Visualizing Personal Progress in Participatory Sports Cycling Events

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RECORDING participation in sporting activities has become increasingly sophisticated with the wide availability affordable tracking technologies. GPS receivers and positionally aware smartphones have given rise to services such as Strava, Ride With GPS and RunKeeper that allow individuals to record and visualize their own sporting performances, set goals and share data with others. Cheap wearable RFID devices allow live checkpoint timing of runners, cyclists and swimmers in multi-stage races. Equally, new approaches to visualizing the data generated by these sensors has provided opportunities to make meaningful patterns of space-time trajectories salient[1]. Drawing on my own experience of participating in long distance cycling events, in this paper I explore some of the design choices that allow individuals to visualize their own progress in mass participation sporting events. I will use the examples given here to consider the differences and similarities of personal visualization with more conventional analytical data visualization design. The continuum between these two approaches is considered when comparing an individual's personal experience with that of others participating in the same event.

SPATIAL NARRATIVES

Long distance participatory cycling events (commonly known as audax, ultra-cycling or randonneur events) typically involve many hours of riding and can cover distances of many hundreds of kilometres. Even with large fields of participants, over such distances it is common for riders to end up cycling alone or in small groups for long periods. And while not a 'race' the ultra-endurance nature of the events, sometimes involving riding for several days with limited or no sleep, presents significant challenges for most riders. As a consequence it is common after an event has been completed for riders to write 'ride reports' of their experience to share with others. Typically these take the form of a conventional written narrative in diary form, often supported by photographs. I was interested in whether visualization might offer an alternative way in which these personal narratives might be constructed. The incorporation of personal narratives in space-time histories is not new[2], but the context of the participating individual in mass sporting events has yet to be fully explored.

Given the long distances covered by these cycling events, an obvious visual representation of progress would be cartographic. Indeed, routes are often shown as linear overlays using mapping services (e.g. Ride With GPS). These can work well for route planning and integration with GPS navigation, but are not so well suited to personal narratives of a ride *post hoc* as the detail of the background mapping leaves little graphical space for other information or links with the temporal[2] in the narrative. I therefore considered alternative minimalist cartographic designs that represented only

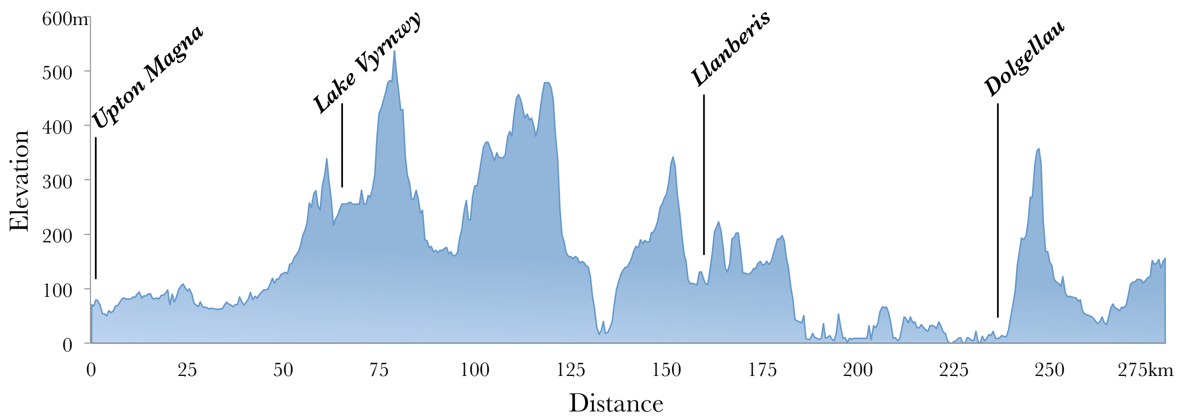

Figure 1. Conventional vertical profile view of the first 280km of the Mille Cymru audax route. Elevation changes are clear, but at the expense of locational detail. Graphical space for adding personal narrative is limited, especially for longer routes.

the key cycling-relevant information, leaving space to add a rider's spatially located temporally sequenced 'diary' entries.

Three elements dominate my experience of long distance riding: *gradient*, especially when climbing, has a big impact on amount of effort and feeling of progress made and anticipation of effort yet to be made; *wind* can dominate a ride experience if strong both assisting and impeding progress depending on direction; *controls* (checkpoints) are the opportunities for rest and feeding stops and are vital in punctuating what would otherwise be daunting distances to ride. Gradient and controls could be shown as a vertical profile map (see, for example, Figure 1), but there is little sense of the geography of the route and little space for personal narrative text. In terrain with a prevailing wind, there are no visual indications as to which parts of the route may be assisted or hindered by wind.

