. *Flickr*. Available at: http://www.flickr.com/photos/miska_too/collections/72157619226259190/ [Accessed April 11, 2012].

Loh, J. & Fiedler, S., 2009. ~IDENTITÄT – The »Gestalt« of digital identity. Available at: http://www.digital-identities.com/ [Accessed April 11, 2012].

Maassen, L., 2009. Brainwave Sofa. Available at: http://www.lucasmaassen.nl/projects/index.php?4 [Accessed April 11, 2012].

Miebach, N., 2011. Changing Waters. Available at: http://nathaliemiebach.com/waters.html [Accessed April 11, 2012].

Moere, A. & Patel, S., 2009. The Physical Visualization of Information: Designing Data Sculptures in an Educational Context. In M. L. Huang, Q. V. Nguyen, & K. Zhang, eds. *Visual Information Communication*. Boston, MA: Springer US, pp. 1–23. Available at: http://www.springerlink.com/content/v14323430020p56j/ [Accessed August 5, 2011].

Moody, T., 2007. VVork and XYZ Art. *Tom Moody*. Available at: http://www.digitalmediatree.com/tommoody/?40531 [Accessed August 5, 2011].

Murray-Rust, P., 2008. Open Data in Science. *Serials Review*, 34(1), pp.52–64.

Pousman, Z., Stasko, J. & Mateas, M., 2007. Casual information visualization: depictions of data in everyday life. *IEEE Transactions on Visualization and Computer Graphics*, 13(6), pp.1145–1152.

Traxler, T., 2008. The idea of a tree. Available at: http://www.mischertraxler.com/projects_the_idea_of_a_tree_recorder_one.html [Accessed April 11, 2012].

Viégas, F.B. & Wattenberg, M., 2007. Artistic Data Visualization: Beyond Visual Analytics. In D. Schuler, ed. *Online Communities and Social Computing*. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 182–191. Available at: http://www.springerlink.com/content/k136266661251468/ [Accessed August 5, 2011].

Whitelaw, M., 2008. Watching the Sky. *Photographies*, 1(2), pp.205–220.

Zhao, J. & Moere, A.V., 2008. Embodiment in data sculpture: a model of the physical visualization of information. In *Proceedings of the 3rd international conference on Digital Interactive Media in Entertainment and Arts*. DIMEA '08. Athens, Greece: ACM, pp. 343–350.