Tangible papercraft visualisations for education

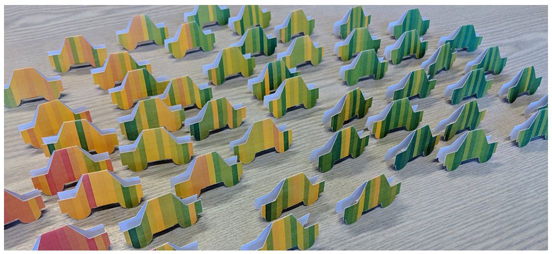

Figure 1: Paper cars representing student performance data.

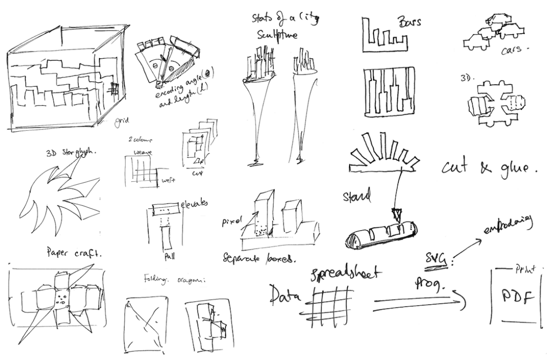

Figure 2: Design ideas as sketches for paper visualizations

Joseph W. Mearman
Peter W. S. Butcher
j.w.mearman@bangor.ac.uk
p.butcher@bangor.ac.uk
Bangor University, UK

Panagiotis D. Ritsos
Jonathan C. Roberts
p.ritsos@bangor.ac.uk
j.c.roberts@bangor.ac.uk
Bangor University, UK

ABSTRACT

We have been exploring how papercraft can be used to create 'data physicalisations' of student data, which act as physical artefacts and data sculptures that can be used in discussions. Papercrafting is cheap and quick to produce, and easily disposed of. Papercrafting student data is powerful as it acts as a focal point for discussions about the progression of their students and the effects of any extenuating circumstances. During such meetings teachers often reference spreadsheets and dashboard visualisations to explore the data. They focus and shift their attention to individual students, often commenting on individual performance and circumstances in turn. Tangible depictions, such as the ones we present, can be passed around, facilitating discussions, and can act as a focal-point for conversation. We present several prototypes and discuss our design process.

KEYWORDS

tangible visualisation, papercraft, origami, information visualisation, data sculpture

Troubling Innovation workshop at CHI 2019, May 04–05, 2019, Glasgow, UK

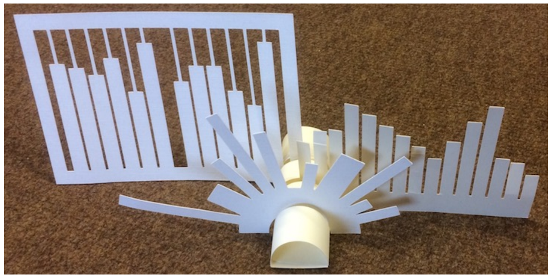

Figure 3: Various types of paper bar-charts

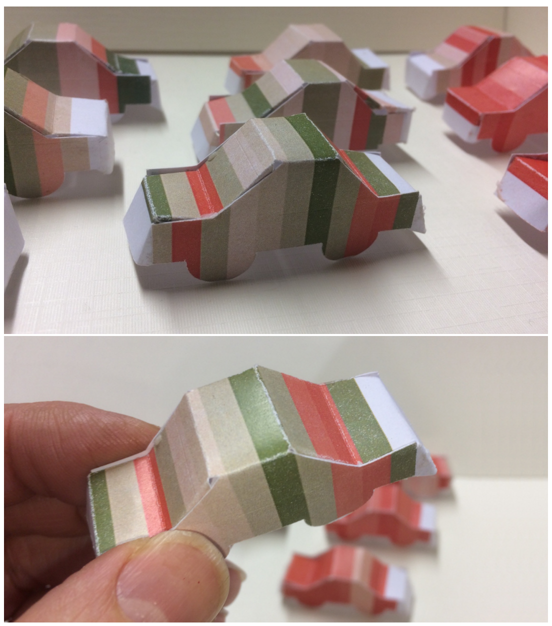

Figure 4: Early prototype of tangible cars, showing 12 stripes (one for each unit) coloured by achievement (green is excellent, beige is average, red is poor).

ACM Reference Format:
Joseph W. Mearman, Peter W. S. Butcher, Panagiotis D. Ritsos, and Jonathan C. Roberts. 2019. Tangible papercraft visualisations for education. In *Troubling Innovation: Craft and Computing Across Boundaries Workshop at CHI 2019, May 04, 2019, Glasgow, UK*. ACM, New York, NY, USA, 4 pages.