An alternative is offered by the *profile map*, first proposed by Daniel Huffman[3]. This minimalist design maps only the route as a black line where its thickness varies in proportion to the elevation of the route along its length. This alone is sufficient to indicate the length, elevation and direction of the route using very little 'data ink'. Given that it is local gradient that is more important to the cyclist, why not map this directly rather than absolute elevation? Huffman considered this but rejected it on the grounds that encoding gradient also requires aspect to be separately symbolised (e.g. through chevrons to distinguish upward from downward slopes) leading to a more cluttered representation. In the context of longer distances there are two further reasons for symbolising elevation rather than gradient. Firstly, perceived 'slope' is a scale-dependent measure – a short steep section of road over 10 metres might be significant to the rider, but would not occupy any visible portion of a map covering hundreds of kilometres. By viewing changing elevation over a scale of kilometres, an indication of likely periods of climbing or descending is made more salient than alternating fine bands of steeper and flatter segments. Secondly, for longer rides it can be common for the same section of road to be ridden several times, often from different directions. Absolute elevation avoids the need to symbolise each traversal (and its associated ascent or descent) separately.

The design offers the possibility to map other variables onto a color component of line segments. Wind direction and speed might be obvious candidates, although for most events, there is unlikely to be sufficiently detailed data available to capture the rider's experience of headwinds as it varies with location, altitude and time. But by maintaining a geographic mapping of the route, the effect of the prevailing wind direction can be estimated along the length of the ride.

Huffman constructed his profile maps by manually interpolating line thickness with reference to elevation contour lines. This process, in the hands of a good cartographer, can produce visually appealing results, but is time consuming to create. Instead, I propose here a simple method to construct profile maps automatically from a digital elevation source such as that provided by a GPS receiver after riding an event, or a raster *digital elevation model* (see Figure 2).

The function that relates line width w in pixel units to the normalized elevation z in the range $[0,1]$ will depend on the visual impression of terrain variation desired as well as the nature of terrain. A simple linear mapping is comparatively poor at distinguishing flat from hilly terrain as local variation in line width tends to be quite small. A rider's subjective effort in response to altitude gain is itself non-linear with steeper, higher elevation riding having a proportionately greater impact on the character of the ride than lower elevation

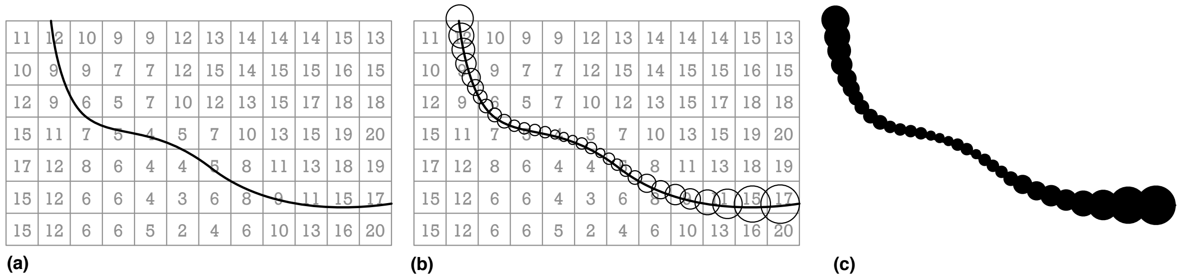

Figure 2. Construction of a profile map. A route is compared with height values of digital elevation model (a). A circle is drawn at regular intervals with radius a function of the interpolated height at its centre (b). Representing the circles as solid discs (c) creates a line with width proportional to elevation. By making the distance between consecutive circles sufficiently small the line appears continuous.

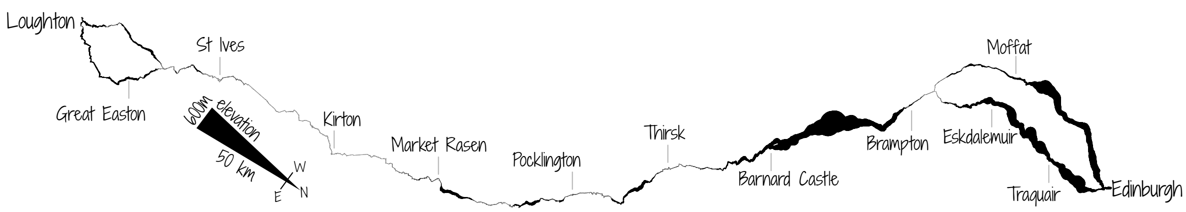

Figure 3. Profile map of the London-Edinburgh-London audax with control locations marked.

flatter terrain. This suggests some form of exponential function may be more appropriate:

$$w = w_{min} + (w_{max} - w_{min})z^a$$

where w_{min} is the minimum desired line width in pixel units (representing the minimum elevation), typically in the range $[0.1, 0.5]$, w_{max} is the maximum desired line width (representing the highest elevation), typically in the range $[5, 30]$ and the exponent a typically in the range [1.2,1.8]. Outside of this range, line width is either undiscriminating ($a < 1$) or it overemphasizes the difference between high and low elevation at the cost of local terrain variation ($a > 2$). Figure 3 shows an automatically generated profile map of the London-Edinburgh-London 1400km audax with control stops marked. This minimalist design allows spatially embedded textual narratives to be added with relative ease while emphasising the role of elevation and direction in the narrative (see, for example, Figure 4).

As a participant in this event, the minimalist design reflects its essence – a struggle between me as rider (reflected in the textual narrative) and the geography of the terrain (reflected in the profile map). It represents a recurring theme in successful sporting personal visualization, that of the design drawing out those aspects of the experience that have greatest emotional resonance.

