Design of a Tangible Data Visualization

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ABSTRACT
In this paper we describe the design of DNA Jewellery, which is a wearable tangible data representation of personal DNA profile data. An iterative design process was followed to develop a 3D form-language that could be mapped to standard DNA profile data, with the aim of retaining readability of data while also producing an aesthetically pleasing and unique result in the area of personalized design. The work explores design issues with the production of data tangibles, contributes to a growing body of research exploring tangible representations of data and highlights the importance of approaches that move between technology, art and design.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Interaction styles.*

General Terms
Design, Experimentation, Human Factors.

Keywords
Tangible data, Personalised items, 3D printing.

1. INTRODUCTION
The increased availability of 3D printing opens up new possibilities for expanding visual display of data to also make use of tactile qualities and three-dimensional form as carriers of meaning in data visualisations [5]. Producing tangible data-visualisations as physical forms seems promising in several respects. Being able to hold and rotate physical objects could allow people to easily see the data from different angles and build a bodily understanding of the shape of the data, and making use of the tactile surface qualities of a physical form could support the layering of multiple dimensions of data and better enable people to get a 'feel' for the data [3].

In contrast to data-visualization approaches that make use of 3D computer rendered graphics presented through the use of displays [4], this work explores the possibilities of 3D-printed *tangible* objects that can be directly held and handled (or even worn). Although these objects are 'tangible' things, our approach should be distinguished from research into Tangible User Interfaces (TUIs), firstly because the work presented here is not interactive and secondly because whereas TUIs often provide for the display and manipulation of data, this is typically through the use of simple geometric forms as interactive 'phicons' which act as *containers* for data [1]. Our tangible data-visualizations are not simple geometric forms, but complex shapes whose physical form is directly derived from an underlying data set.

This project also seeks to explore issues of personalized items. Desires for personalization raise many issues for design. Every person is unique. We have our own ways of looking, behaving, speaking, acting, thinking, learning, deciding and choosing. The purpose of this study is not to find the answer why we are different. Rather, it is to address the need for personalized design that people exhibit. Every person has a unique taste and chooses differently. We have our favorite colors and styles, and some people even choose clothes to reflect their identity. In this respect freedman makes a valuable point about data visualization, which is that it doesn't need "...to be boring to be functional or extremely sophisticated to look beautiful" [2]. In other words it is possible to create data visualizations to be both beautiful and functional. This project sets out to create a visualization of personal (DNA profiling) data that is both aesthetically pleasing and readable by the user.

2. RELATED WORK
There is a growing body of research exploring tangible representations of data to which our work contributes. Measuring Cup is a data form project by Mitchel Whitelaw that presents 150 years of Sydney temperature data in a cup-shaped object about 6 cm high [6]. The Weather Bracelet is another project by Mitchel Whitelaw in which he created a wearable data object, based on 365 days of Canberra weather data using 3D printing.

Several companies have already begun offering personalised products based on DNA profile data. Dutch DNA provides custom made forms of jewelry or furniture based on DNA profiling information[1]. DNA11 is another website that creates portraits and personalized art canvases based on a person's DNA profile[2].

The increasing availability of DNA analysis and profiling services combined with the possibility for personalisation of product production through technologies such as 3D printing raise many issues for design. The purpose of this study is to explore how issues of personalization play out in relation to data of a particularly personal kind – DNA profile data

3. DESIGN APPROACH
We initiated the design process using DNA profile data to generate the first design. We improved the design over multiple cycles that included interpreting data, editing the design, creating the digital 3D model, preparing the model for 3D printing and

[1] http://www.dutchdna.nl/dutch-dna/

[2] http://www.dna11.com/about-us

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actual production. At the end of each step we analyzed the results based on the goal to create a personalized wearable object, maintaining the balance between data readability and aesthetics of the design.

Our key questions for the design were:

- What are the design considerations for tangible data visualization in this project.
- How to design a personalized item e.g. bracelet or ring based on DNA profiling data as an example for personal data in this project.

4. DESIGN OF THE FORM

For the purposes of this study, we worked with one of the authors' own DNA profiling data obtained through an online DNA identification service based on the PowerPlex® 16 System.

Humans have 23 chromosomes and each of these chromosomes has a long and a short arm. The test results we obtained for the DNA provided a listing of significant DNA markers within the sample. Using information from the UCSC Genome Bioinformatics website[3], we identified which chromosome and which arm on the chromosome (short or long) each of the markers in our test results belonged to (Table 1).

