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A pixel is not a pixel: simple data charting made physical

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Abstract: The humble pie chart, the basic line graph: we are used to these and other forms of basic graphs. These have become commonplace and they can blend into the background, another plot on the screen real estate that accompanies our lives. To stand out, screen based data visualizations have become ever more beautiful, intricate and bespoke, but in so doing their legibility can suffer.

In a project on community data, run in collaboration with residents of Tenison Road in Cambridge, we have been exploring how to present data to the community that will be accessible to as many local people as possible. We chose to use our highly visible window-frontage, visible from Tenison Road itself. As a technology company, our street facing window is full of screens, which could easily have been used for our purposes. Instead we have designed and built physical visualizations of a pie chart and a line graph. These are simple in the sense that they are easy to read and make playful use of some readily available material (like retractable tape measures). Their design is sensitive to the need for readability and spectacle.

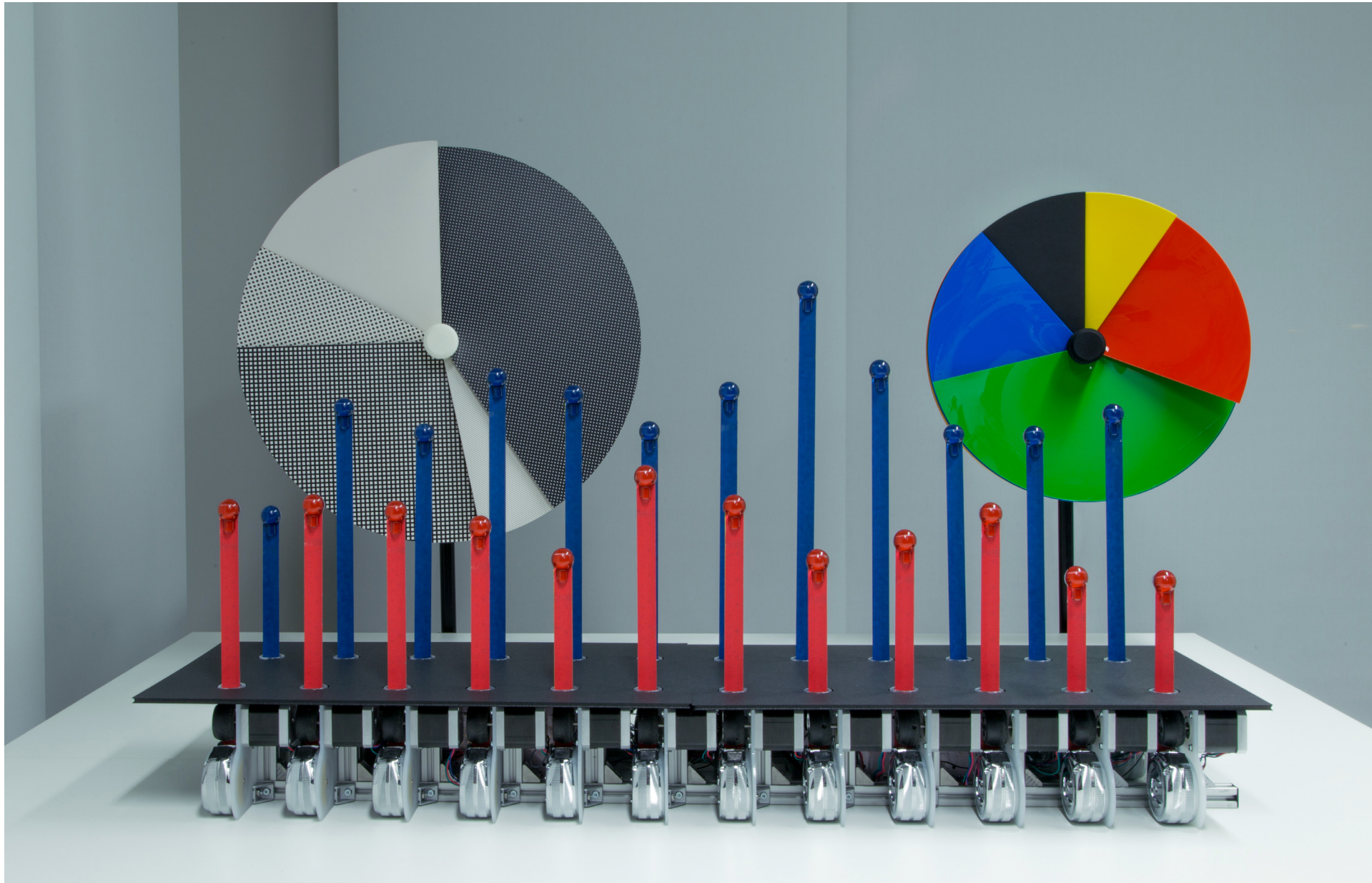**Keywords:** Data visualisation; Charts; Physical charts; Physical displays.

