Mutlivariate Labeled Cartograms

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Abstract: We combine the approaches of typographic variation in labels with cartograms to create multivariate labelled cartograms. These multivariate labelled cartograms can scale to a large number of entities and a large number of data attributes. We also introduce techniques of positional and proportional encoding which apply attributes to only portions of labels thereby aiding the encoding of many data attributes or quantitative data.

Keywords: Typography, cartogram, visualization, font attributes

1. Introduction

Typography has been used in maps for hundreds of years to encode data into typographic elements such as size, oblique, case, underline, spacing and font-family, for example, the *Atlas of Modern Geography* (Stieler, 1925) in figure 1.

Fig. 1. Portion of map from *Stieler's Atlas of Modern Geography* (1925). Labels use variation in case, weight, underlines (dash, solid, double), obliques, spacing and font-family to encode data in labels. From David Rumsey map collection, http://www.davidrumsey.com/luna/servlet/s/5v96h4

However, thematic maps such as cartograms and choropleths represent data on maps typically with non-textual representations, such as changing the color or size

of geographic areas. Typography is typically minimal or secondary to the other elements of these thematic maps. Popular thematic types include choropleth maps and various types of cartograms such as contiguous shape preserving cartograms, Dorling cartograms and so on (figure 2).
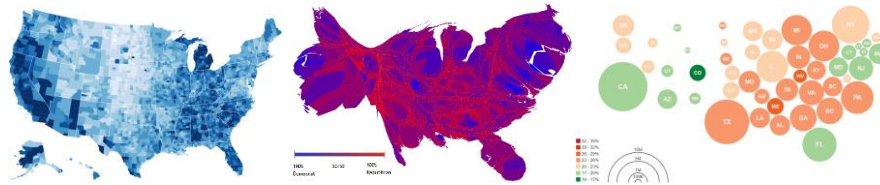

Fig. 2. Example choropleth map encoding data via color of each county (left); a contiguous cartogram representing data by adjusting the area of each county, plus a second data attribute by color (center); a Dorling cartogram representing states as circles, with size and color indicating data attributes (right). Left image d3.js (bl.ocks.org/mbostock/4060606), center Wikipedia (en.wikipedia.org/wiki/Cartogram), right University of Washington (homes.cs.washington.edu/~j-heer/files/zoo/ex/maps/cartogram.html).

Many of these thematic maps have various well-known problems:

- Some areas can be too small for the color to be discernable (e.g. Singapore).
- Large regions are more prominent than small regions, but some tasks require that regions are perceived equally, for example comparison of policies.
- The viewer may have low geographic literacy: A National Geographic Roper Survey (GfK, 2006) showed only 8.3 out of 17 major countries could be identified by 18-24 year old Americans (e.g. Iraq, North Korea, China, etc).

Instead, we focus on using labels enhanced with typographic attributes to make cartograms which encode many dimensions of data. Our unique contributions include:

- Cartograms where the label is the key element in cartogram.
- Many choropleth and cartograms indicate only one or two data variables, e.g. color (in a choropleth map), or size and color (in a cartogram). Typographic attributes can encode many more data variables into a single glyph.
- Encoding data along the length of a string to enable more levels or more data. (Positional and Proportional encoding).

2. Background

Given centuries of history of typography and cartography, plus more recent visualization research, there is a wealth of history to inform the use of typography in thematic maps.

2.1 Visual Attribute Research

Bertin's *Semiology of Graphics* (1983) presented a systematic organization of information graphics including visual attributes (i.e. retinal variables) such as size, hue and brightness, and their representations as points, lines or areas, from which a wide variety of charts, graphs and thematic maps could be constructed. Bertin did not explicitly identify text labels as a visual attribute. Use of labels and specific typographic attributes occur only tangentially, such as hand-annotated maps at the elemental level labelling proper nouns in all caps (page 308-309).