Table 1: Actual DNA profiling data in PowerPlex® 16 System rearranged and added chromosome column

Chromosome	STR Locus	Alleles Called		
2p	TPOX	8		11
3p	D3S1358		17	
4q	FGA		22	
5q	CSF1PO	10		12
5q	D5S818		11	
7q	D7S820		8	
8q	D8S1179	11		12
11p	TH01		6	
12p	vWA	16		17
13q	D13S317		13	
15q	Penta E		11	
16q	D18S539	9		11
18q	D18S51	13		14
21q	D21S11	28		30
21q	Penta D	10		11
Xp,Yp	Amelogenin	Male (XY)		

With this information, we developed a visual mapping shown in (Figure 1). In this figure the blue squares indicate the 23 chromosomes counting from top to bottom. The white circles indicate the position of the result for each marker on either the short (left side) or long (right side) arms of the chromosome. The white squares are counting units to indicate how far along the arm the marker's result is situated. Finally, the centre line shifts either left or right as it goes from top to bottom depending on whether each marker is on the long or short arm of its chromosome.

[3] http://genome.ucsc.edu/

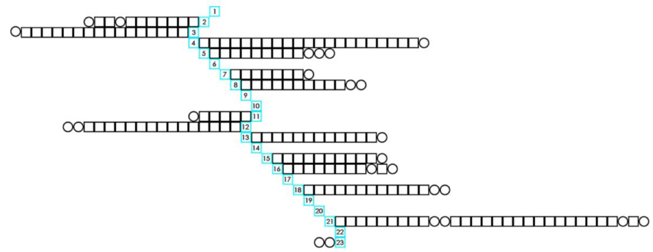

Figure 1: Mapping of DNA test result data

This mapping was then used as the basis for generating a 3D model of the data by angling the left and right arms up and wrapping them around to form a circular structure that could be worn as a bracelet or ring and create the iconic shape of DNA helix (**Figure 2**).

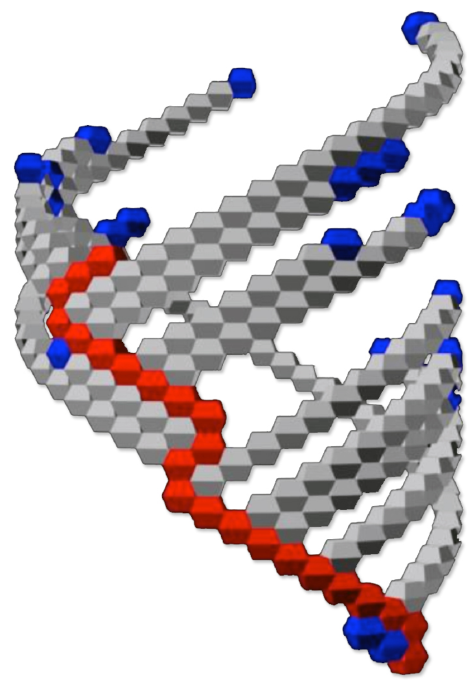

Figure 2: Mapping wrapped into circular form

4.1 Design of Tactile Elements

To facilitate readability of the data in a final 3D printed form, it was necessary to find an alternative to the colour-coding used in the above diagrams. The 3D printing technology that we used supports only single material such as plastic, ceramic or silver and since we wanted to engage more tactile sense rather than visual we developed a surface texturing system to distinguish our design units visually and tactilely. (Figure 3) shows a test print of a range of candidate textures that were tested as part of an iterative process of designing this surface texturing. It was important throughout the design process to create physical models of the design, because details of tactile and visual feel are impossible to judge from 3D renderings alone. For example, in the test printing shown in (Figure 3), many of the surface details that were clearly delineated in the computer rendering became indistinct in the physical object.