Figure 1. The Three Physical Charts: Two Pie Charts and the Bar Graph.

Summary

These days 'Big Data' is a big issue. From our daily newspapers to new scientific journals, and from TV & radio to blogs, the proliferation of data and the proliferation of new techniques for grappling with that data is presented as a new horizon in our understanding of ourselves and our understanding of the world we live in. These datasets are vast and varied: census results; local statistics on crime, education, property prices, etc.; our shopping habits; our tweets and Facebook likes; scientific measurements, etc. etc. If we are to believe the hype these data sets and more are enabling unprecedented access to who we are as individuals and citizens, what we want, and even the very nature of knowledge.

But with each new advance in the vast amount of data we can glean, store, analyse, and present, the questions we seem to pose of our datasets and the techniques we use to find and present our answers become increasingly removed from the everyday experiences of data and our naïve ways of understanding it.

To redress this gap in the rhetoric surrounding big data, this gap between the promise of data and the day-to-day experience of data, we have been working with a local community to understand what people mean by 'data' and what they hope it might be used to do for them. The street running next to our lab in Cambridge, Tenison Road, runs from Cambridge Station up towards Anglia Ruskin University and it is this community, the community we at Microsoft Research form a part of, with whom we have been working to comprehend these everyday understandings of data: 'small data' if you will.

Several classes of data emerge as important in the community. There is data that helps us negotiate better facilities and protect our environment. Traffic volume and speed is of particular concern at present to this community. Similarly measuring the effect that traffic and building projects have on air quality indicators provide data that is useful in discussions with the council about local traffic calming provisions.

Another interesting set of data points are those that help us tell stories about the places we live. Residents have been working with us to collect an historic archive of the street, and we have been looking at mapping as a way to record textured local knowledge.

Then there are the questions we would like to pose of each other. Questions relating to local issues like the provisioning of new street signs through to pragmatic issues like borrowing a ladder or questions that help to paint a picture of the space a community lives in like which garden gets the first snowdrop. To facilitate these questions within our project we have designed a device that residents can use to pose and to answer questions. We have conceived and built this as a small dedicated device

though much of the functionality could readily be achieved within a web page or a smartphone app. Instead making it physical allows us to keep the relationship between us and our data in the foreground during the project.

With big or with small data the techniques that we use to look at data are crucial in prescribing exactly what we can learn from and do with data. These techniques may be designed to help us discover things, trends, patterns, or answers, within the data or they may be designed to help us tell stories about and with the data. Some of these techniques are very old, for example the first pie chart can be traced to 1801, and some are cutting edge inventions, for example those used to visualise bioinformatics data. One benefit of such advances is that more and more complex data can be examined, but one drawbacks is that the charts themselves become less legible and the preserve of data experts. Simple charts become almost too commonplace and fail to stand-put.