Table 1. Table of Visual Attributes

Table of Visual Attributes		Information Visualization Researchers									Vision Rsch	Cartography	
		Bertin 1967	Cleveland 1985	MacKinlay 1986	Wilkinson 1999	Ware 2000	Mazza 2009	Brath 2011	Ilinsky 2012	Chen, Floridi 2013	Preattentive Perception	MacEachren 1995	Tyner 2010
Trans-form	Position	X	X	X	X	X	X		X	X		X	X
	Length		X	X		X	X		X	X	X		
	Size (Area)	X	X	X	X	X	X		X	X	X	X	X
	Orientation	X		X	X	X	X		X	X	X	X	X
	Volume		X	X		X							X
Shape	Shape	X		X	X	X	X	X	X	X		X	X
	Angle		X	X					X		X		
	Curvature								X		X		
	Mark								X		X		
	Line Ending							X	X	X	3	X	
	Closure								X	X	X		
	Local Warp								X				
	Edge Type								X	1,2			
	Corner Type								X	3			
	Icon, glyph, etc									4			
Colour	Brightness	X		X	X	X	X		X	X	X	X	X
	Hue	X	X	X	X	X	X		X	X	X	X	X
	Saturation			X	X	X	X		X	X		X	X
Texture	Granularity	X		X	X	X	X		X	X		X	X
	Pattern				X	X	X		X				
	Orientation				X	X							
Relation	Connection			X				X	X	X			
	Containment			X				X	X				
Optics	Blur					X				X		X	X
	Transparency					X				X		X	X
	Stereo Depth										X		
	Concavity									X	X		
	Light Direction									X	X		
	Shadow									X			
	Partial occlusion									X			
Move-ment	Flicker					X				X	X		
	Speed					X				X	X		
	Direction									X	X		
Misc	Numerosity									X	X		
	Spatial Grouping									X	X		X
	Arrangement											X	X
	Resolution											X	X
	Artistic Effects										X		
	Text Labels				X		X		X	X			

Since then, other researchers have expanded on Bertin's visual attributes from various fields including visualization, cartography and perception; but researchers have generally ignored text or minimized text to a singular visual attribute, as shown in table 1. The cartography column *Tyner 2010* summarizes visual attributes from sources including Kraak & Ormeling, Krygier & Wood, MacEachren (shown here as a separate column), Monmonier, Slocum and Tyner. The *Preattentive Perception* column summarizes psychology research, e.g. see Healely and Enns (2012).

Past researchers may have not focused on text and associated font attributes such as bold or italics on the assumption that these attributes are already captured by the other visual attributes such as intensity or angle. But this oversight leaves ambiguity and questions. For example, a label size can be adjusted by font size, font spacing, font width (e.g. narrow and wide variants of a font) or stretching and scaling a font. Or another example: intensity of type on a page can be adjusted with the font weight (e.g. light, book, bold, black) or the brightness of the font fill (e.g. light grey, dark grey, black). Which should be used? Can they be combined together?

2.2 Cartographic Typography

Typographic variation to indicate different data in maps has existed since early maps. For example, the medieval Gough map of Great Britain dating from around the 1360's indicates cities in black text, two key cities in gold, and counties in red text in boxes, figure 3.

Fig. 3. Portion of the *Gough map* with different types of place names in different colors. The Gough Map, author unknown, 1360, Shelfmark: MS. Gough Gen. Top. 16. Photo by Author. Bodleian Libraries, University of Oxford, http://digital.bodleian.ox.ac.uk/inquire/p/e4dc07a6-3ec8-414a-aa92-2e9815f93276. Used with permission under Creative Commons 3 license.

After the invention of the printing press in the mid-1400's, the use of colored text became less frequent. However, other typographic attributes such as italics or

case were used to indicate different types of data. The differentiation occurred whether hand-engraved text (such as Mercator's map of Palestine in 1537, e.g. see Osley 1969 for discussion) or movable type, as seen in fig. 4, a snippet of Munster's *Geographia Universalis* (1540).
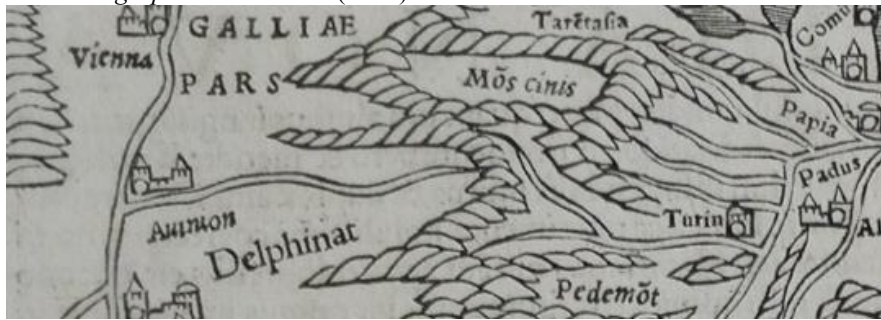

Fig. 4. Portion of map from Munster's *Geographia Universalis* with different types of place names in italics and capitalization. Sebastian Munster, "Italia XIIII> Nova Tabula" from *Geographia Universalis*, 1540. Map #83 from Isotype Collection, University of Reading Department of Typography, used with permission.

