Displaying changes in bivariate relationships over age and time

Tim Riffe*[1] and José Manuel Aburto †[2]

[1]Max Planck Institute for Demographic Research
[2]Epidemiology, Biostatistics and Biodemography, Department of Public Health, University of Southern Denmark

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Abstract

Background Lexis surfaces are an established visualization technique to show how a given value changes over age and time. Vector fields are a two-dimensional representation of two variables: direction and speed (or force).

Objective We aim to increase the information density of patterns shown on the Lexis surface by placing a vector field on the Lexis surface.

Results We show Lexis fields using different combinations of visual encodings, such as color, contour layering, and angle, length, curvature, and thickness of field elements. These instruments enable information layering that is not otherwise possible on standard Lexis surfaces.

Conclusions Lexis fields extend the analytic power of the Lexis surface, and these can be rendered to display information at higher densities than commonly made Lexis surfaces.

Introduction

Lexis surfaces are a graphical tool used to display data on the Lexis coordinate plane, a Cartesian plane that is also a simplex relationship between age, period, and cohort. Surfaces are often displayed as heat maps, contour maps, perspective plots, or variants of these things. Various kinds of quantities, such as raw magnitudes, differences, ratios, intensities, proportions, derivatives, and even compositions (Schöley and Willekens 2017)) can be displayed on Lexis surfaces in order to put age, period, cohort, or other patterns in relief.

Maps in general combine layers of categorical, continuous, and symbolic information on a common spatial projection. Lexis surfaces in contrast almost exclusively display one visual layer at a time. Even the composite surfaces of Schöley and Willekens (2017), which display layered information are rendered as a single visual layer. Small multiples of Lexis surfaces on the other hand constitute a de-layering, as these are spatially disjoint. We propose to enrich Lexis surfaces by adding a visual layer of quantitative information coded symbolically as a vector field, and we liken to cartographic information layering.

Vector fields are a graphical form generally used to display variation in speed, direction, or force over a plane. Point estimates of these quantitie on the plane are often represented with segments or arrows, where length may be proportional to a function of magnitude (force, speed), and angle indicates direction, potentially disambiguated with an arrowhead. We propose a fusion of Lexis surfaces and vector fields, *Lexis fields*, as a tool to display variation in relationships between variables over age and time. A Lexis field may either be rendered atop on a Lexis surface, representing two map layers — a true Lexis map — or as a single-layer alone visualization.

Our example shows patterns in the relationship between remaining life expectancy and the standard deviation of remaining lifespan over age and time based on all available populations in the Human Mortality Database from 1950 onward.

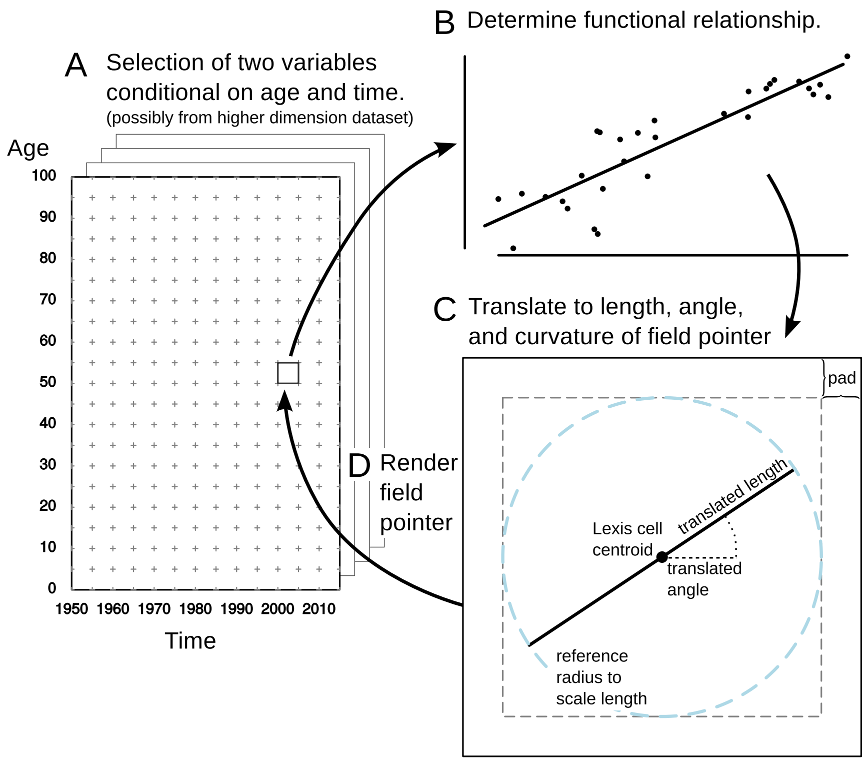


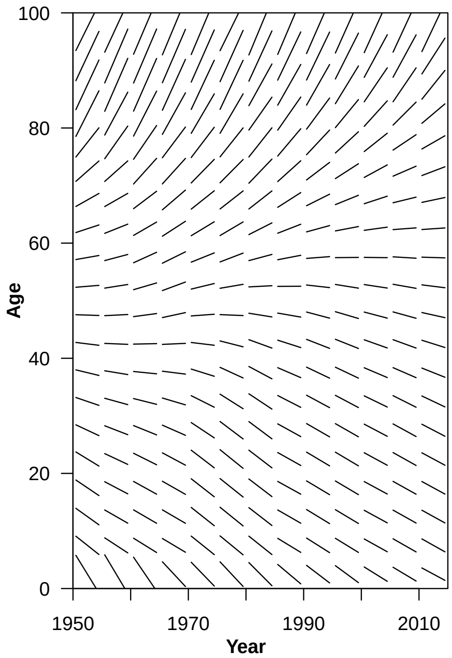
Figure 1: A diagram depicting the translation of functional relationships in data conditioned on age and time to visual encoding on a Lexis field. **A**: Condition data selection on age and time. **B**: model the functional relationship in data subset. **C**: Translate the model to field elements, 'pointers', using angle, and possibly also length, curvature, thickness, etc to encode model qualities. **D**: Populate the Lexis plane with field pointers to create a Lexis field.