VISUALISING RELATIVE POSITION

The profile map provides an opportunity to integrate personal experience with a depiction of terrain, but says little about the other riders in an event. While not a race, it is often of interest to riders to know how they are performing relative to others in the same event. As riders may be separated by many hours, even days on longer events, this is often not possible during the ride itself. Visualizing relative position can provide the rider with the opportunity to relate their personal experience of a ride with those of others.

Relative position in timed sporting events is most commonly represented as a ranked table of completion times with occasional ‘split’ times at intermediate checkpoints used as supplementary information. A long (1000km or more) audax event might typically have 10-20 of these intermediate timings and so presents an opportunity to show how ranked position changes over the course of an event. Visualizing change in rank over time was proposed using *Rank Clocks* by Batty in 2006[4] where a relative position in an ordered list was projected onto a polar coordinate system to produce spiral-like features where radial angle represents time and distance from centre represents rank. While compact, and capable of showing several hundred items simultaneously, the radial projection can be difficult to interpret and gives undue salience to lower ranked items that appear larger away from the centre of the projection. Instead, I propose here a

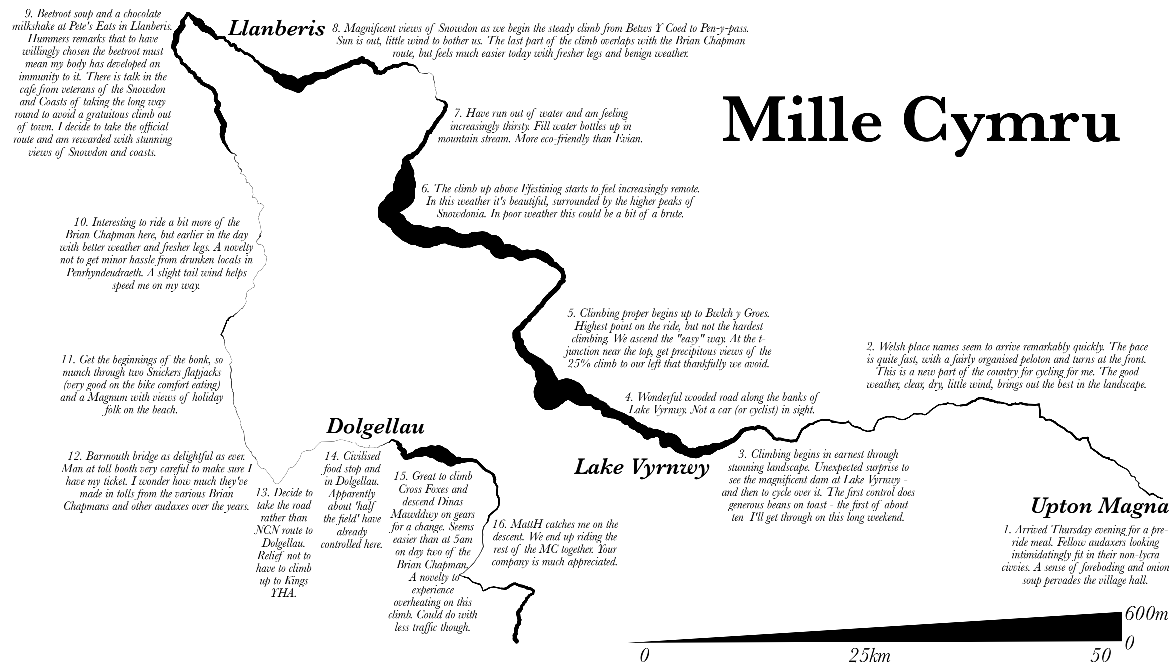

Figure 4. Excerpt from the northern portion of the Mille Cymru 1000km audax profile map with personal spatio-temporal narrative ordered anticlockwise from the east. The elevation profile is the same as that shown in Figure 1

ranked position chart using a conventional Cartesian projection.

Figure 5 depicts a simple position chart showing my own relative placing during in the 2011 Paris-Brest-Paris ride.Vertical changes in the position line indicate movement up or down the ranked order of riders at any given point. Because the horizontal axis represents distance along the route rather than time, changes in the difficulty of the terrain are accounted for in the ranked order. The steepest segments of the line therefore tend to represent atypical rest or sleep patterns such as riding though the night (e.g. from Loudeac to Carhaix), or extra sleep stops (e.g. from Dreux to St Quentin). As a piece of personal visualization the design allows annotation to provide a brief textual narrative, but importantly allows the individual to make some comparison with the group as a whole.