By the mid-1800's, typography evolved to include attributes such as different typefaces, weights, underlines and small-caps. Similarly, maps evolved to use these many typographic attributes simultaneously within a label to indicate many data attributes. Figure 5 left shows a portion of an Ordnance Survey map legend (from Hodson 1926) where city labels indicate 1) the literal name of the city with text, 2) administrative centers with italics, 3) population category with font size, 4) country via font type (serif for UK, slab-serif or serif variant for Scotland), and 5) whether it is a town (uppercase) or village (lowercase),

Similarly Stieler's atlas (1925) uses different typefaces, case, underlines and spacing (fig. 5 right). Interestingly, Stieler encodes quantitative data with a few ordered levels with typographic attributes, such as underlines ordered dot, dash, thin, thick, double thin, double thick; or populations indicated as a combination of case and italics ordered lowercase italic, lowercase roman, uppercase italic, uppercase roman.
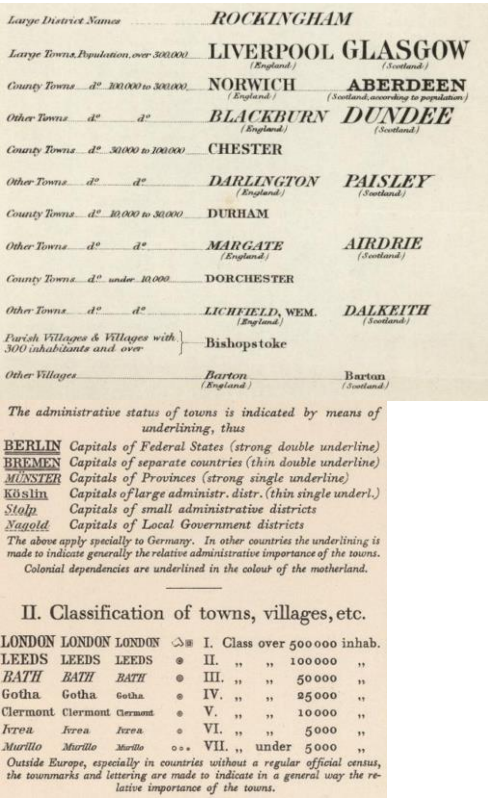
Fig. 5. Left: Portion of legend from *Ordance Survey* map where labels indicate 5 different data attributes using literal text, size, case, italics and typeface. Right: Portion of legend from Stielers' altas with ordered representations of administration centers and population categories using typographic attributes. Images © 2016 Cartography Associates (http://www.davidrumsey.com/luna/servlet/s/s15w94, http://www.davidrumsey.com/luna/servlet/s/791qv7).

Typographic conventions for categories in maps have been identified by various researchers. For example, Cuff and Mattson (1982) surveyed cartographic labelling conventions including uppercase, italics and serif/sans serif as shown in table 2.

Table 2. Table of Letter Convention of major map publishers (redrawn based on Hod89)

Publisher Feature		National Geographic		National Atlases		Atlases		
		Reference	Magazine	U.S.	Canada	CIA	Goode	Oxford World
Water	Salt	*CAPS*	*Mixed*	*CAPS*	*CAPS**	*Mixed*	*CAPS**	*CAPS**
	Fresh	*Mixed*	*Mixed*	*Mixed*	*Mixed*	*Mixed*	*Mixed*	*CAPS**
Land Features	Other	*CAPS**	*Mixed*	CAPS	-	CAPS	CAPS	CAPS
	Peak	*CAPS**	*Mixed*	Mixed	-	*Mixed*	*Mixed*	CAPS
	Range	*CAPS**	*Mixed*	CAPS*	-	CAPS	CAPS	CAPS*
Cultural	City	Mixed	Mixed	CAPS*	CAPS*	CAPS*	***	Mixed
	Park	*CAPS*	CAPS	*CAPS*	-	-	CAPS	*CAPS*
	Political	CAPS	CAPS	CAPS	CAPS	CAPS*	CAPS	CAPS
Thematic	Notes	*Mixed*	*Mixed*	Mixed	Mixed	*Mixed*	*Mixed*	*Mixed*
	Legend Item	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
	Legend Head	Mixed	Mixed	CAPS	CAPS	Mixed	Mixed	Mixed
	Title	CAPS	**	CAPS	CAPS	Mixed	CAPS	Mixed

Brewer's *Designing Better Maps* (2005) indicate use of typeface, italic/roman, hue, alignment for categoric data and size, weight, scaling (condensed/expanding), brightness, case and spacing for ordered data. Krygier (2005) indicates the use wieght, italic, size, hue, brightness, case, spacing and condensed/expanded. Krygier also recognizes but recommends against underlines. Mulenhaus (2014) discusses qualitative attributes including font family (recommending sans serifs), oblique and type arrangement; and quantitative attributes including case, value and weight.

Visual attributes and typography occur separately in most cartography texts (e.g. MacEachren, Tyner, Muelenhaus, Krygier), and generally typographic attributes are not considered elements for thematic maps, *even though* they share many similarities to visual attributes.

2.3 Typographic Attributes

Table 3 summarizes typographic attributes can be used to encode data into labels and their relationship to well understood preattentive visual attributes (e.g. see Wolfe & Horowitz 2004):

Table 3. Table of typographic attributes, relation to visual channels and types of encoding.

