and input into the design of new features based on what is now available are invited.

References

South Land to New Holland: Dutch Charting of Australia 1606–1756, National and State Libraries Australasia (NSLA), formerly the Council of Australian State Libraries (CASL), *2006.*

Australia in maps: great maps in Australia's history from the National Library's collection. 2008. Canberra : National Library of Australia>

"Maps of Australia" prototype: http://mapsearch.nla.gov.au/

National Library of Australia Catalogue: www.nla.gov.au/catalogue/

Mapping: Methods & Tips

A Technique for Encoding Elevation Changes Along a Route

Daniel Huffman
University of Wisconsin at Madison

For many bicyclists and runners out in rugged areas, knowing the character of the route's terrain is critical: where the steep climbs, the downward slopes, and the flat stretches lie. Many bike maps, however, do not encode this information–they focus instead on showing the road network and which routes are safest for bicyclists. These are certainly important, but they do not help readers determine if they should press on to the next hill or stop and rest.

Proposed Symbology

The solution I propose is relatively simple: encode the elevation along the route using line width as shown by Figure 1.

Though simple, the symbology here is quite efficient. By varying the width of the line with elevation, this map allows the reader to access three data sets: the elevation of the path, the slope, and the aspect. When viewing the first variable, the reader's brain can derive the other two, by examining the spatial pattern of how elevation changes. The elevation itself is not particularly useful, but slope and aspect are critical pieces of information for the bicyclist or runner. Both need to be on the map together–knowing the slope of a hill is important, but users also have to know whether, as they head along the road, they'll be climbing up a particular steep slope or coasting down it.

So, the usefulness of the map relies on the reader's being able to determine how elevation is changing from one point on the route to another, in order for them to derive the slope and aspect. The symbology, then, needs to make this pattern of change as easy to understand as possible. Consider two different techniques for encoding elevation as shown in Figure 2.

The first encodes elevation along the path using color value and the other by varying line width, as I advocate. The slope of the route is much easier to figure out when line width changes than when the color value does. That the color at the left end of the line is lighter than the color at the right is relatively easy to determine. However, quantifying *how much* darker will be a challenge for the reader, when compared to the simpler task of quantifying how much wider the line is at one end than the other. Easy comparison of points is essential for understanding the change in elevation, and therefore the slope and aspect. Speed and simplicity of use is also important on account of the conditions under which such maps will be used. Some bicyclists do not even stop their bikes when reading maps, and so the map must work when they're not looking closely or long at it. Encoding elevation by line width has an additional advantage over any sort of color scheme: line widths are more robust–they won't vary according to lighting conditions as the readers travel in and out of shade of trees and in varying levels of cloud cover.

However, using color value does have two advantages of its own. The first is that by not changing line width, lines don't become too wide (causing crowding) or too narrow (and thus being hard to see). The second advantage is really more of a lack of a disadvantage–the highest elevations are not dominant. In Figure 1 the bottom half of the route stands out the most. Being at the highest elevation, it has the widest lines. But the route here also consists of largely flat stretches, which means that it's not a concern to bicyclists or runners–they want to know about the hills, about how the elevation changes. Encoding elevation

