Accepted on 14 June 2023 for publication and presentation at European Conference in Cognitive Ergonomics (ECCE 2023) : Responsible Technology : Community, Culture, and Sustainability.; 19-22 Sep 2023, Swansea, U.K.

This is the accepted version of 'Interactive forecasts : exploring very uncertain projections of quantitative variables' published in *ECCE '23: Proceedings of the European Conference on Cognitive Ergonomics 2023,* which can be accessed at https://doi.org/10.1145/3605655.3605785.

Interactive Forecasts: Exploring Very Uncertain Projections of Quantitative Variables

Interactive Forecasts

How might we display very uncertain projections of quantitative variables, so that everyday users make better decisions?

Martin Colbert

School of Computer Science and Mathematics, Kingston University London, m.colbert@kingston.ac.uk

Predictive systems use a variety of Big Data and Artificial Intelligence technologies to 'predict' the future course of selected quantitative variables (inflation, house prices, passenger numbers etc.) with various degrees of precision and certainty. The challenge for user interface design is to display the output of these technologies, particularly information about uncertainty, in a way that supports exploration and decision-making by everyday users. This Work in Progress paper reports the design and formative testing of an 'Interactive Forecast' - a mock-up of a predictive system, in which the very uncertain future path of a quantitative variable was not represented explicitly by chart elements, but rather implied by the whitespace between elements (axes, labels) and other data (lines on the chart). A video of the mock-up is online. In the formative test, participants' 'guess-timates' of the future value of the quantitative variable were consistent with reading the display in the intended way. However, the test also identified confusions and ambiguities with the mock-up, which hampered participants' interpretation. Future work will continue to iterate, to complete the design of the Interactive Forecast, and to refine the user testing process.

CCS CONCEPTS • Human-centered computing ~ Visualization ~ Visualization techniques • Human-centered computing ~ Visualization ~ Visualization application domains ~ Information visualization

Additional Keywords and Phrases: visualization, predictive system, user test, understanding uncertainty

ACM Reference Format:

First Author's Name, Initials, and Last Name, Second Author's Name, Initials, and Last Name, and Third Author's Name, Initials, and Last Name. 2018. The Title of the Paper: ACM Conference Proceedings Manuscript Submission Template: This is the subtitle of the paper, this document both explains and embodies the submission format for authors using Word. In Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 Introduction and Background

Many Big Data and Artificial Intelligence Systems use a variety of algorithms and data sources to predict the future course of a selected quantitative variable, such as inflation, time-to-failure, asset prices or passenger numbers, with various degrees of certainty and precision. Decision-makers then explore the predictions and their computation, to make better, more informed choices [1]. The challenge for user interface design is how to best display the output of these systems, particularly uncertainty information, so that everyday decision-makers explore a range of possible futures fully, and make better, more informed decisions. Fan charts represent a probability distribution of a variable around its mean value, and so represent the increase in uncertainty as a projection extends into the future *explicitly* using graphical elements (see Figure 1) [2]. Presentation options for the fan include gradients rather than bands to indicate the density of the probability distribution, and a vertical bar at selected points in time to highlight confidence intervals. Additional annotations and symbols can express uncertainty explicitly in text [8]. Evaluation studies suggest that fan charts can help test participants to make judgements more consistent with statistical expectations, to perceive the predictive system as trustworthy, and to make better decisions, especially if they have experience of this kind of task and interaction [5, 6, 9]. That said, fan charts may not be suitable, even misleading, if the output of a predictive system is qualitative, rather than quantitative ("higher than today") or when the projection is very uncertain (the fan rapidly increases in height and soon extends off the top and/or bottom of the chart). In such cases, future projections are often excluded from any visualization. A traditional line chart is used to depict historical data only, and the 'predicted' trajectory of the quantitative variable is outlined and explained in accompanying text paragraphs only.

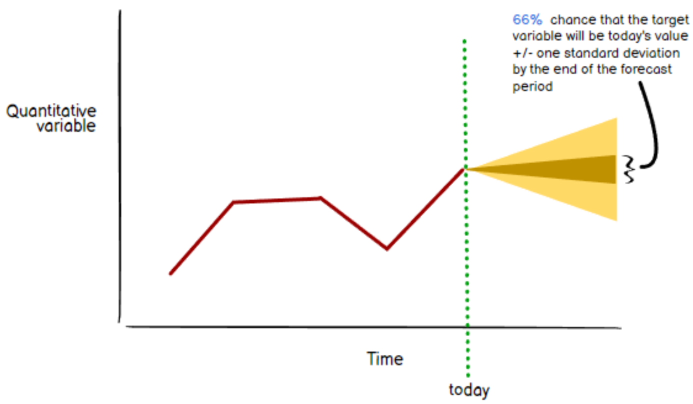

Figure 1: Fan Chart

The inclusion of illustrations in a text report is thought to convey information more effectively and engagingly than text alone [7], so simply excluding key information from charts seems unlikely to be the best possible support for decision-making. Perhaps there is an opportunity to support decision-making more fully – we just need to figure out how to include 'very uncertain projections of quantitative variables' in a line chart appropriately.