Group	Font Attribute	Position	Length/Size	Intensity	Orientation	Shape	Containment	Preattentive Potential†	Best for encoding: Q: quantitative, O: ordered, C: categoric, G: grouping/relationship, L: literal	Example
Glyphs	Alphanumeric Text Glyph					◆		D	**L, O**	ape bat cat dog 123 456
	Symbols					◆		D	**C**	! ? # @ #comment $var
Font Family Attributes	Font weight		•	◆				HP	**Q** (2-9 levels)	1.0 2.0 3.0 **5.0 8.0**
	Oblique / Italic				◆			HP	**C, Q** using slope angle	-2.0 -1.0 0.0 *1.0 2.0*
	Case inc small caps			•		◆		P	**C**, possible O (2-3 levels)	BIG Avg. Small tiny
	Typeface					◆		P	**C** (2-6 levels)	Swiss French German *Italian*
	Underline	◆	•					HP	**C, O, Q** (using length)	plain dash single double
	Condensed		◆	•				HP	**Q, O** (2-4 levels)	1200 **2000 3000**
Sequence	Squished		◆	•				HP	**Q**	thin plain wide fat
	Spacing		◆	•				HP	**Q, O**	tall grand venti
	Super/subscript	◆	•					HP	**C** (2 levels)	Normal High Low
	Delimiters						◆	D	**G**	(but) *and* <or>
Font Design	X-height		◆					HP	**O, Q** (few levels)	ick ick ick
	Contrast / Stress angle					◆		P	**O** (few levels)	LOW MED. HIGH
	Serif length / Bracket size		◆					HP	**O, Q** (too small to see?)	

◆ / • indicates primary / secondary visual channel for font attribute   † HP: Highly probable, P: probable, D: doubtful
Note: does not include traditional visualization attributes such as size, color, texture, outline, blur, shadow, etc., which are applicable to any marker including type.

- *Glyphs* are the characters which literally encode data. Alphanumeric glyphs are orderable, but symbols are not.
- *Font Family Attributes* are type features typically made available with a typeface family, such as **bold**, *italic*, typeface and condensed/expanded fonts.
  - *Font weight* can encode ordered data. Up to 9 weights are available in some fonts but fewer levels are perceivable at small sizes. Weight is suitable for sequential ordering.
  - *Oblique* can have both a reverse slope, non-slope and familiar forward slope, making it feasible to represent divergent ordering (e.g. positive and negative values).
  - *Case* can be used in Latin-based alphabets to create an ordering from lowercase, to SMALL CAPS, to UPPERCASE.
  - *Typeface* can be used for qualitative data (i.e. categories). While there are 100,000+ fonts, only a few broad types work at small sizes and are significantly different from each other to be noticeably different.
  - *Underline* are broadly available in most fonts, and, as shown in the atlas in figure 1, can be used to create an ordering.
- *Sequence*: indicates differences that occur only in the context of a sequence of glyphs, such as a superscript or s p a c i n g. Squishing text is not recommended by typographers but a few fonts are specifically designed for scaling, e.g. Neue Swift. Pairs of delimiters such as (), <>, ** are a potential means for differentiating some labels.
- *Font Design* indicates features typically modified by a font designer when creating a new font. While these may be feasible typographic attributes to encode information, in practice, they are not easily accessed from most applications. Parametric fonts do expose many low level features (e.g. proto-type.io)

The *Visual Channel* columns indicate the relation between the typographic attribute and well researched visual channels. For example, font weight at a macro-level can be understood to alter the *intensity* of characters while at a micro-level it can be understood as varying the *size* (i.e. width) of letter strokes.

Some visual channels have stronger cues for guiding attention and can visually pop-out. This is summarized in the column *Preattentive Potential.* For example, both intensity and size are considered preattentive, so font weight, which uses both, is considered highly probably in this table.

These preattentive capabilities imply that typographic attributes can be utilized similar to other visual attributes – that is – to create thematic maps. Plus, by using type, a literal encoding can also be represented.

3. Equal-area Cartograms with Multivariate Labels

As listed in the introduction, choropleth and cartograms have problems. Instead of encoding the geographic entity's identification with shape, a label can be used instead. The label can literally encode the entity and use visual attributes to pop-out encoded data using traditional visual attributes and/or typographic attributes. Figure 6 shows two simple equal-area cartograms of U.S. States as squares (left) and rectangles (right). In both examples, data is indicated by the fill color.
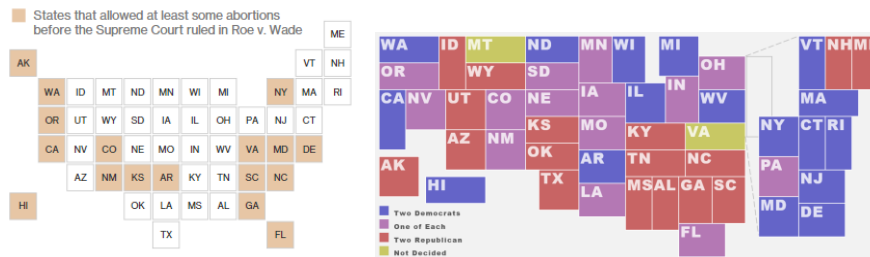

Fig. 6. Equal-area cartograms. Left: squares indicate states and hue indicates abortion rights. Right: rectangles indicate states and hue indicates senate composition. Left image from Bloomberg.com June 26, 2015. Right image by author.