One way beyond this dilemma is to stay true to the simplicity of charting ideas like pie charts and line graphs but to render them physically rather than presenting them on screen or in print. The presence of such charts makes them stand out and helps us to present the data we are collecting with residents back into the community where the data is of interest.
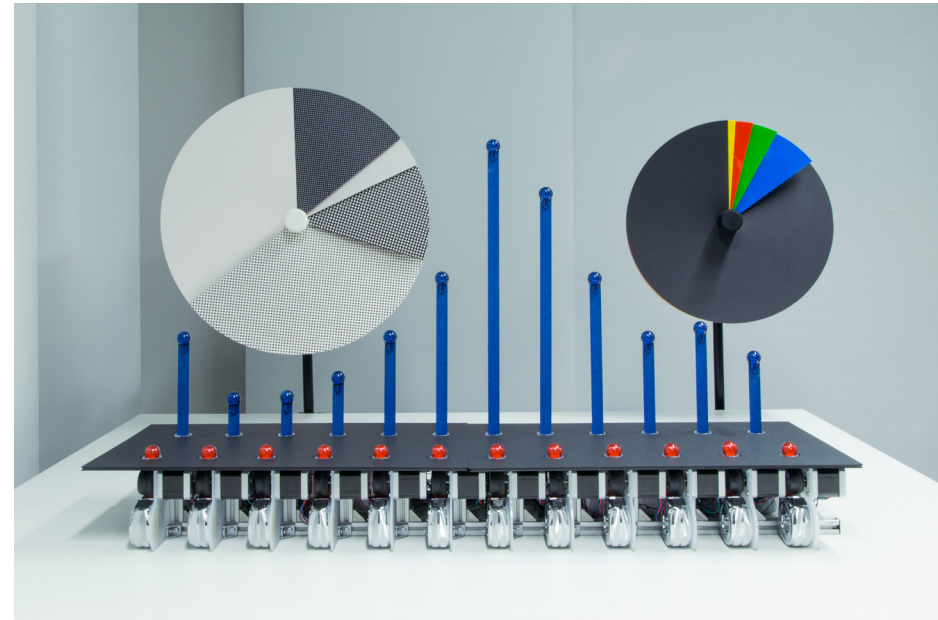

Figure 2. The Charts Opening Up.

The Charts

The physical charts are an attempt to make data and data visualisations legible to ordinary people in their daily lives. In response to the increasing sophistication of data visualisations and the seemingly unquestioning quest for novelty, the charts make playful use of long established and highly familiar representations like pie charts and bar graphs. Rather than estrange viewers, the objective is to enable them to, at a glance, engage with and comprehend data.

Currently, the physical charts are being used to display real-time data on a road in Cambridge. They switch between showing, one, vehicle journey data measured on the road, two, aggregated air quality measurements being recorded by residents, and, three, results from local polls and votes. As such, the charts provide a way for locals to see data that has an immediate relevance to them and that they may use to have some say over improving community life.

Overall, the aim of the physical charts has been to work on an approach to data visualisation that weaves data into people's ordinary lives. The hope is that by materialising the data in the highly visible, legible and dynamic charts, onlookers see it as knitting into daily life, becoming a meaningful and relevant part of how they see themselves, individually and collectively.

The physical and dynamic qualities of the charts are intended to draw people in to viewing data, differentiating them from screen-based visualisations that are beginning to lose their salience in our information-rich environments. The beauty of the charts is in how simple they are to read and how the physical mechanics produce strikingly visual (and tactile) representations of data.
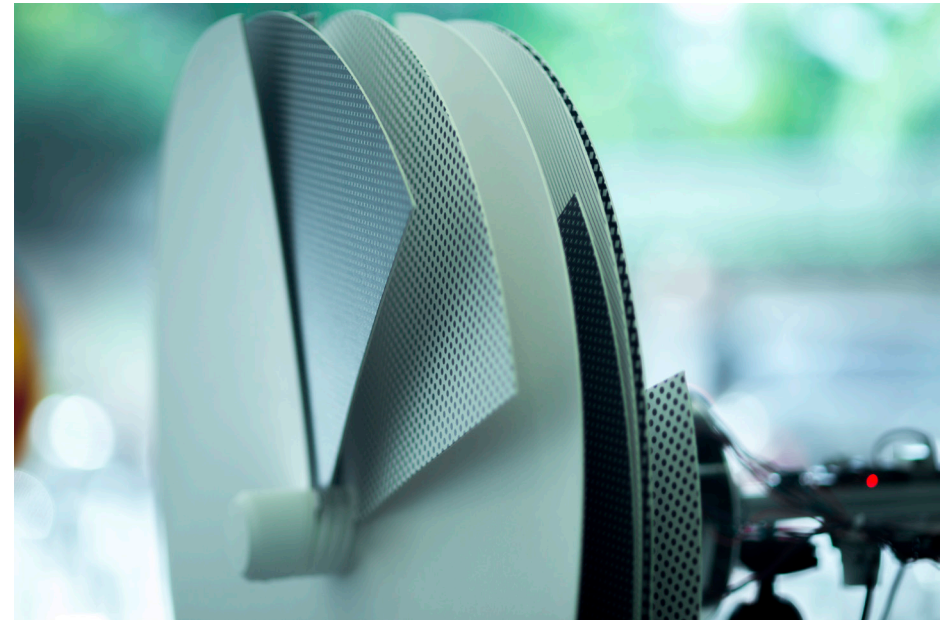