INTRODUCTION

Tangible artifacts have been created throughout history as illustrative and explanatory tools [4]. Representing data through physical or other non-visual forms [1], can help to promote discussion and can evoke creative discussion from viewers. Sometimes these models become tangible interfaces [8], and other times they are haptically recreated by computers [3]. Our interest, in this case, is to create data physicalisations as embodiments of student data using papercraft.

Forms of papercraft have been around for many thousands of years. Paper can be folded, moulded, cut into shapes and glued together. In this work we focus on paper cutting, folding and gluing. CNC paper cutters enable intricate patterns and designs to be quickly and accurately cut, scored and marked on paper, which can be folded, tucked and glued together to create meaningful 3D representations. We have been using a Cricut Explore Air 2 cutter; this hobby cutter is relatively cheap and easy to set up. It is therefore easy to create designs and rapidly explore different configurations.

In this short paper, we present two case studies. First, we look at crafting traditional visualisations, such as bar-charts, that depict our underlying data. Secondly, we investigate creating a data sculpture representing the student journey. Although tangibles can aid students' learning [2], our goal in this paper is to represent student data for educators, such as to facilitate discussion.

Our design process is fourfold: **(1)** We create quick sketches of the ideas [5, 6], which are often quick conceptual sketches that we use to inspire and discuss as a group (see Figure 2). **(2)** We then develop rough papercraft prototypes. These prototypes are quickly put together by hand in a co-design meeting, where we discuss and collaborate in a group design session. Our process is that everyone creates their ideas and then shares and elaborates them to the group. The more popular ideas then get refined into the next stage. **(3)** We then use computer programs to mock-up the design in vector drawing packages (we have used OmniGraffle, Visio, Cricut Design Space, Draw.io, and other CAD and vector design packages). The designs are exported to SVG that can be uploaded to the cutter. We then cut initial prototypes. Some prototypes encode the student data through colour. With these, we print on to the sheet before cutting, go through several alignment tests using scoring, and then cut the printed sheet. In our second case study, every model has the same shape, but colours differentiate them. Prototypes that we encode value to size (or other physical attributes) are created individually and placed closely together on the design canvas to be cut together. **(4)** Finally, we refine the designs and replicate the process to create representations of several students. We have tried different grades of paper/card and have found that a lightweight card-stock works best (e.g., 150 to 200 gsm), which gives enough strength to the individual elements while allowing the card to be easily cut and folded.

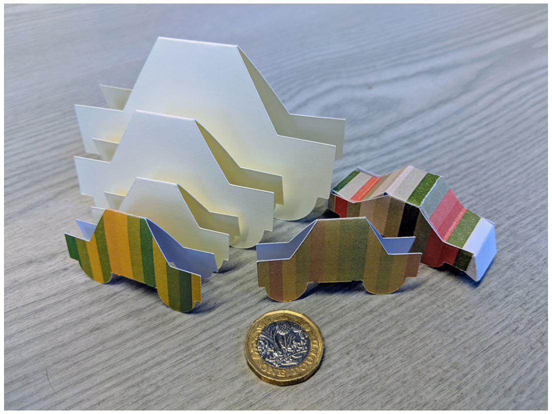

Figure 5: Prototypes for the tangible cars (1 pound coin for scale).

Figure 6: Simplified car model, that can be assembled without glue. Cut by the Cricut Explore Air 2 cutter.

PAPER BAR-CHARTS

In this case study, we intend to present the student data accurately. Our vision is to display the information quantitatively, such that the teachers can see the values (overall module grades, averages etc.). In planning (stage 1 and 2) we went through many different configurations; from flat bar-charts to three-dimensional bars. Figure 3 shows three flat designs, from an enclosed bar-chart to radial bars and a traditional bar-chart design. The advantage of these designs is that they can be easily picked up, can be stacked together to allow visual comparison between several students, and can be passed around for discussion. Further research is required to evaluate the effectiveness of this type of visualisation compared with traditional spreadsheets or dashboards. These designs will be refined further in future and could prove useful for more precise comparison of data.

THE STUDENT JOURNEY REPRESENTED BY CARS

Our second study focuses on creating a *data sculpture*. Through our discussion during the creation and inspection of the paper bar-charts, described above, the teachers kept on pondering about the overall student journey. Exploring this concept, we aim to create an overview of all of our first-year students. This is meant to be a snapshot of the students' work, illustrating their attainment over an academic year. Merely through the process of visually clustering each tangible, the users can get a feel for the distribution of the data, any clustering, and any individuals that stand out.

Our initial car design model culminated in being too complicated. We wanted hundreds of these cars, and each took too long to cut, fold and glue, as they needed 20 folds. We, therefore, decided to simplify the model for the final car data sculpture, going through several designs (see Figure 5). The improved design (see Figure 6) requires only three folds and no glueing to construct. To colour the tangibles, we took the student data and created blocks of colour that were printed on the card (see Figure 7), the coloured sheets were then aligned with a calibration point on the cutter, and the car nets were then cut out. This multistage process is required because the cutter only has a simple pen drawing interface, and cannot print many colours. To complete the car sculpture we visually compared and positioned the cars on a table, with the better students at the front, and the poorer performing students at the back (see Figure 1). The per-module colour encoding was mapped from 100% - 50% to a green-red scale (green representing students attaining higher grades).