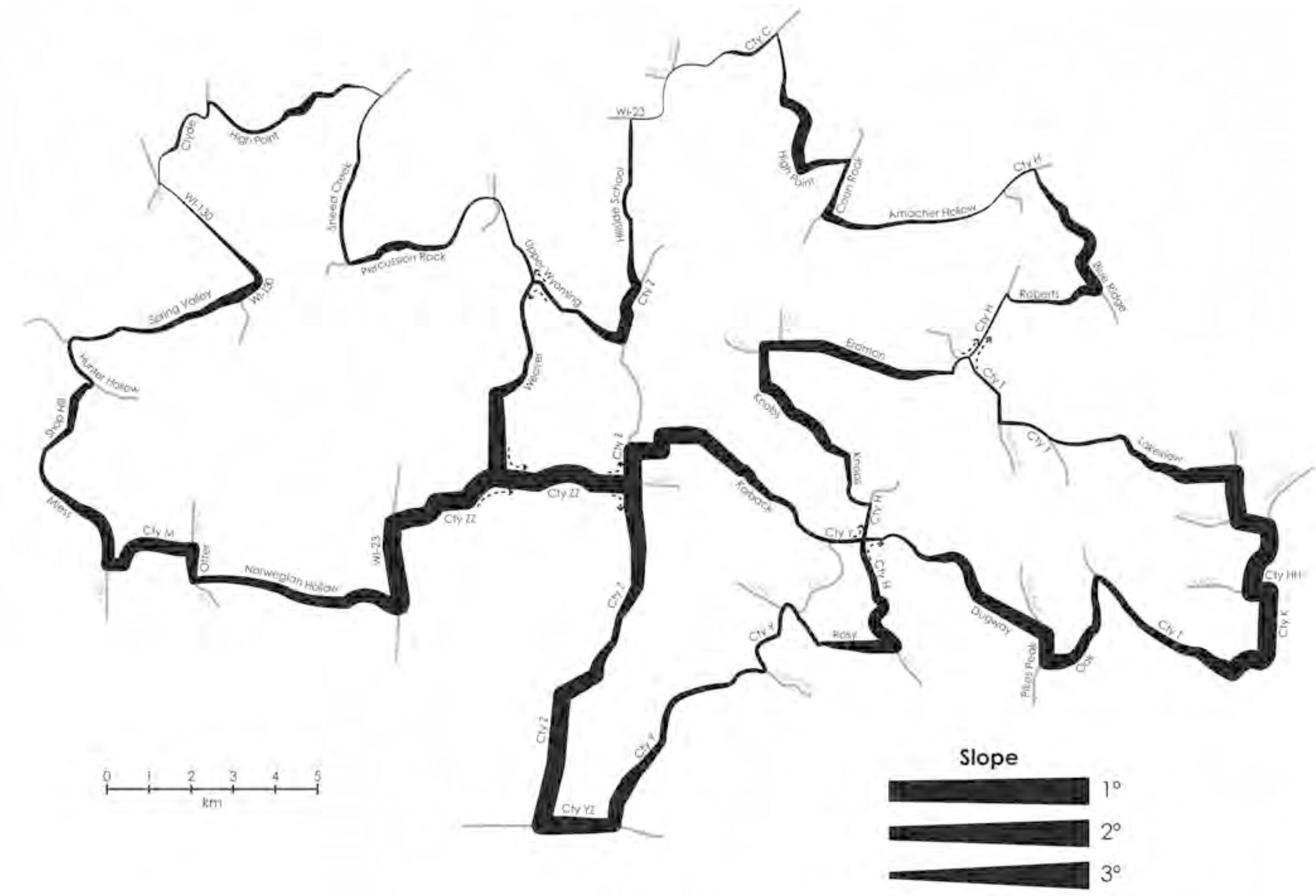

Figure 1. A sample map showing the proposed symbology.

by colors keeps the reader from being distracted as much by the high elevations, which will not stand out quite so much.

There is one further potential disadvantage to the proposed technique. Two equal slopes can look unequal, if they are at different elevations. Figure 3 shows two road stretches, each the same length, and each having the same change in elevation. One takes place at a lower elevation, however, and appears as though it is a steeper slope, when in fact the two are even, and are in fact drawn with the exact same line angles on the page.

Figure 2. Using a change in color value (top figure) and line thickness (lower figure). (see page 91 for color version)

Figure 3. Possible confusion over identifying changes in elevation.

Instead of encoding something the bicyclist is not interested in (elevation) and leaving it to their mind to derive the things they do want to know (slope and aspect), the latter could be encoded directly. Showing the slope is relatively simple, as it is a number. A color ramp or changing line width or other non-categorical symbolization will work for this. Aspect, however, poses a challenge, since it depends on which way the bicyclist is traveling down the road. It's uphill one way and downhill the other. A few possible solutions come to mind. Arrows could be drawn next to the route to indicate which way is uphill (or downhill). Color hue could be used for the route to show the aspect (red for north, blue for east, etc.), paired with changing value, saturation, or width for slope. A more interesting alternative is seen in Figure 4: using a pattern of chevrons or arrows to draw the route, each of which points downhill, and varying the size of those arrows or their lightness to show the degree of the slope.

There are more possibilities, obviously.

Figure 4. A possible symbolization method for showing aspect.

But these solutions have one significant weakness when compared to showing elevation directly–the reader has to process two different symbols (or two properties of the same symbol) and extract two pieces of information, rather than one. Most bicyclist and runner map readers intend to use the map to figure out the lay of the land,; they expecting to see something resembling terrain–hills, valleys, etc. Figure 4 above is too abstract-- it no longer feels like land, and so is harder to interpret. This is one reason why people like hill shading–mountains look like mountains, and that's something they can understand without a lot of mental processing. Experimental testing may show that it is possible that readers could eventually train themselves to interpret something like Figure 4 faster and easier than Figure 1, since it does show what they want to know and with the least amount of ink possible and without showing anything extraneous. But that will take effort and learning.

Production Technique

The linear symbols are built by determining the elevation of the route at several points and then connecting those points with line segments that increase or decrease in width according to the elevation at each endpoint, as in Figure 5.

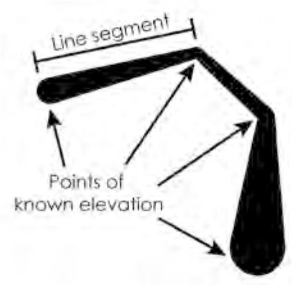

Figure 5. Showing the location of points of known elevation and line width changes in between.

The first step, then, is to create a set of points of known elevation. These points must be sufficient to roughly define the shape of the route and must adequately convey all major elevation changes. A good starting point for the latter is to use a GIS package to calculate the intersections between elevation contours and the users' chosen route. More points may need to be manually added to make sure the shape of the route is adequately conveyed as well, such as at road junctions and curved segments. Once the points are chosen, a circle is placed at each and scaled proportionally to the elevation. Figure 6 shows a field of points sufficient to create linear elevation symbols for the roads in an example area, each appropriately sized.