Figure 3. The Card Pie Chart from the Side.

Pie Chart

A mechanically actuated pie chart for visualising up to five re-assignable categories. Displaying datasets in real-time or animating through recorded data.
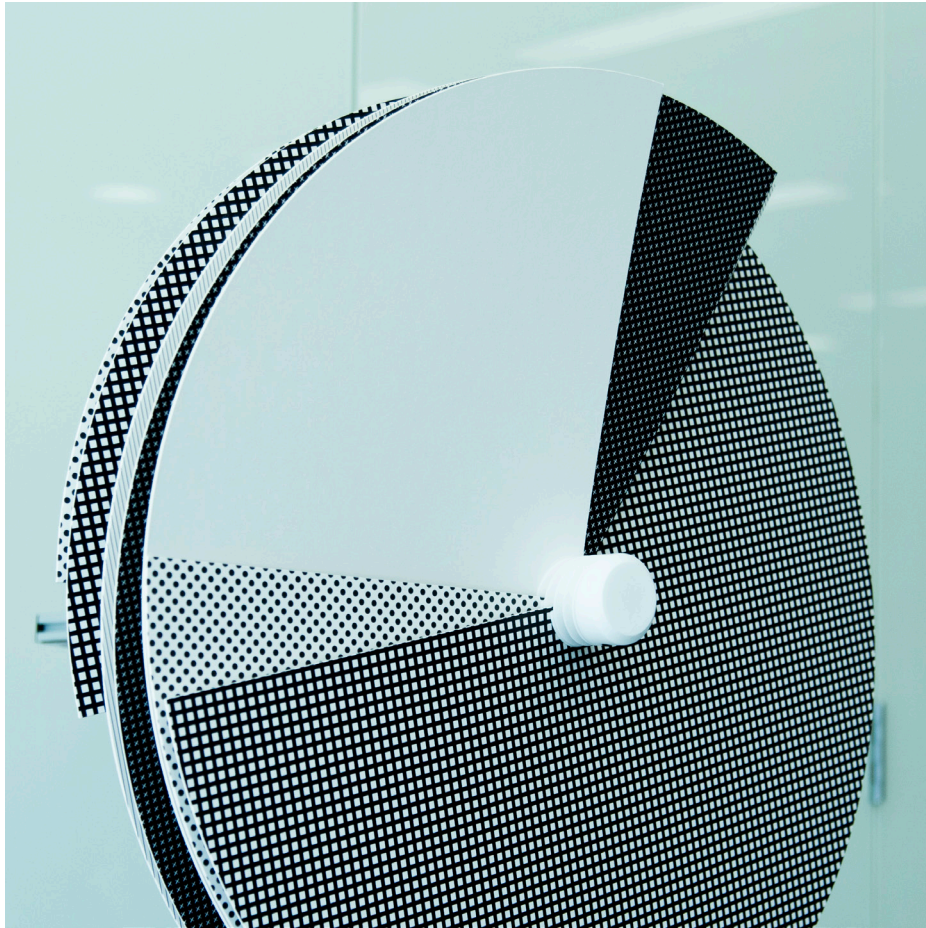
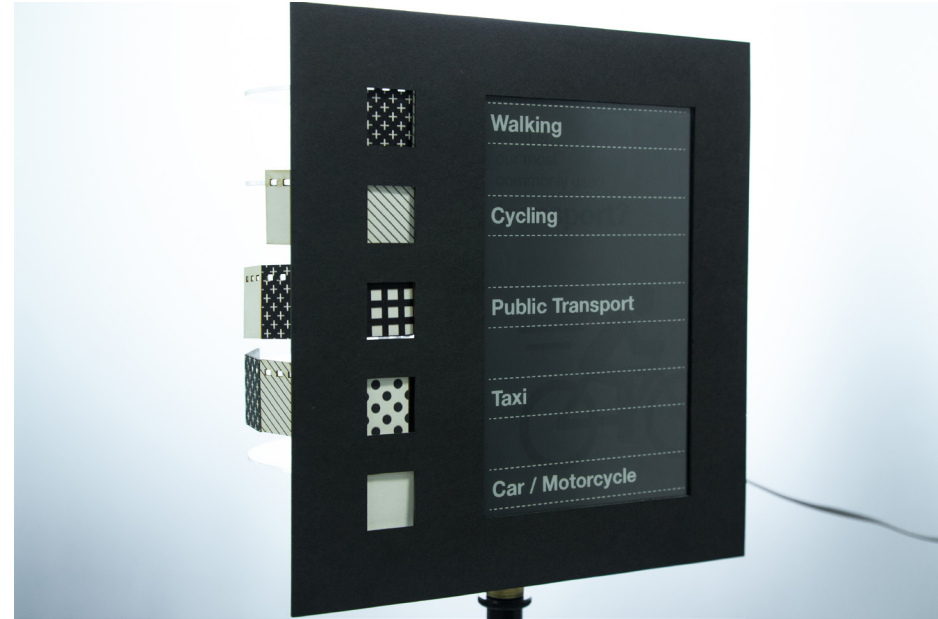*Figure 4. The Card Pie Chart from the Front.*