2 Aim

The aim of this project is to design an interactive visualization that improves user comprehension of, and engagement with, very uncertain future projections of quantitative variables. The design and testing of the visualization will lead to design guidance and commentary that might be suitable for inclusion in design pattern libraries, such as [4].

This paper reports an initial project iteration, comprising design and formative user testing.

3 DESIGN

3.1 Implying Very Uncertain Projections with Empty Space

The main claim embedded in the visualization discussed here is that the placement of labels and annotations on a chart can be used to delimit an 'empty space' between them, and that this space can imply to readers a range of possible future trajectories of a quantitative variable.

The idea of representing an uncertain trajectory as whitespace (and so *implicitly*) is not a common idea in chart design. Whitespace is traditionally used to separate graphic elements, so that readers can access individual elements easily, or to focus attention, by reducing the clutter around content that matters. In this work, whitespace is used as a temporary blank canvas – a space in which to imagine future possibilities.

Uncertain future projections have been represented implicitly before by chart animations in which each possibility is displayed for a few moments, implying that any individual projection is uncertain [6].

3.2 Mock-up: an 'Interactive Forecast'

An Interactive Forecast was mocked-up as a single page, using the Balsamiq wireframing tool (see Figures 2, 3 and 4). This Interactive Forecast was designed for the purpose of this research. The mockup presents dummy data, apparently viewed in May 2021, that shows the actual number of applications to start a university course in the coming September 2021. Actual applications received for the current year so far (2021) are indicated by a solid purple line. Applications received in 2019 are shown in a dotted blue line for comparison. The right-hand side of the chart displays 'factor bubbles' - 'speech balloons' intended to represent the impact of anticipated future events upon the path of recruitment. Positive factor bubbles colored green appear to 'push the line up' (more students apply as the year unfolds) and negative, red 'cloud' appear to 'weigh the line down' (applications are withdrawn). The design intent is that the combination of graphical elements – data series lines, factor bubbles, axes and labels – together delimit an area of whitespace which delimits a range of possible future trajectories for the number of applications.

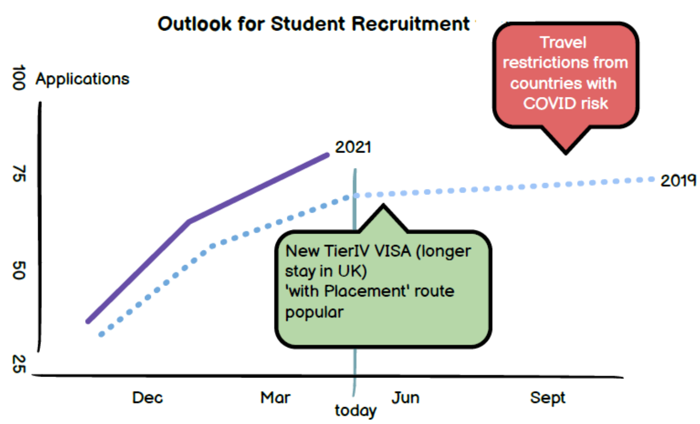

Figure 2 Interactive Forecast: Base Case scenario

On opening the 'Interactive Forecast', the first tab displayed shows the 'Base' case scenario – the most likely scenario - by default (Figure 2). This chart intends to show that recruitment was stronger between January and May 'this year' (2021) than during the same period a previous year (2019). According to the 'Base' case scenario, future demand for places is supported by the introduction of a new study visa, which is attractive to applicants, but tempered by travel and work restrictions associated with COVID pandemic, so overall applications are projected to reduce slightly through the coming summer 2021 – as implied by the 'gap' between the bubbles on the right-hand side of the chart.

In the 'Best' case scenario (Figure 3), COVID is controlled early, face to face teaching resumes, and the new VISA proves very attractive, so applications are projected to *increase significantly* compared to 2019 – as implied by the whitespace at the top of the chart. In the 'Worst' case scenario (Figure 4), new strains of COVID require another lockdown in the university, which deters applicants from travelling, and s*o applications for 2021 are projected to fall* significantly to less than 2019. A walkthrough video that describes how this Interactive Forecast might be used is available [online].