Figure 5 was originally constructed manually in 2011 using Microsoft Excel, but given a table of split times for a set of riders it is possible generate such charts automatically and to make a stronger connection between individual and group progress. Rather than show only a single rider's progress, all riders can be visualized together – effectively a form of parallel coordinates plot. Figure 6 shows the relative positions of 1000 riders over 21 checkpoints in the 2013 London-Edinburgh-London audax with a single (interactively selected) rider's progress highlighted. This was built using *JavaScript* and *Processing* to enable web-based interaction. Lines are constructed as Catmull-Rom splines to produce curved lines that honour all data points. They have the property of creating smoothly changing curves but at the cost of possible 'overshoot' at sharp changes in direction. While overshooting is undesirable, the spline form has the advantage of giving a more individual signature to each rider's unique profile making it easier to spot trends and structure in the complete dataset. By rounding the curve at stopping points where commonly there is a change in line direction, the uncertainty in timing where arrival at each control is recorded, but not exit time, is given visual expression.

The thinning of the chart towards the right gives an indication of how many riders have dropped out of the event and at what point. The darker vertical patches created by many crossing lines (e.g. from Pocklington to Thirsk and from Market Rasen to Kirton) indicate periods when many riders changed their relative position, usually due to some choosing to sleep while others continue. There is also vertical differentiation in the amount of line crossing. Those with the fastest times at the beginning of the event tend to retain their relative position throughout (less crossing towards the top of the chart). Likewise, those at the back of the field tend to remain so for the majority of the event. Most of the changes in rank tend to happen in the mid-

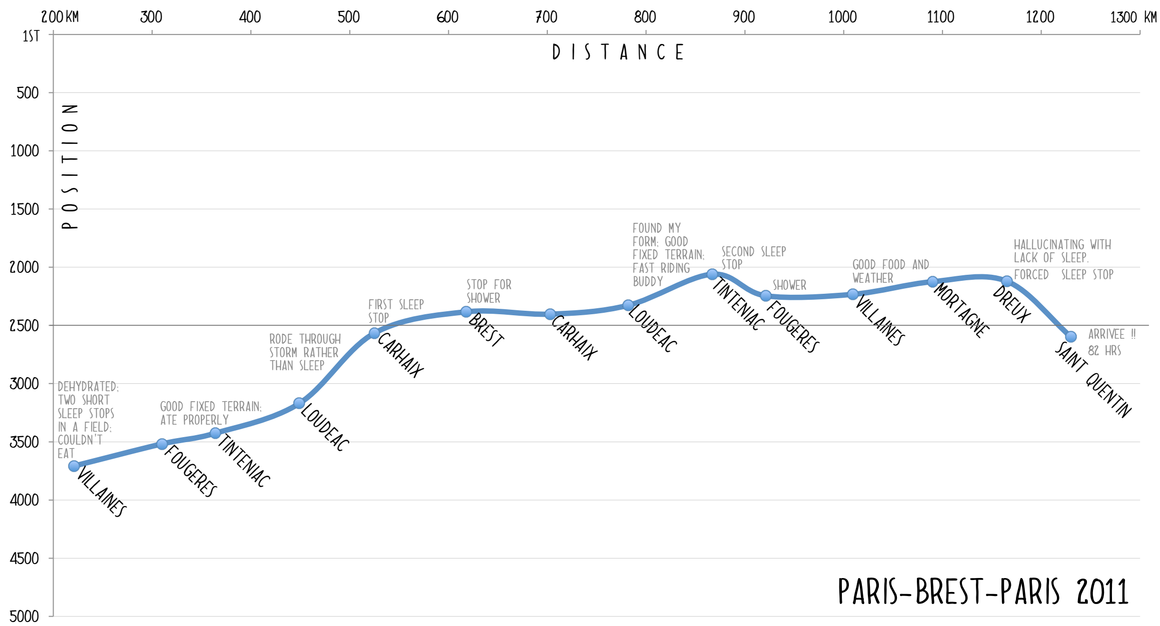

Figure 5. Original visualization of the author's relative position over the course of the four-day Paris-Brest-Paris event.

dle of the field. This distinction is most pronounced towards the end of the event, such as between Market Rasen and Kirton.

Change in position is important to many riders as these are the points when there is opportunity for social interaction at controls, or because they are due to periods of relatively strong or slow progress. They are often the periods that dominate the experience of the rider. By making them salient in the visualisation design, the personal visualization offers opportunity to engage the reader.

Event Elimination

For many riders, one of the most significant factors that shapes the event experience is the possibility of being eliminated by failing to reach a control within the prescribed maximum time limit. Typically on a long event, between 20-40% of participants may be eliminated in this way. The reduction in the size of the field due to elimination, mechanical, health or other issues is evident from the thinning of the position chart in Figure 6, but this says little about which riders did not finish (known as 'DNF') or where they stopped riding. Figure 7 highlights in red, the 22% of riders in the 2013 London-Edinburgh-London who did not complete the event. It reveals the extent to which time elimination was responsible for overall DNF figures as the majority who DNF were towards the back of the field for most of their ride. In contrast it also shows a group of riders near the head of the field who remain in front until Edinburgh (the half-way point) and then elect to retire for reasons other than being out of time.