Figure 5. The Card Pie Chart ePaper Legend.

The accompanying physical key provides annotation for the dataset displayed on the chart - and which category each of its slices represent. Using material swatches from the chart and e-paper screens ensures that the devices can be read in a wide range of lighting conditions.
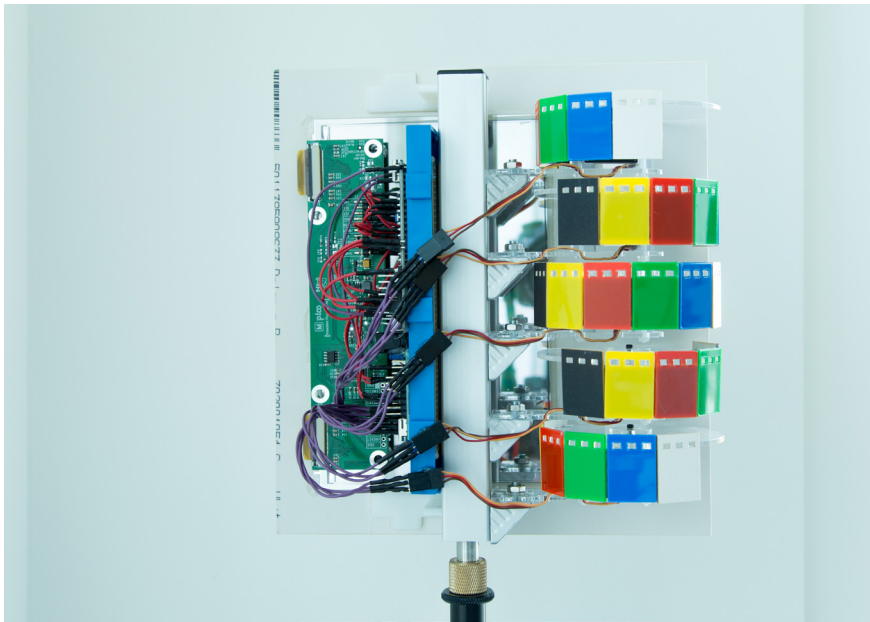
The slices can be sized and coloured appropriately to best suit its environment. Small or large, constructed from paper, plastic or other sheet material, etc. The physical charts are energy efficient - they only draw power when they are changing data.