3.1 Multivariate Labels

Once a labeled equal-area cartogram has been created, the labels can be used as the basis to encode data, using a wide variety of visual attributes including font-specific attributes. Figure 7 uses font weight to encode 2010 GDP per capita, font spacing indicates GDP growth, font oblique angle to encode inflation (reverse slope for deflation, e.g. Ireland), and color encodes region. This representation can be used to answer simple questions of a single variable, e.g. Are their countries

with high growth rates (A: Yes, widely spaced China, Korea, Seychelles). Complex questions across multiple variables can be answered too, e.g. Are there countries with high GDP, high growth and low inflation (A. Heavyweight, widely spaced, non-italic, e.g. Macao, Sweden); or, Are there countries with low GDP, high growth rates and low inflation (A. Lightweight, widely spaced, non-italic, e.g. Kenya, Timor-Leste).
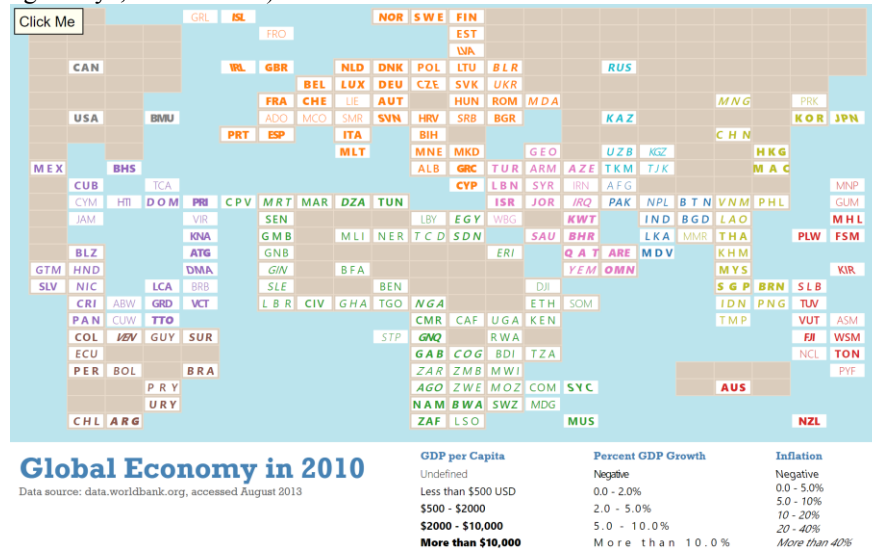

Fig. 7. A Mutlivariate Label Cartogram indicating data via color, font weight, spacing and oblique slope angle. Image created by authors.

3.2 Scalability to Thousands of Labels

The approach can scale to different layout algorithms and higher data densities. Figure 8 shows 2269 UK Postcode districts plotted directly by latitude and longitude on the right; with a cartogram of the same data on the right. In the left view, most labels are occluded and the plot only illustrates the post code densities. In the right view, each label is clearly distinguished and readable on a modern monitor (e.g. 1920x1080). Visible patterns can be identified. For example, color indicates the occupation with the highest difference vs. national average. Green for agriculture in the west, blue for finance around east London, amber for mining in the north-east, etc.
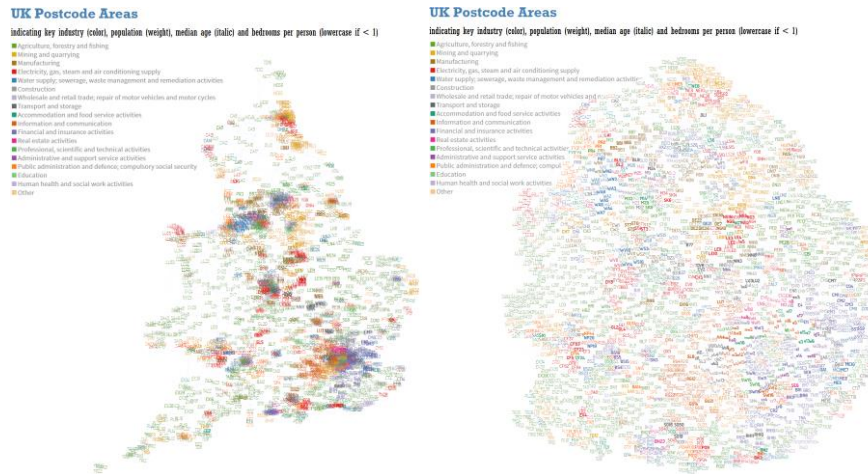
Fig. 8. Left. 2269 UK postcode districts, located geographically, showing data by font weight, oblique angle, case and color. Right: Cartogram of the same data.