Time in hand

The overview of DNF patterns offered by the position chart describes something of the experience of the shifting positions and the ever-present threat of DNF via time-elimination, but it does not really emphasise the personal experience of the rider. For the majority of participants on a long event like this, there is a real fear of being out of time where fatigue, weather conditions, terrain and 'mechanicals' add to the unpredictability of the challenge. The strategy of many is to 'bank' time by riding above the minimum speed limit to provide a buffer against unpredictable delays later in the ride. This may be visualized as a 'time-in-hand' chart where the horizotnal axis represents distance and the vertical axis the difference between the rider's control arrival time and that calculated assuming the minimum permitted speed. Figure 8 shows this for all riders with a single interactively selected rider's time-in-hand highlighted.

The characteristic wave pattern shows the common strategy of banking time by riding faster on the road and then stopping for longer rests, including feeding and sleeping at controls. The steepness in downward parts of the curve shows how much time was spent at the preceding control. It is apparent that those at the front of the field who gain most time-in-hand (at the top of the chart) spend very little time stopped at controls. Those with least time in hand (towards the bottom of the chart) show shallower drops at controls

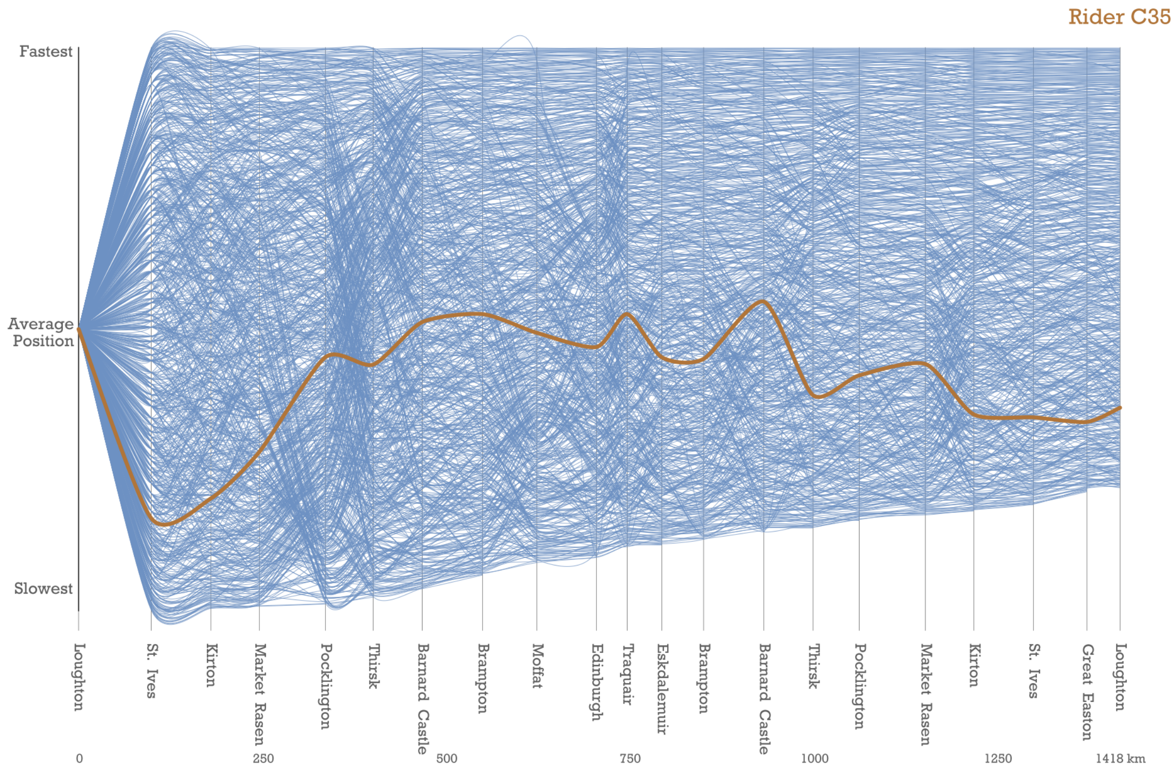

Figure 6. Relative position of 1000 riders in the 2013 London-Edinburgh-London audax. The relative ranking of rider C35 is highlighted.