Figure 6. The Card Pie Chart Legend from the Back.

The pie charts have been used to display a variety of datasets, e.g. comparing levels of air pollution measured on a street, the proportion of cars that are speeding on a residential road, and the results of community polls, etc.
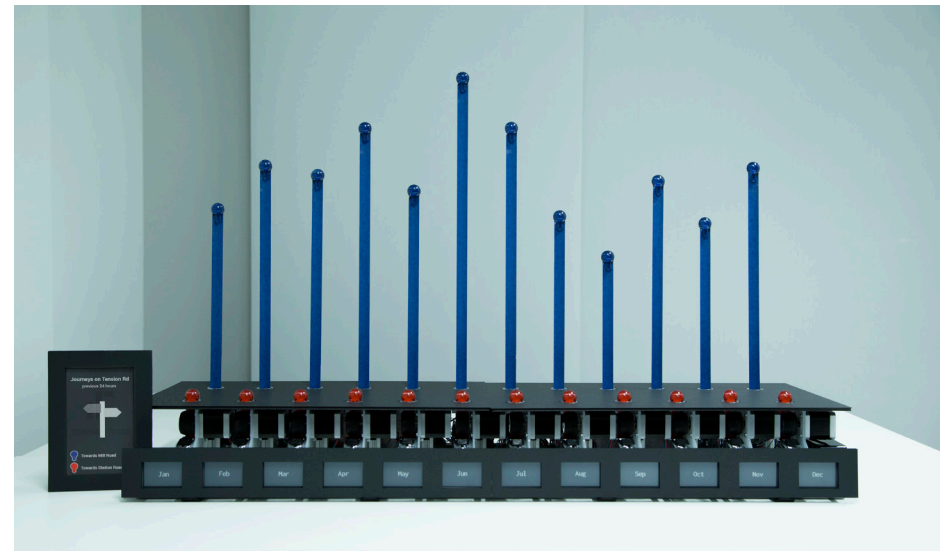
Bar Chart

Figure 7. The Bar Chart with One Row of Bars.

The bar chart consists of two rows of 12 individually actuated bars. The extension of each bar is dictated by the size of the item it is representing - this vertical dimension can be applied to count, speed, decibels, temperature, etc.
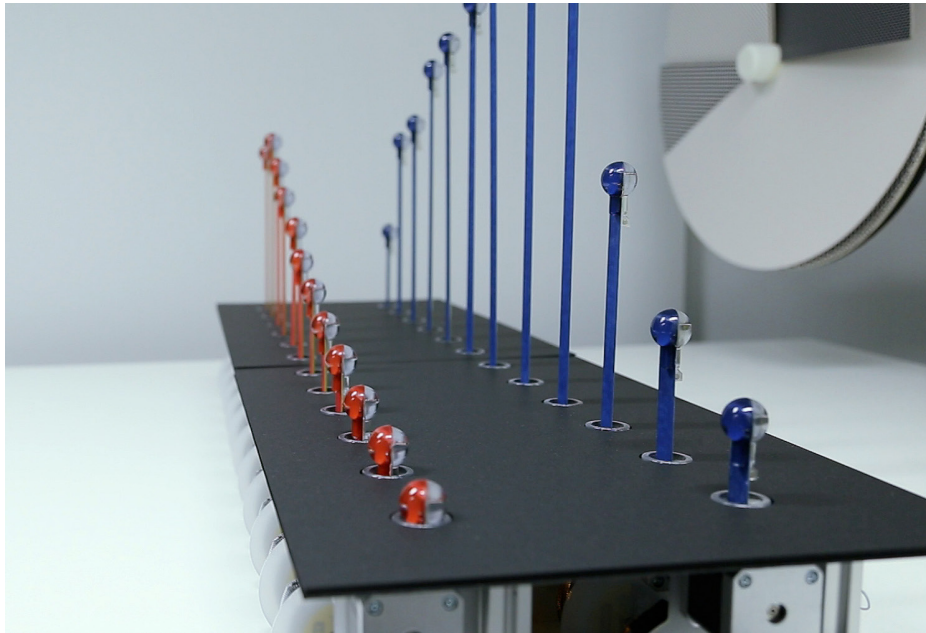
Figure 8. The Bar Chart Bars.