Figure 9 shows a closeup. Letters indicate postal code districts, e.g. Mxx for different districts within Manchester. Weight indicates population within a district. Oblique angle indicates median age: reverse slope indicates a younger age, forward slope indicates older age. Case indicates number of bedrooms per person: uppercase if more than one bedroom, lowercase if less than one. In figure 9 patterns in oblique angle indicate regional variation in age, e.g. most of the postcodes near the top left (LLxx indicating districts near Llandudno) slope right (indicating older median age) while districts within Manchester (Mxx) tend to slope left (indicating younger median ages).
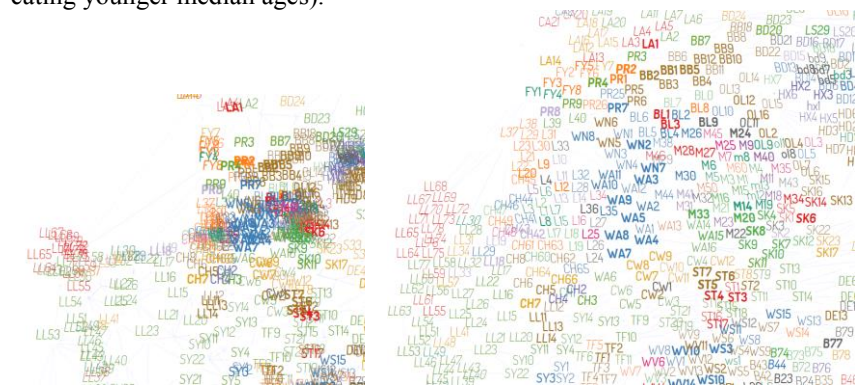

Fig. 9. Closeup of Northern Wales, Liverpool and Manchester.

3.3 Long Labels

In both preceding examples, short mnemonic codes were used for labels. In some applications only long labels of varying length are available. This create two problems: 1) it is difficult to fit long labels into circles or squares; and, 2) long labels have greater visual area than items with short labels, thereby making the entity with the long label more salient over the entity with the short label (e.g. the label *San Francisco* is more prominent than *Rome*). Solutions could include:

- *Forced Contraction:* Limit strings to an arbitrary number of characters followed by an ellipsis to indicate missing characters (e.g. San Fran…).
- *Popular Contraction*: Some place names have well known contractions, e.g. NYC for New York City.
- *Use areas with long aspect ratios*: The areas used in the equal area cartogram can be long and narrow to better fit long labels.
- *Labels exceed areas*: While it is ideal to fit the label to the area, labels can be longer than the target area.

Figure 10 shows a portion of a cartogram of central Canada census data – long labels exist for a number of entities in this dataset. In this example, labels identifying census area are directly associated with brightly colored fixed size areas, reducing the visual prominence of label length. For example, short heavy weight labels (e.g. Montreal, Toronto) are more prominent than long lightweight labels (e.g. Saint-Jean-sur-Richelieu or Kitchener-Cambridge-Waterloo).
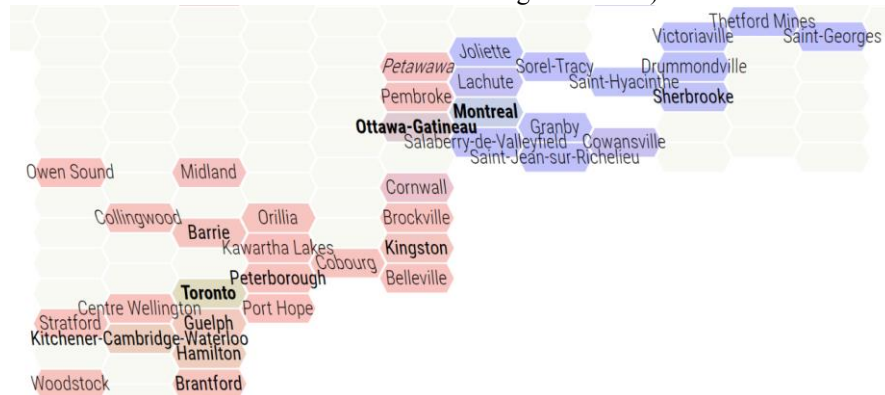

Fig. 10. Closeup of Canadian cartogram with font weight indicating population, oblique slope angle representing the proportion of women to men, and hue indicating primary language (blue for French, red for English, green for other languages, with the target hue indicating the proportions for each language).