1 Lexis field construction

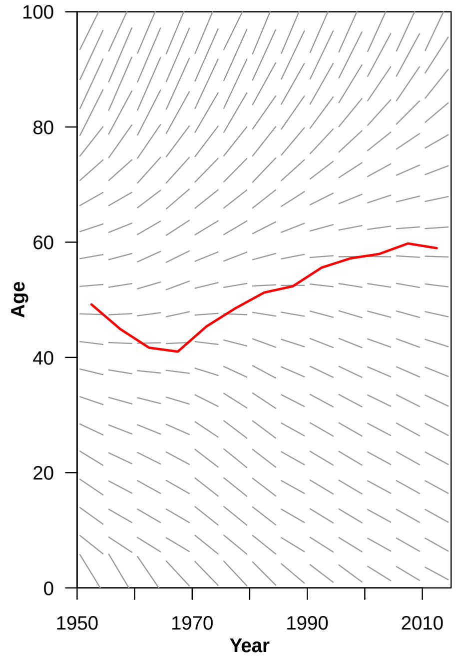
We offer several experimental variants of Lexis field design for our two examples. The first of these, Figure 2a, is a bare-bones Lexis field that serves to illustrate the underlying concept. This display differs from a standard vector field in two notable ways. 1) Segments are drawn rather than arrows, because each slope can be interpreted as a subplot, where the convention is to always read a relationship from left to right. 2) The left and right extremes are fixed for each segment according to the year-width rendered, in this case 5-year groupings. This means that relationships farther from zero also result in longer line segments, but the length of the line segment is not strictly proportional to the magnitude of the slope coefficient or any other quantity. For each subplot, the x range represents the same hypothetical range of variation in remaining life expectancy or 2 years. The y-axis is arbitrarily, but identically scaled for each subplot. Other criteria for slope length would also be possible and will be considered.

Figure 2b is identical to the previous, but adds a red contour line at the turning point in slopes. In this case there is only one sign change is slope coefficients over the age pattern. It is easier to locate and detect change in this (novel) threshold with the line markup than from the bare Lexis field. Indeed one could add further isoclines at slope break points, as in Figure 2c or 2d, and insodoing we begin a transition into the more standard graphical form of contour maps. Figure 2c blends the Lexis field with a heatmap, where hue indicates both direction and magnitude of slope coefficients. In this case, slope coefficients are double-coded, and this display is likely the most legible, but it comes at a cost of clutter. Figure 2d removes the slope segments, but is otherwise identical. We wish to explore variants of the first three of these Lexis field proposals, and may possibly display more example relationships between other variables in a full manuscript, data permitting.

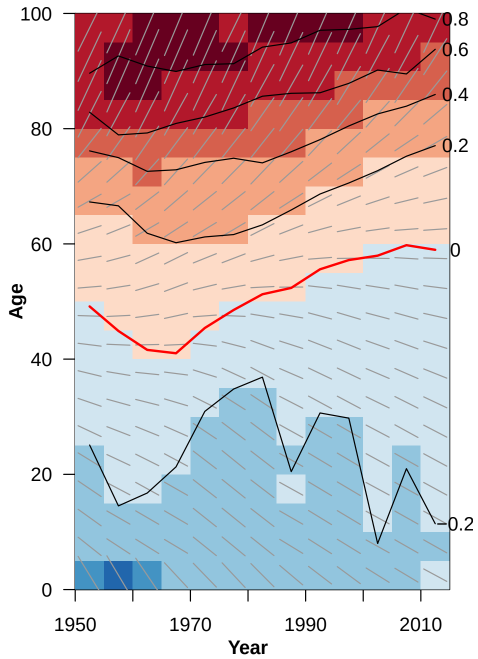
*riffe@demogr.mpg.de
†jmaburto@health.sdu.dk



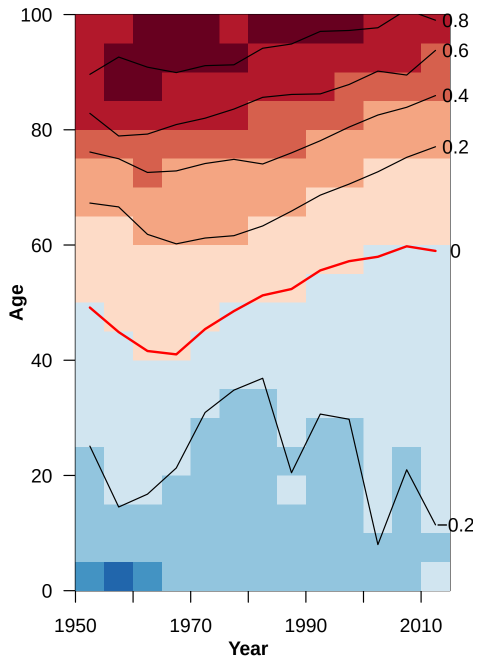
(a) A simple field.



(b) A simple field, with the zero-slope isocline drawn (red).



(c) Slopes doubly coded with field segments and discrete color, further slope isoclines drawn.



(d) Discrete color heatmap with selected isoclines drawn.

Figure 2: Four versions of Lexis fields displaying the linear relationship between the standard deviation and mean of remaining lifespan, males (HMD)

References

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