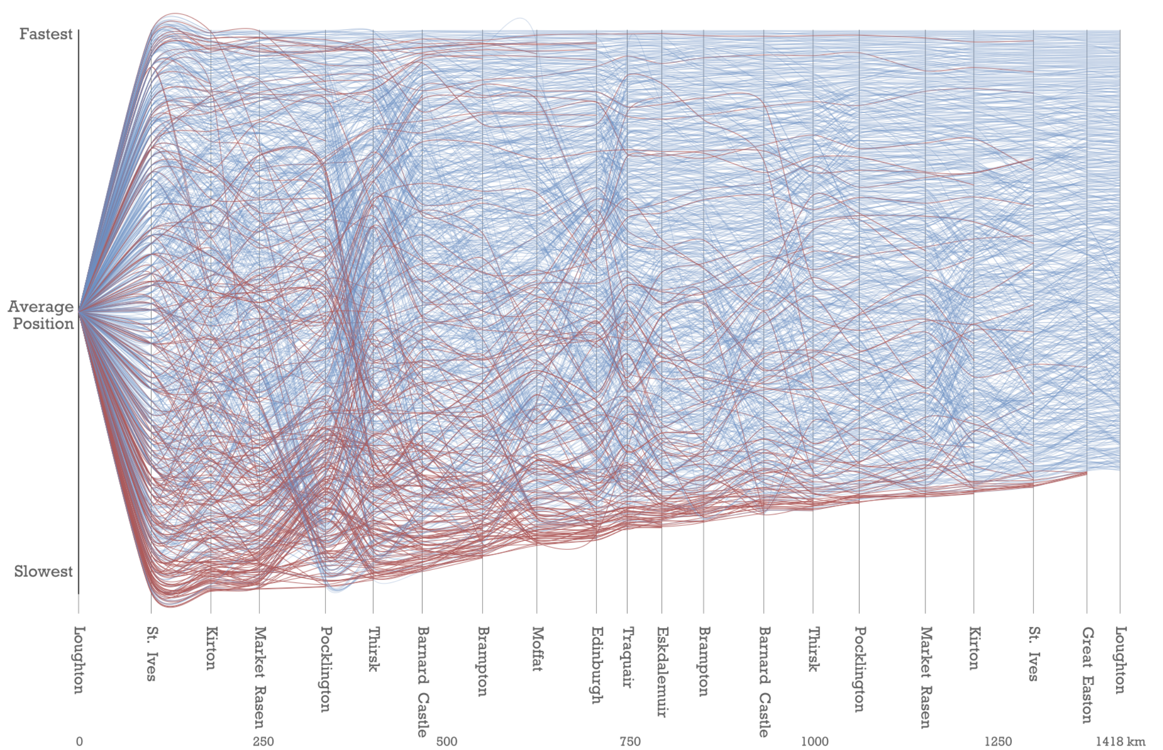

Figure 7. Relative position of 1000 riders in the 2013 London-Edinburgh-London audax. Riders who DNF shown in red.

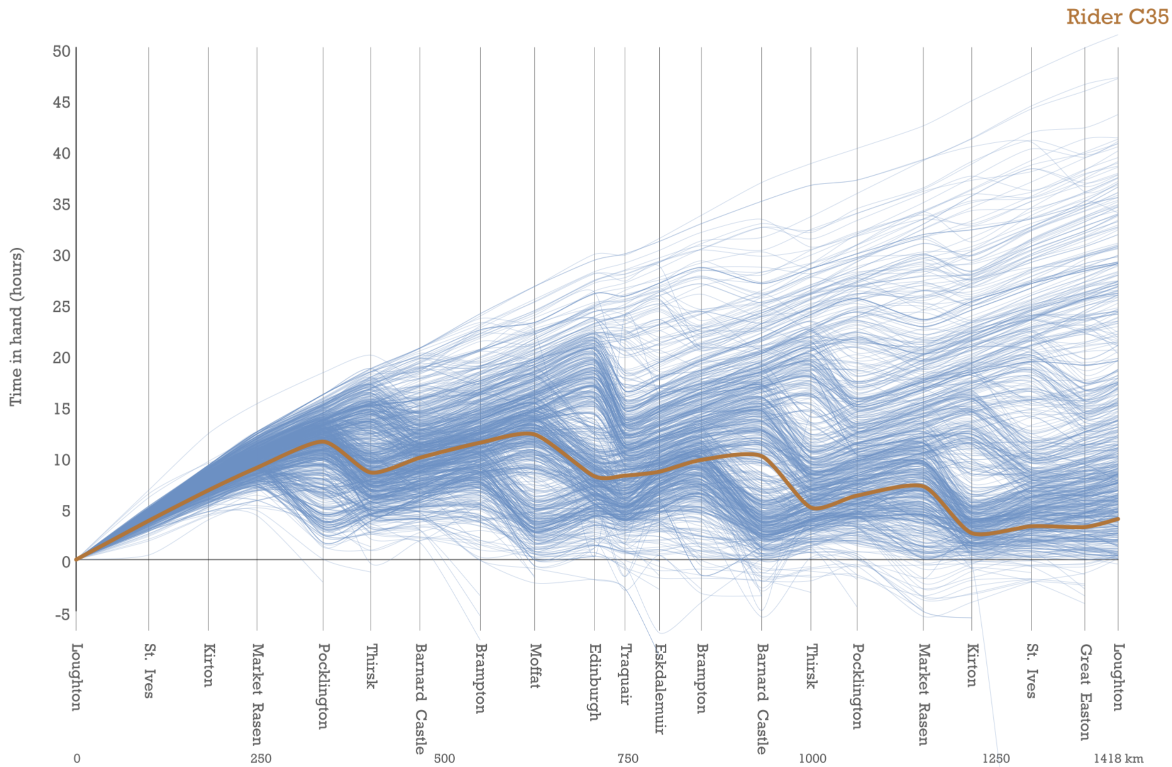

Figure 8. Time in hand for all riders in the London-Edinburgh-London audax. Rider C35 highlighted.