3.4 Positional and Proportional Encodings

When labels are based on a sequence of characters, these characters can be manipulated individually. Instead of encoding a value by applying it to all characters, it can be encoded to a subset of characters:

Positional Encoding: By treating each character independently, each position can encode different data. For example, the cartogram in fig. 11 indicates nine different risk factors: bold, italic and underline applied independently to each letter of the three-letter ISO code. At a macro-level, country codes with few additional formats are less risky than country codes with many formats.
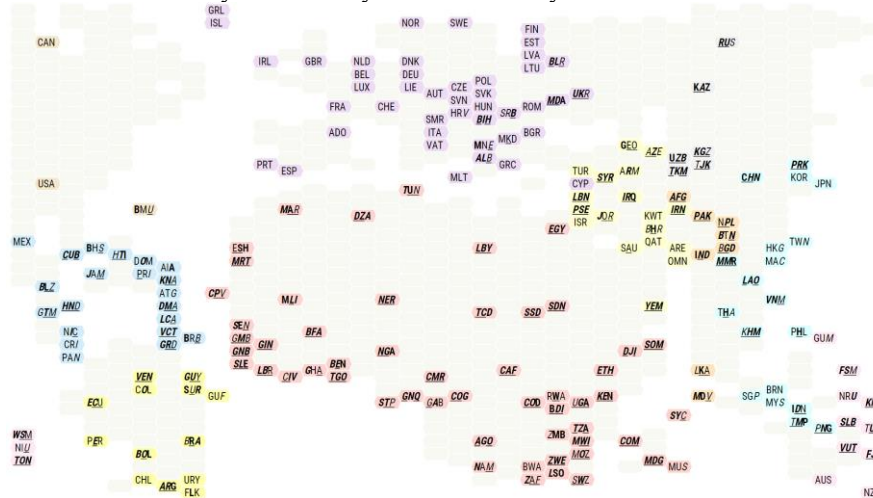

Fig. 11. Map indicating nine different risk factors indicated by bold, italic and underline applied independently to each letter of three-letter ISO code.

Proportional Encoding: Any typographic format can be applied to a sequence of characters to indicate quantities. For example, in figure 12, the proportion of uppercase is used to indicate life expectancy: JPN has longer lives than USa, which in turn is longer than Mda, and in turn longer than zaf.
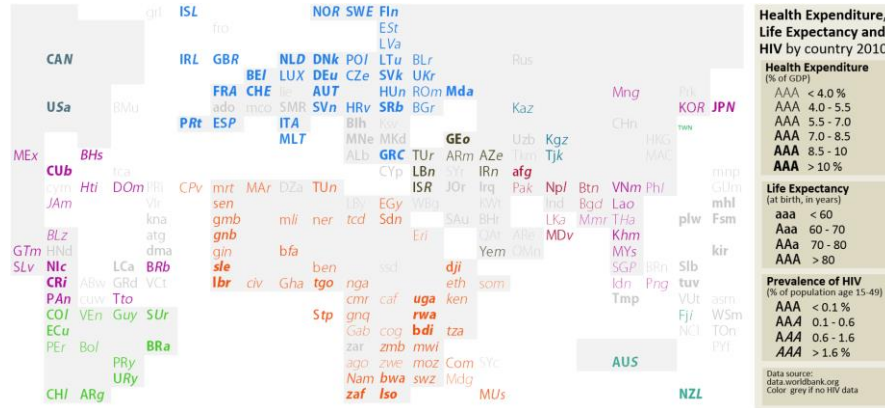
Fig. 12. Map indicating life span using proportions of uppercase, and prevalence of HIV by proportion of italic to indicate data.

3.5 Label-based Cartogram Layout

While the focus of this paper is on the use of font attributes to encode information in cartograms, different algorithms have been used to produce the above cartograms.

Grid: The cartograms in figure 7, 10 and 11 use a regular mesh-based cell deletion approach (e.g. rectangular grid or hexagonal tiling). It starts with a large, regularly subdivided mesh such that each geographic entity (e.g. country, district, city, etc) has a unique location in a particular cell in the mesh. Then, successive rows (or columns) are merged such that merging two adjacent rows (or columns) can retain all entities and no two entities occupy the same cell. This is repeated until no further merge operations can be completed.

Force Directed: The cartograms in figure 8 and 9 use a force-directed layout based on an extracted mesh. First, all entities are placed on a plane using latitude and longitude. Then, a Delaunay triangulation is used to connect adjacent entities into a triangular mesh. Next, a force-directed layout is used to push apart entities which are close together (repulsive charge), while keeping adjacent entities adjacent (edge forces). This algorithm repeats until defined criteria has been reached (energy threshold). The result of the force-directed layout still had various locations where labels are partially overlapped. This is due to the fact that the force-directed layout is an overall energy system and two points can still be close together given the nuances of the local connections. A final step walks through all the pairwise overlapping bounding boxes and pushes labels apart iteratively (until some stopping criteria or set number of iterations).