Figure 9. The Bar Chart ePaper Legend.

One row can be set to display a particular dataset, while the other can be set to show something different - such as the rainfall over the previous 12 months vs. the volumes of traffic on a street over the same period - patterns and possible inter-dependencies can be quickly identified.

Each pair of bars share a single e-paper label - as new datasets are visualised, they change to indicate what the bars represent - allowing the chart to cover varying timeframes, or any arbitrary set of categories. Each dataset is assigned on the accompanying title screen.
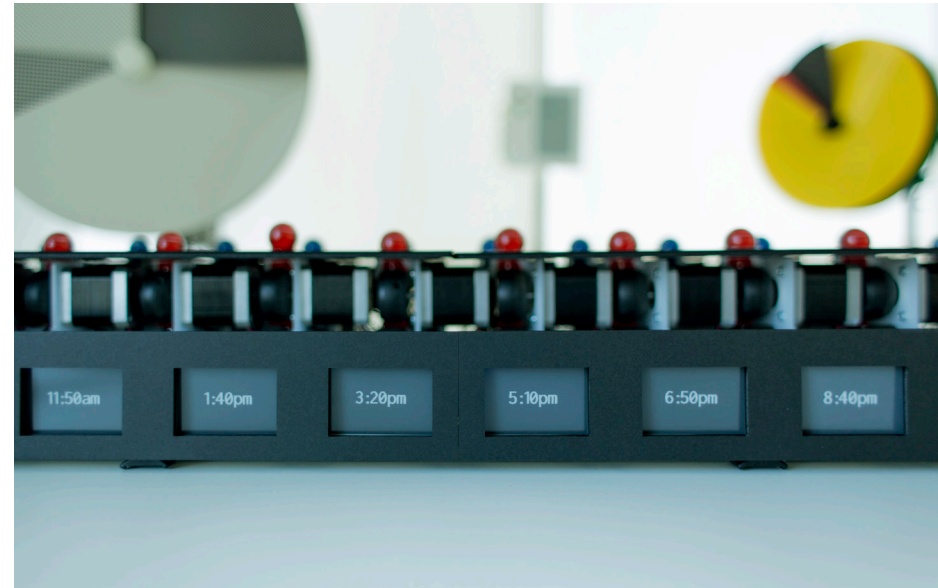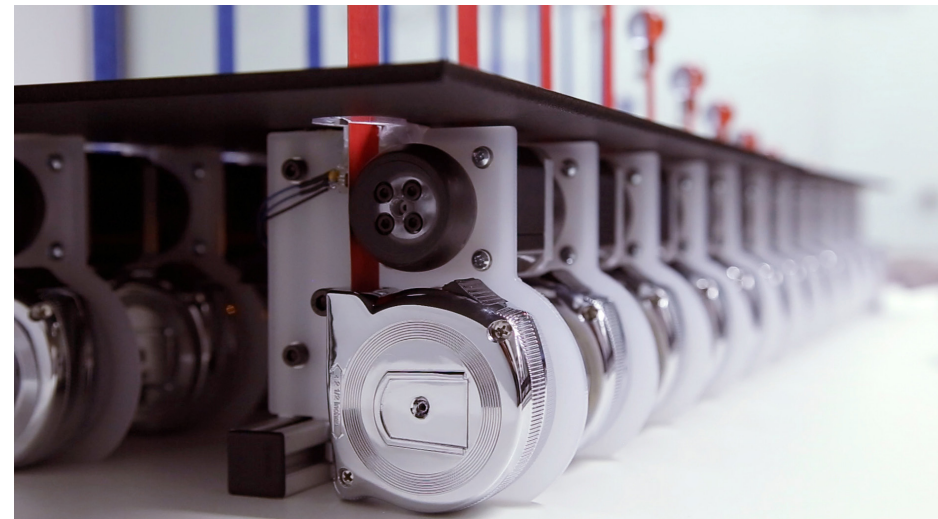