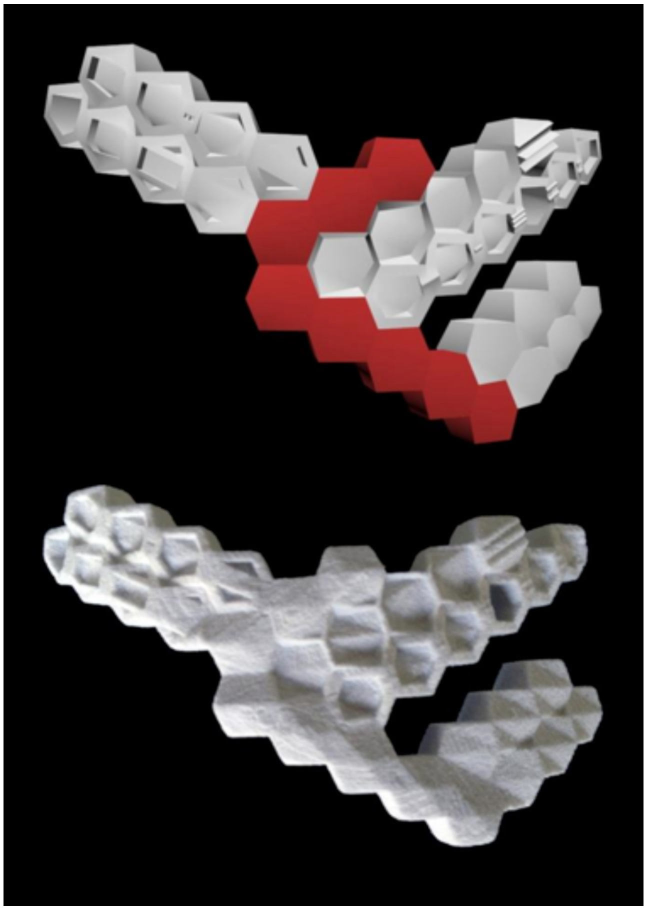

Figure 3: Texture study digital 3D vs. actual print

From this and other test printings of different textures, we developed a system for distinguishing between centre units, counting units along the arm of the chromosome and result units, which would translate well into a printed form (Figure 4).

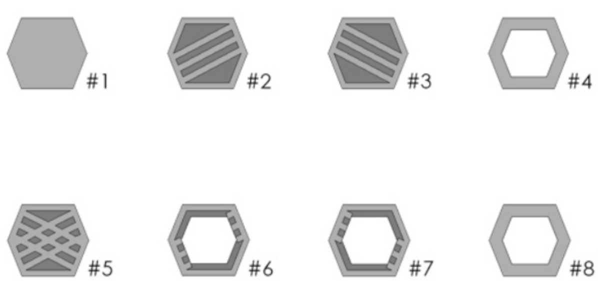

Figure 4: Textures of individual units (top) and combined (bottom)

For the centre units, we kept a smoother texture so that the units would join together into the centre line (4.1). For the counting units, we found that diagonal lines across each unit worked well because they served as a visual and tactile guide along the arm of the chromosome. The direction of the diagonal could also indicate either a left or right-facing arm (4.2, 4.3). Finally, for the result units, we applied a frame with a hollow centre to make it stand out both visually and tactilely (4.4).

One issue with wrapping the arms into a circular form (Figure 2) is that some of the longer arms may cross over each other. In one respect, this crossing-over is desirable because it makes the overall form stronger and more wearable, but for the readability of the individual units, it could cause ambiguities and conflicts in the surface texturing system described above. We dealt with this in the visualisation by combining textures where markers crossed over. This is shown in the bottom row of Figure 4, which shows (from left to right) two counting units crossing (4.5), counting units and result units crossing (4.6, 4.7) and two result units crossing (4.8).

4.2 Final Printing of Jewellery

After creating suitable textures we combined all the elements into a final tangible design. Even though we had settled on the final form for the piece, there were still several iterations of test prints required to find a final form that would reliably print and was strong enough to actually be worn. Initially, we printed bracelet-sized pieces as shown in (Figure 5).

Figure 5: 3D printed bracelet of DNA profile data

Once we were satisfied with the form of the bracelet-sized pieces, we produced a ring-sized piece in silver, which is shown in (Figure 6). There were less tangible texture details in silver version due to small size of the ring and limitation to produce such details in small scale but we produced the silver version to fulfill the need of personalized item and take the project beyond prototyping and get as close as possible to actual production.

An aspect we found attractive about the final form is that although the data is not immediately obvious, it can still be deciphered. Thus the form requires some level of engagement from the wearer. The form also manages to be evocative of DNA without relying on obvious visual clichés such as a double helix.

Figure 6: Final 3D print of DNA Ring in silver

5. DISCUSSION

This project has allowed us to explore some of the issues involved in the design of tangible data visualisations. We adopted an iterative process in this project, where each iteration included design, creation and reflection that helped us to move our design towards the final result.

They were 4 equally important elements in this project:

I. Creating an actual physical item (production)

II. Aesthetics of designing item (design & aesthetic)

III. Visualizing data and keeping it easy enough to read (data readability)

IV. Creating a personalized item (personalization)

If we wanted to put more effort on either one of these elements, we should have sacrificed the other. For example adding details in order to improve the aesthetic value would likely make it more difficult for the user to read the data and perhaps more difficult or impossible to produce. Similarly if we wanted to concentrate on data visualization and keep it so simple and straightforward it would likely lack some aesthetic qualities.

One important lesson from the design process was the importance of moving between digital and physical materials of design throughout the process.

Further work remains to be done in terms of producing more designs for other people and seeing how they relate to and imagine them. To see how people might perceive their differences through their bracelets to figure out if these items reflect any of our characteristics (at least biologically). For instance, perhaps there are those who have the same length on their 3rd arm of their bracelets; they have some similarity; because they have these similarities on their DNA. Or even if this is not really possible from such a simple profile data it would still be interesting to see if people perceive their DNA to be similar to others or how this leads them to reflect on their DNA in relation to others.

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