4. Discussion

There are many different aspects to the effectiveness of typographic attributes that could be evaluated: speed of perception vs. ease of decoding, interference between attributes when using multiple attributes in the same label, potential information loss, legibility and number of levels per attribute which can be perceived, impact of typographic attributes on readability, aesthetics of typographic-attribute based maps, intuitive encodings of typographic attributes, and so on. Evaluations are on-going: some have been done and many more should be considered.

Information lossiness is an evaluation of the fidelity per visual attribute in an encoding; and an estimate of permutations across multiple attributes to compare relative lossiness (Brath and Banissi 2015). A simple example is shown in fig. 13: both maps use 5 levels of hue. However, the colors of countries can be clearly identified in only 143 out of 187 countries in a choropleth map (at 520 x 310 resolution), while the corresponding label-based cartogram has all 187 countries with values readable (at the same resolution). In this examples the choropleth has a fidelity of 76% compared to the cartogram. This approach can be extended to representations with many more attributes to consider the effect of tradeoffs between different encodings. In general, label-based cartograms outperform choropleths and cartograms as many areas otherwise too small to be distinguished can be made visible and explicitly labelled. E.g. compare left and right images in figure 8.
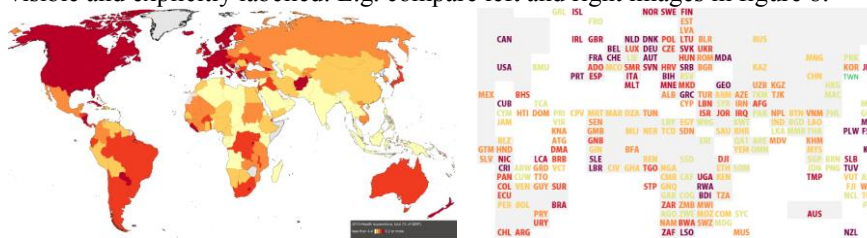

Fig. 13. Comparison of a choropleth map and equivalent label-based cartogram. Choropleth via data.worldbank.org/indicators (access September 15, 2013), right image authors.

Identification and location tasks go beyond lossiness. Using a similar approach to the National Geographic map literacy survey (GfK 2006), the two maps in figure 13 were used with 17 participants in specific tasks. The identification task required the viewer to identify two circled countries in each map type. The location task required the viewer to indicate the color of two named countries for each map type. Viewers were either graduate students from computer science or employed in the domain of computer software development. Given that the subjects were older than the 18-24 year olds in the National Geographic study, countries used for the tasks were less commonly referenced in popular media, such as Niger, Albania, Ivory Coast and Slovenia.

Table 1. Correct responses to map identification and location tasks.

Task and percent Correct Responses	Choropleth Map	ISO-labeled Cartogram	ISO Cartogram Outperformance
Identify circled country	15%	65%	4.4x
Locate country and indicate color	53%	85%	1.6x
Total	34%	75%	2.2x

For both tasks the ISO-labeled cartogram outperformed the choropleth map 2.2 times. Overall this implies that the textual mnemonic with relative positioning acted as a better aid for recall than the geographical outline with accurate positioning. The performance difference was significantly greater for the identification task. Possibly this was due to the ISO-label acting as a mnemonic cue which did not have the same effect in the location task, or perhaps it is a result of the small study size. A larger study with a larger set of subjects would be desirable.

Critiques from typographers and information visualization experts raise different concerns. *Legibility* relates to the clear decoding of individual alphanumeric glyphs and is an issue related to type size. For example, fewer levels of weight will be discernable at small type sizes. *Readability* relates to the ease of reading type: encoding data proportionally along the length of a string (e.g. USa) may be more difficult to read than an attribute applied across full words. Somewhat related to readability is familiarity with common formats and typefaces, e.g. a switch between serif and sans serif may be un-noticeable given our familiarity with both whereas a switch between serif and blackletter may be more noticeable. *Intuitive encoding* helps the viewer decode a visualization when multiple variables are encoded. For example, using font weight to indicate population (fig. 8, 10) or GDP (fig. 7) is an intuitive relationship between the magnitude of the font weight and a measurement of magnitude. Using an arbitrary combination of weight, slope and underline (fig. 11) is non-intuitive. *Long label* bias is brought up by many critics – a few possible approaches have been presented here but not evaluated.

4. Conclusion

We have shown that there are label-based alternatives to standard cartograms and choropleth maps. Labels have the potential to be more effective at tasks such as identification and location, reduce lossiness, and can be used to encode multiple data sets into multiple visual attributes beyond color, size and shape, for example, using bold, italics, underline, case and tracking.

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