An interactive tool for constructing optimal brain colormaps

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Goal

Create a software tool to aid in the construction of optimal colormaps for viewing and labeling brain anatomical images.

Background

The application of color is an indispensible means of visually distinguishing anatomical regions of the human brain [1,2]. The need to distinguish between adjacent regions for labeling and viewing purposes has become particularly urgent with the inception of large-scale anatomical labeling projects, such as the BrainCOLOR project, in which hundreds of MR images of the human brain are being manually labeled (www.braincolor.org/protocols) as well as viewed online (www.braincolor.org/roygbiv).

Choosing a color space

Our colormap must consist of colors that are perceptually distinct, so it is reasonable to choose a color space that is perceptually uniform, where a separation between two colors in the color space is as discriminable as the same separation between two other colors in the color space.
The International Commission on Illumination (CIE) devised a color space in 1931 that facilitates color description (Fig.1). Subsequent improvements led to the CIELAB and CIELUV color spaces, as well as a cylindrical variant, CIELch, all of which attempt to be perceptually uniform.

Fig.1

Constructing a colormap

We uniformly sampled hues from the CIELch cylinder (Fig.2) at different distances from the center (70-100% chrominance) and at different luminance values. The resulting colormap (Fig.3) has the same number of colors as regions we wish to color (49 cortical regions in the BrainCOLOR protocol). We intend to expand the number of colors to include subcortical and other regions.

Fig.2

Fig.3

1. Schott GD (2010) Colored illustrations of the brain: some conceptual and contextual issues. Neuroscientist. 16(5):508-18.
2. Schoonover, C (2010) Portraits of the Mind: Visualizing the Brain from Antiquity to the 21st Century. Abrams (ISBN-13: 978-0810990334)

CIE1931 figure: http://en.wikipedia.org/wiki/File:CIExy1931_MacAdam.png
CIELch figure: http://202.197.191.206:8080/44/course/chap18/sourse/efg%27s%20Color%20Page.htm

Maximizing discriminability among adjacent regions

To easily distinguish brain regions from each other, we wish to maximize the color difference between adjacent regions. We do this by constructing a graph that represents connections (edges) between regions (nodes).

We define an *optimal mapping* of colors as the combination of colors assigned to nodes with the maximum sum of color differences between connected nodes, defined by the CIE2000 Delta E measure (http://en.wikipedia.org/wiki/Color_difference).
However, we cannot compute 8.8 x 10^{18} permutations of the 49 colors in the colormap, so we break up the brain into sublobes and compute the permutations of portions of the colormap at a time:

Frontal Lobe (7,6,9):
- Lateral Surface (7)
- Medial Surface (6)
- Inferior Surface (4)

Opercular Region (3)
Insular Region (2)

Temporal Lobe (8):
Lateral Surface (4)
Supratemporal Surface (3)
Inferior Surface (1)

Parietal lobe (6):
Lateral Surface (4)
Medial Surface (2)

Occipital Lobe (8):
Lateral Surface (4)
Inferior Surface (1)
Medial Surface (3)

Limbic Cortex (5):
Cingulate Cortex (3)
Medial Temporal Cortex (2)

Grouping regions by using similar colors

For labeling a brain image, maximum discriminability is paramount. For viewing a brain image, however, it is useful to visually group regions by assigning similar colors to the regions within a group. To create this visual grouping, we colored each subgraph with a neighborhood of colors (sampled within a wedge of the CIELch cylinder).

7 color groups; luminosities 60, 75, 90; chromaticity 70%

7 color groups; luminosities 60, 75, 90; chromaticity 100%

15 color groups (sublobes); luminosities 50, 70, 90; chromaticity 70%

Conclusion and Future Work

We have created Python software for creating and applying colormaps to brain images.
Download the software from: http://binarybottle.github.com/brainCOLORmap
The software calls the Python libraries: *NumPy, NetworkX, Python-Colormath, Matplotlib, and xlrd,* to:

1. convert a table of adjacent regions (an adjacency matrix) to a weighted graph of colored nodes
2. compute permutations of colors for each subgraph to optimally distinguish colors of adjacent regions
3. apply similar colors to predefined groups of regions

There are many improvements we could pursue. We have targeted the following for future work:

- ➜ Develop a whole-graph optimization algorithm to replace our brute force computation of subgraph permutations.
- ➜ Restrict the color space to colors that can be displayed; currently, the CIELch colors that should appear different from one another may appear similar after conversion to SRGB colors.
- ➜ Seed color values to better control the range of colors for each group of regions.
- ➜ Accommodate visual concerns such as color blindness by adapting the colormap accordingly.

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