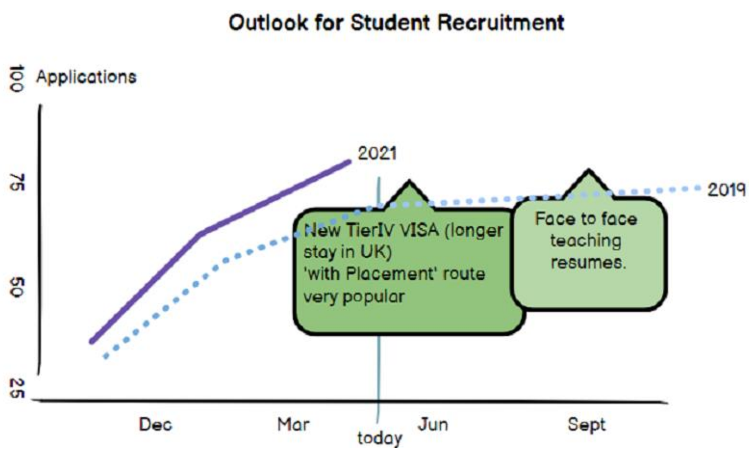

Figure 3 Interactive Forecast: Best case scenario

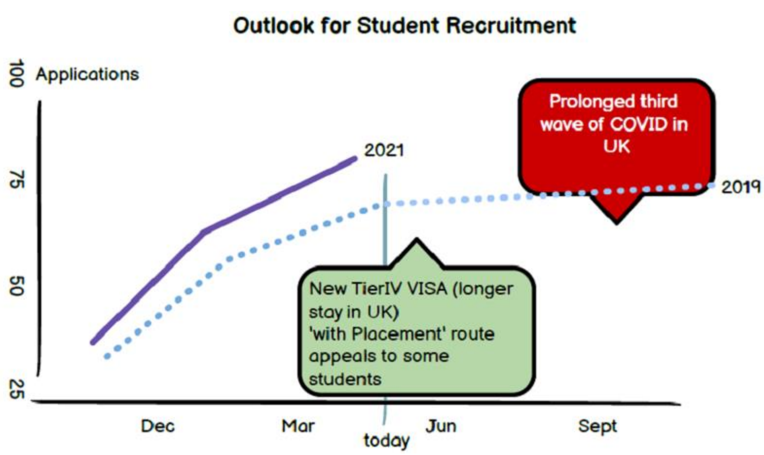

Figure 4 Interactive Forecast: Worst case scenario

Beneath the chart area are tabs for selecting the scenario to view. Riffling through these scenarios highlights to users the *change* on the chart – in this case, the different color, position and text of 'factor bubbles' (see [8] 'dynamic querying').

4 USER TEST

The aims of the formative user test were twofold – first, to confirm the claim that the shape of whitespace can be used to imply uncertain projections, and second, to identify confusions and ambiguities which hampered interpretation of the visualization. The prototype was the subject of a remote, unmoderated user test conducted on a public user testing platform. Test participants were 6 university-educated 25-65 yr olds (5 males and 1 female) from the US and UK, recruited from the platform's participant panel. Participants were asked to "spend 10 minutes using the interactive chart and to talk aloud about their thoughts and feelings as they did so. What was the chart telling them? What did they like about the chart? How might the chart be improved". After 10 minutes, 3 participants answered the question "According to the chart, in the worst case, how many students are predicted to start the course in September?", and then rated the apparent certainty of the systems' output ("How certain or uncertain is the prediction on the chart?"). Three participants answered the same question about the 'Base' or' Best' case scenarios.

In relation to the claim that whitespace implies uncertain trajectories, two findings are relevant:

1. Participants estimated 87 applicants in the 'Best' or 'Base' scenario, and only 66 applicants for the 'Worst' case – answers that are consistent with expectations. However, participants' commentary suggested that the estimates were only weakly influenced by the space defined by 'factor bubbles'. Participants did not mention any such space, or the position or size of factor bubbles, but either mirrored the path of 2019 data in 2021, or figured the 'Worst' case scenario projection must end up lower than in 2019. "It [the trend line for 2021] is slightly higher than 2019 from the outset … so tracing across ...'. To test whether factor bubbles can imply a range of possible paths, other points of reference must be removed. Perhaps, by default, just the data for 2021 should be displayed first. The user may then add in reference points, as required;
2. Participants *did* notice the empty space to the right of the trend line. Their commentary suggested they were all were aware of considerable uncertainty, because the trend line for 2021 stopped half-way across the chart! "it is not possible to know really, but I'll say about 85', or 'I want to say projection rather than prediction … about 82'. To ensure that the 'right' empty space is perceived, perhaps the space delimited by factor bubbles could be temporarily suggested by an animated background, or additional tails on the factor bubble