Figure 10. The Bar Chart Tape Measures Revealed.
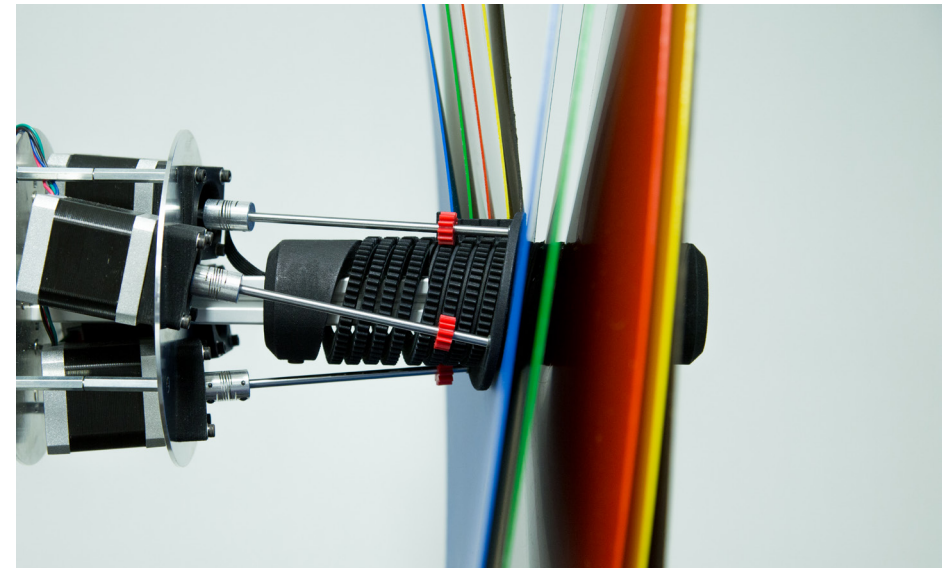
Figure 11: The Acrylic Pie Chart Side-on.

Figure 12: The Acrylic Pie Chart Mechanism.

Bar charts are particularly useful at describing time-based sensor data - comparing how the two-way traffic flow or speed down a street develops throughout the day. Similarly, this chart only uses power when it changes - The display of static data uses no energy.

The pie charts are constructed around a unique 3D-printed helical guide (SLS nylon) which allows each slice to emerge from behind the front face. The stepper motors which drive each slice are mounted on bespoke mounts to acheive the required drive angle. The bar charts are made from an array of motor-controlled measuring tapes enveloped in coloured masking tape. A stepper motor meshes with each tape using a 3D-printed rubber wheel (Objet). All the physical charts are controlled using .NET Gadgeteer electronic devices and receive data over Wi-Fi from a central server based in the Azure cloud.

The use of materials such as paper and card, as well as familiar items such as DIY measuring tapes, was to add a sense of warmth and tactility to the data - encouraging the viewer to think about the stories which drive the visualisations. To ensure maximum clarity of the displayed data, the charts have been designed to be as visually similar to their 2D versions from which they were inspired. This requires that all the mechanics and control systems are hidden when viewing from the front.

Concluding Discussion

We can see from the artefacts presented that rendering data physically, as opposed to on the screen, can enliven humble forms of data visualization like the pie chart and the bar graph. Their placement in physical space hopefully enables them to form a narrative around data.

The charts have brought a new sense of scale and theatre to the simple data collected about the street and for the residents, though that sense of scale feels very different when one encounters the charts close to or sees them set in the glass office frontage.

It is hard to say what impact they have had. They clearly delight those who see them, both members of the public and design professionals but the extent to which they reformulate the nature of data in the world or the data visualization communities understanding of these simple chart forms is not clear. As Moritz Stefaner said "that is a lot of work for a pie chart".

References

Although there is a lot of work from commercial designers about physical displays (see, for example, Sagmeister & Walsh's Happy Show http://www.sagmeisterwalsh.com/work/project/the-happy-show/ or Jason Bruges installations http://www.jasonbruges.com/projects) There is very little academic work to cite. One notable exception is Jansen, J., Dragicevic, P., and Fekete, J. 2013 paper "Evaluating the efficiency of physical visualizations" (In Proc. CHI '13. ACM Press (2013), 2593-2602).