SUMMARY AND CONCLUSIONS

We have explored and created several papercraft models which display student data. We have adopted a simple co-design process to deliver different papercraft models. Our bar-chart models present

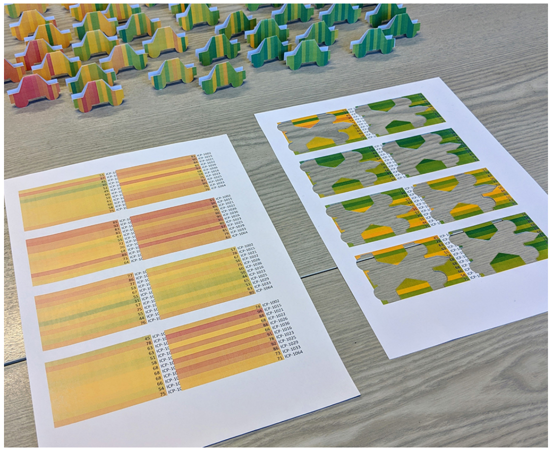

Figure 7: Encoding the car data and producing nets from a template.

quantitative data, whereas the car designs provide an overview of students on a degree programme. Our car data sculpture has already evoked discussion, where participating academics have discussed individual student performances, as well as the overview of how well our cohort are performing. There is potential to use these models in teachers' meetings and in discussions with individual students.

Nonetheless, there are many challenges. Even though we spent time and effort creating a simpler car model, the cars still take some time to construct. It would be useful to develop tangible visualisations of the student data that can be fabricated more quickly; this would enable the sculptures to be used more regularly in different teacher-student meetings. The car sculpture provides an overview of the information we wish to explore, but we are also exploring methods to represent data more quantitatively. There may be a way to merge the bar-chart idea with the car models and display additional information by changing attributes other than just colour. Additionally, one student observing our set of cars wanted to identify themselves, which is currently not possible because the data had been made anonymous. To solve this problem, a hash, glyph, icon or recoverable code could be included to allow students to identify only themselves.

We believe that paper crafting has vast potential to create data physicalisations as embodiment of data [9] because they enable different data-interactions and allow the user to see the information in an alternative way, and may help with data visualisation storytelling [7]. The low cost nature of digital paper cutters has democratised paper cutting crafting, allowing bespoke papercraft models to be readily designed and easily created.

REFERENCES

[1] J. McCormack et al. 2018. Multisensory Immersive Analytics. In *Immersive Analytics*, K Marriott et al. (Ed.). Springer International Publishing, Cham, 57–94. https://doi.org/10.1007/978-3-030-01388-2_3

[2] P. Marshall. 2007. Do Tangible Interfaces Enhance Learning?. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction (TEI '07)*. ACM, New York, NY, USA, 163–170. https://doi.org/10.1145/1226969.1227004

[3] S. Panëels and J. C. Roberts. 2010. Review of Designs for Haptic Data Visualization. *IEEE Transactions on Haptics* 3, 2 (April 2010), 119–137. https://doi.org/10.1109/TOH.2009.44

[4] S. A. Panëels, P. D. Ritsos, P. J. Rodgers, and J. C. Roberts. 2013. Prototyping 3D haptic data visualizations. *Computers and Graphics* 37, 3 (2013), 179 – 192. https://doi.org/10.1016/j.cag.2013.01.009

[5] J. C. Roberts, C. Headleand, and P. D. Ritsos. 2016. Sketching Designs Using the Five Design-Sheet Methodology. *IEEE Transactions on Visualization and Computer Graphics.* 22, 1 (Jan 2016), 419–428. https://doi.org/10.1109/TVCG.2015.2467271

[6] J. C. Roberts, C. J. Headleand, and P. D. Ritsos. 2017. *Five Design-Sheets – Creative design and sketching in Computing and Visualization.* Springer. https://doi.org/10.1007/978-3-319-55627-7

[7] J. C. Roberts, P. D. Ritsos, J. Jackson, and C. Headleand. 2018. The explanatory visualization framework: An active learning framework for teaching creative computing using explanatory visualizations. *IEEE Transactions on Visualization and Computer Graphics* 24, 1 (Jan. 2018), 791–801. https://doi.org/10.1109/TVCG.2017.2745878

[8] B. Ullmer and H. Ishii. 2000. Emerging frameworks for tangible user interfaces. *IBM sys.* 39, 3.4 (2000), 915–931.

[9] J. Zhao and A. Vande Moere. 2008. Embodiment in Data Sculpture: A Model of the Physical Visualization of Information. In *Proc.DIMEA.* ACM, 343–350. https://doi.org/10.1145/1413634.1413696