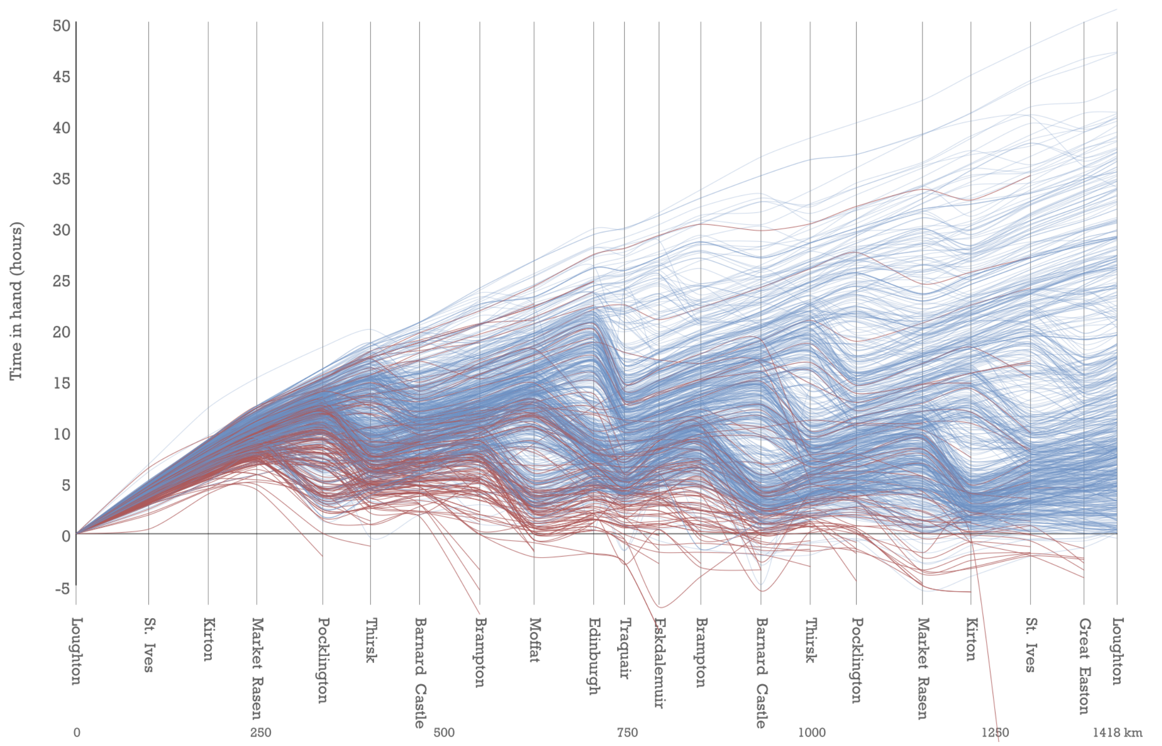

Figure 9. Time in hand for all riders in the London-Edinburgh-London audax. Riders who DNF shown in red.

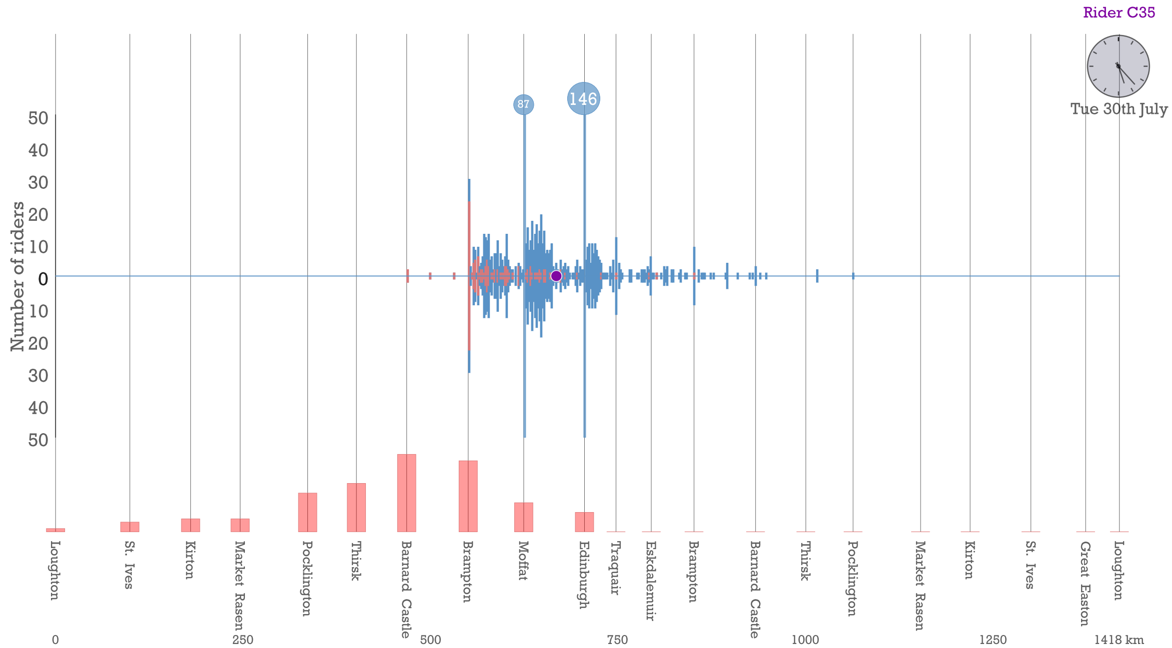

Figure 10. Snapshot from animation showing frequency of riders on the road and at controls (blue lines and circles). Densities above 50 riders per km are shown as numbered circles. Thin red bars show the frequency of riders remaining who will DNF. Lower red bars show number of riders who have DNFed at each control by this point in time (5:22am). Rider C35 is highlighted as a purple circle, who at this time is riding between Moffat and Edinburgh.