The following confusions and ambiguities were also identified:

1. Some participants were unclear about the data series to which the factor bubbles applied - did they apply to 2019 *and* 2021, or just 2021? Perhaps the border of the factor bubbles could be color coded to match the trend line of the appropriate year, or have a title such as "Positive Forces in 2021";
2. The implications of factor bubbles were not immediately clear to some participants. One participant did not know what to call the 'factor bubbles', and so referred to them simply as 'text'. Explicit definition of these elements in a legend, or other annotations, may help participants to learn the conventions of this type of chart. The impact of factor bubbles - to lift or depress a future trajectory - could also be conveyed more explicitly, for example, with animations on Click or MouseOver events, or by visual styling of the bubble.
3. Some participants found it difficult to express their answer to the question, "How many students are predicted to start in September?". There were at least two reasons for this. First, it was not perceptually possible to read off a specific integer value given a point on the chart. The tick marks along the vertical axis were well spaced out, and the chart was quite small. Second, the expected response format (and acceptable response format options), were not clear to participants. The moderation software simply comprised an empty field for text entry, so participants were not completely confident as to the kind of answer they were at liberty to provide.

5 DISCUSSION

Overall, the early findings weakly support the claim that whitespace can imply very uncertain predictions. The detailed design and layout of various user interface elements appeared to also affect users' comprehension of the chart on this occasion, and measurement of users' responses. However, these effects do not necessarily invalidate the main claim.

Future work will fully develop the Interactive Forecast through iterative design and testing. In addition to considering the changes suggested above, clicking through 'Factor Bubbles' could progressively disclose analysis of those factors in a separate panel. Text labels may also be added to the diagram as required, for example, to communicate key messages – charts do not only comprise graphical elements. The horizontal position of Factor Bubbles might indicate the time and/or strength of their effect. Perhaps whitespace could also be used to indicate uncertainty for other types of charts.

Future work will also refine the test process. User response formats may be used to encourage a complete answer from participants. For example, a request for participants to mark a confidence interval on the diagram may elicit perceived uncertainty more accurately than rating scales, or a blank text field. Also, although genuinely independent feedback from around the world is desirable, so too is a more balanced sample of genders, particularly when studying certainty.

REFERENCES

Gupta, P. K, Tuncer Oren, and Mayank Singh. 2019. Predictive Intelligence Using Big Data and the Internet of Things. IGI Global, Hershey, PA, USA 17033.

Abel, G. J. 2015. fanplot: An R Package for Visualising Sequential Distributions. The RJournal 7(1) 2015.

van der Bles, A. M., van der Linden, S., Freeman, A. L. J., Mitchell, J., Galvao, A. B., Zaval, L. and Spiegelhalter, D. J. 2019. Communicating Uncertainty about Facts, Numbers and Science. R Soc. Open. Sci. 6. 181870. doi:10.1098/rsos.181870

Financial Times Visual Vocabulary https://www.vizwiz.com/2018/07/visual-vocabulary.html (accessed 22/05/2023)

Joslyn, S. and Savelli, S. 2021. Visualisation Uncertainty for Non-Expert End Users: The Challenge of the Deterministic Construal Error. Frontiers in Computer Science. Vol 2 January 2021. doi: 10.3389/fcomp.2020.590232

Kale, A., Nguyen, F., Kay, M., and Hullman, J. (2019). Hypothetical outcome plots help untrained observers judge trends in ambiguous data. IEEE Trans. Visual. Comput. Graph. 25 (1), 892–902. doi:10.1109/TVCG.2018.2864909

Redish, J. 2007. Letting Go of the Words. Elsevier Science & Technology

Shneiderman, B. 1994. Dynamic queries for visual information seeking. IEEE Software, 11, 70-77.

Stephens, E. M., Spiegelhalter, D. J., Mylne, K., and Harrison, M. 2019 The Met Office Weather Game: investigating how different methods for presenting probabilistic weather forecasts influence decision-making, Geosci. Commun., 2, 101–116, https://doi.org/10.5194/gc-2-101-2019.