In order to create line segments that gradually and evenly change width, the project is next taken into Adobe Illustrator, where the Blend tool is used. This tool fills in the space between two objects with intermediate steps, to create a smooth transition, as in Figure 7. In this case, the intermediate circles are changing size to blend from one point of known elevation to another. Hundreds of steps in the transition may be needed in order to give the appearance of a solid line, as seen on the right-hand side of the figure. Blends can also be done along a curved path to help better represent the shape of the underlying road. Once the blend has been performed, the circles can be merged together into one simple, rounded line segment. The segments can them be joined into a complete route. The joints will be smooth and rounded, because the segments are based on circles.

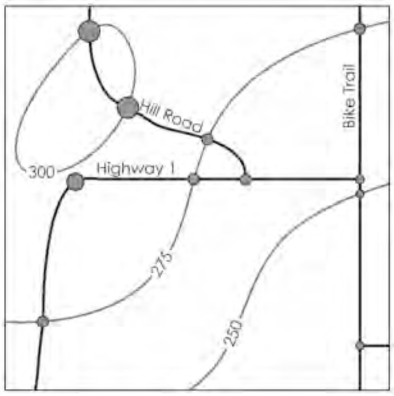

Figure 6. An example of a road network. (see page 91 for color version)

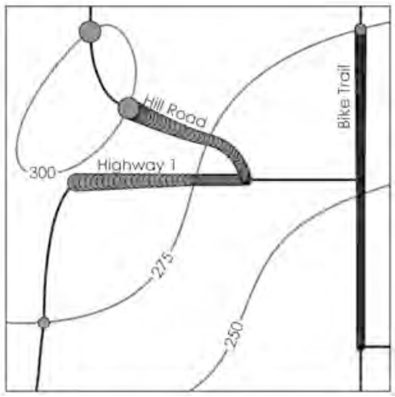

Figure 7. A sample of using the Blend tool in Adoble Illustrator. (see page 91 for color version)

The end result is a map in the style of Figure 1, in which the line width of routes varies according to elevation, offering map readers a simple way of understanding the terrain they will be facing on their journey.

An Alternate Production Technique

Worth noting is an alternate production technique developed by Jo Wood of City University London, who saw an earlier draft of this article published in an online blog. Mr. Wood begins with GPS tracks, recorded from previous rides along a route, as his starting data. He then runs them through a program written in Processing[1] to quickly generate a map based on this large set of input points. His technique has a couple of important advantages: it is much more automated than the one proposed above, and it generates a more complete terrain profile, being based on a larger set of elevation points than a manual selection technique. It does, however, require a prior trip along the route with a GPS unit.

Summary

Regardless of the technique used, the proposed symbology offers a simple and effective way to show map readers the character of the terrain they will be facing on a route by encoding elevation with line width. Readers can quickly understand changes in elevation and derive the slope and aspect information necessary to help them make decisions along the route. It is visually simpler than encoding slope and aspect directly and is not so abstract that it cannot be easily understood as representing a landscape. It is also compatible with current cycling maps–it still allows the depiction of road networks, which can be color-coded based on such things as traffic conditions or shoulder width. The technique simply uses up a portion of the "visual variable space" that is currently not being employed on most road maps. It offers a way for more–and highly useful – information to be added to route maps where terrain is important, to the benefit of bicyclists and runners.

---

[1]Processing is an open source programming language and environment for people who want to program images, animation, and interactions.

Visual Fields

Mollymaps started in my journal pages while studying abroad in central Asia. They were a way to recount a day's wanderings on foot. When I successfully got out of helping to write a group research project in exchange for drawing all the maps, I learned maps could be used as barter. I spent the entire year after college traveling around the world and, oddly enough, trading maps for room and board. Mollymaps has since developed into a small freelance business, celebrating the places that matter to people.

I still get nervous showing final products to clients—maybe because I am truly aiming to make the map that is in their heads, from their experience. And that's impossible, but I have to try anyway. When they look at the map, I want them to see their experiences. I want the map to be a place where a few shared memories can live. I don't always reach these goals but that is my aim.

I'll probably always make maps for whomever asks. But I'm a little tired of my 'happy pastures' maps—those that make landscapes look perfect, quaint and static. The hand-drawn message can do much more than appease our need for idyllic landscapes. Maps can draw attention to the tragedies and unsettling changes in our landscapes through the tragic beauty of irony, and the sobriety and sway of pen-to-paper expression. My project now is to take my skill set and apply it to environmental risks and injustices such as mountaintop removal, climate change vulnerabilities, point source pollution, irresponsible development; the list is rich with stories of real places and communities. Maps can draw us together to embrace or to revolt. All too quickly we are accepting the creation and use of slick, repeatable maps ("starbucks maps" as John Fels called them) and while they may be participatory, ubiquitous and novel, are they compelling? There will always be a need for the storyteller, reminding us again and again of the exacting beauties and tragedies of individual human experience.

Molly Holmberg

For more information about Molly Holmgren's work, see www.mollymaps.com