as their slower riding speed means they have less time banked in order to rest. The highlighted rider shows a pattern typical of many who alternate the ride-sleep-ride pattern (4 sleep or extended rest stops evident from the curve) against a steadily declining moving average speed. As the rider moves towards the end of the event, they are able to ride increasingly close to the elimination time as the scope for unpredictable delays diminishes.

Figure 9 shows the same time-in-hand chart but here highlighting those riders who did not complete the whole event. As a depiction of the personal experience of riding it shows even more strongly how being ‘chased by the clock’ carries a very real risk of being eliminated from the event.

PERSONAL AND SYNOPTIC VISUALIZATION DESIGN

While the design of the visualizations here has been to support the individual in understanding their own progress, there is also benefit in using the same visualization to support the organisers of such participatory events. Knowing, for example, where and when the peak flow of riders will be so as to provide adequate food, bed space and efficient processing of riders is helpful to both rider and organiser. Riders may wish to avoid long stops at busy controls; organisers can deploy resources more effectively to meet anticipated demand. It is also true that for many participatory sporting events such as these, organisers are volunteers who themselves are participants in other events. As such, designs oriented around supporting the ‘personal’ may not be significantly different to those with a more synoptic analytical perspective. Connecting the ‘personal’ with the ‘group’ as many of these visualizations illustrate is also part of the process of participant volunteer-orientated organisations providing appropriate support to others within the organisation.

One example of connecting the individual participant’s personal visualization with the synoptic organisers’ perspective is to superimpose a rider’s own progress through the event over the density of all riders along the route and animate change over time. Animation was used as it allowed both distance (horizontal axis) and time (animation time) to be visualized concurrently. This was important because it is the intersection of many riders in the same place that can place particular demands on participation and event management. The supplementary video[1] shows one such animation with a snapshot depicted in Figure 10. In order to assist with managing the arrival and care of

[1] Animation available at vimeo.com/111463034

riders at each control, participants of larger events are typically started in waves spread over several hours. But the advantages afforded by group riding can mean that riders will actively seek to cluster during an event. The frequency animation shows how this complex dynamic affects demand for resources at each control and how that changes over the length of the event. These patterns were not visible in the relative position and time-in-hand charts which were both standardised with respect to the rider's individual start time. Organisers at controls who provide food and rest facilities often describe a 'bulge' of riders arriving when their support activity is most frantic. I wished to reflect this in animation design by using the metaphor of an oscilloscope representation sound wave 'pulses'. By additionally showing those riders who DNF, often staying for extended periods at the control at which they retire, a picture of the demand on control facilities can be created. This can be used as part of the planning process both during the event itself and to anticipate the pattern of demand in future events. Yet it also has the characteristic of a piece of personal visualization. As a rider, the idea of clusters of other riders strung out ahead and behind on the road is a common mental image, especially when riding alone. Being able to locate one's own progress in relation to these clusters reinforces the connection between the individual and the group.

CONCLUSIONS

The visualizations shown here were presented as an interactive web application (gicentre.org/lel2013) shortly after the 2013 London-Edinburgh London event and made available to riders. There they could enter their own rider ID to view their personal progress in relation to others. Static views of the visualizations along with selected statistics from the event were published in the November 2013 edition of the Audax UK magazine *Arrivée*[5]. Feedback from participants and organisers who used the visualization suggests that some at least used it to plan strategies for future events. In that sense they fulfil the traditional role of visualization and visual analytic systems. Yet the context of personal engagement with data through visualization offers potential for a more affecting experience.

Does personal visualization in a non-professional context require designs that are distinct from more traditional, often scientific, information visualization and visual analytics? While there are some obvious design requirements that relate to professional vs non-professional audiences, a more interesting question arises around how to reflect the individual's experience in the design of the visualization. Is simply depicting data about an individual sufficient to do this? I would argue that for personal visualization to resonate it needs to do more.

In the designs presented here, I have tried to reflect my experience as a participant in cycling events in the visualization design process. This does not mean using bicycle-related visual metaphors, as might be the case in an infographic design, but instead, to make salient something of the emotional responses that arise from the experience. The tradition of participants in ultra-endurance events reporting their experiences as stories was reflected in the support of a spatial narrative in the profile map. The idea that in a mass participation event that can be a somewhat solitary experience, the design of the position chart addresses a desire to be able to compare one's own situation with others. In participating in an event where a major part of the challenge is to complete it within limited time, designs were chosen that emphasise time-in-hand and the fear of 'DNF'. By tapping into those themes that have emotional resonance as a participant, good personal visualisation design can engage the consumer of the visualization in ways that might be more challenging in a more traditional detached scientific context.

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