

Gerrymandering and computational redistricting: conceptual and software challenges

Olivia Guest

<http://oliviaguest.com>

Nov 15, 2017

UCL Research Programming Technical Social

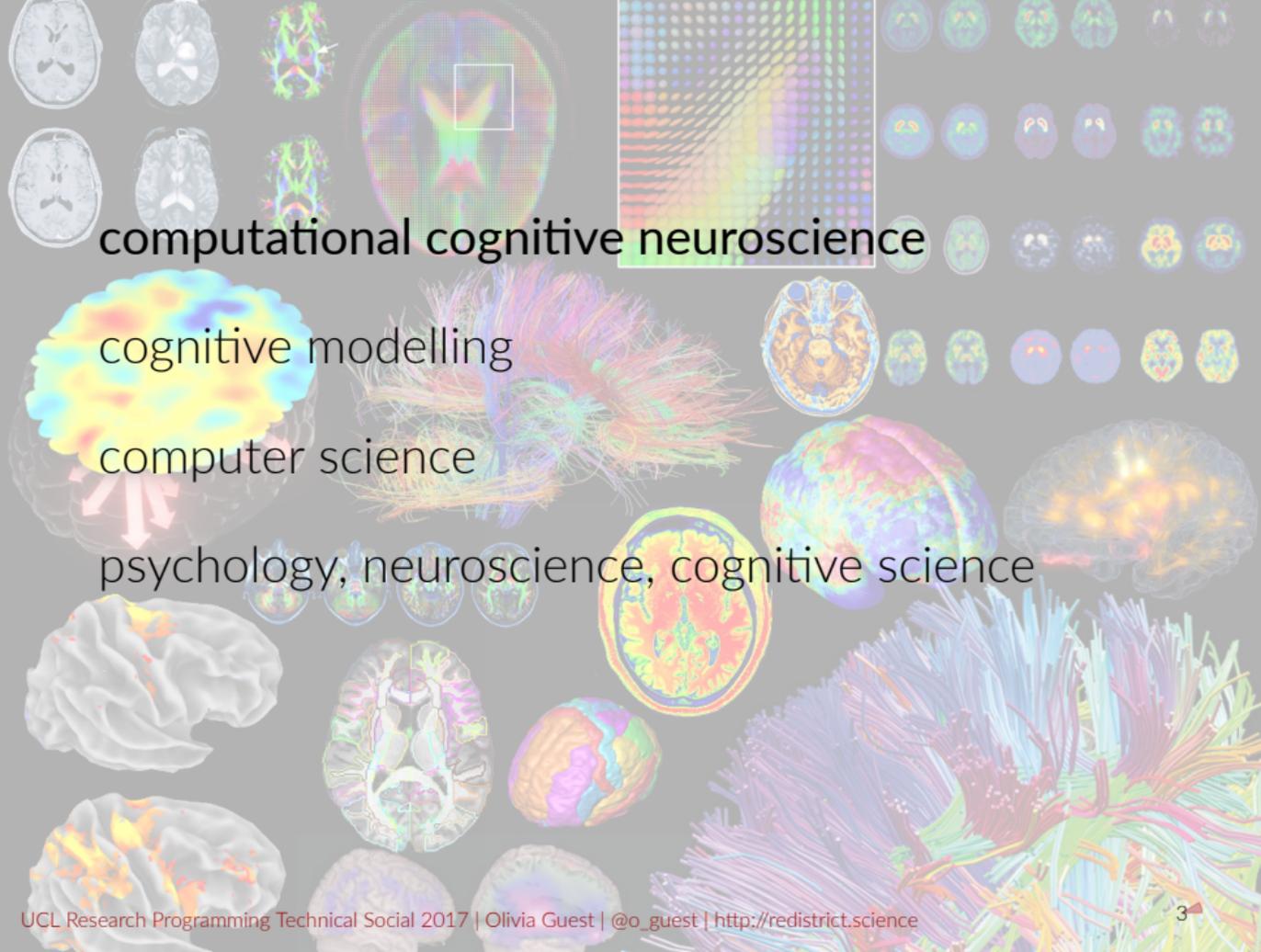
Collaborator

Bradley C. Love

University College London &
The Alan Turing Institute

<http://bradlove.org>





computational cognitive neuroscience

cognitive modelling

computer science

psychology, neuroscience, cognitive science

Talk Outline

Part 1: Science

Talk Outline

Part 1: Science

Part 2: Conceptual and software challenges

“how it was done”

What is gerrymandering?

(re)draw districts
to benefit party

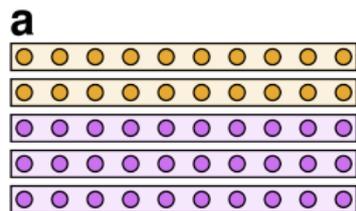
corruption

complex shape

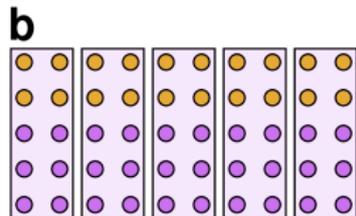


What is gerrymandering?

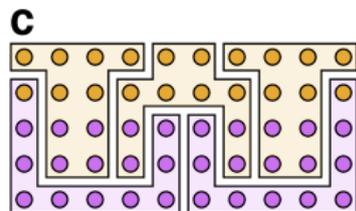
compact, fair



compact, not fair



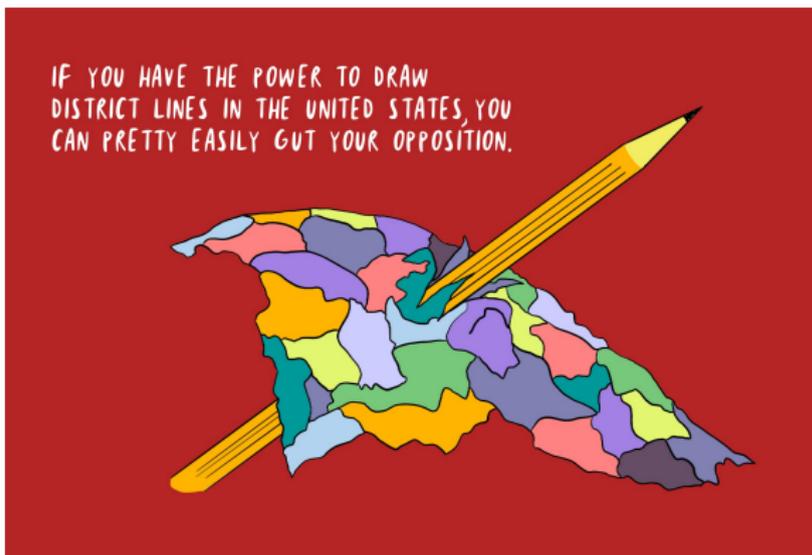
not compact, not fair



What is gerrymandering?

17 R states:
72% of seats;
52% of vote

6 D states:
71% of the
seats;
56% of vote



by Olivia Walch, @oliviawalch

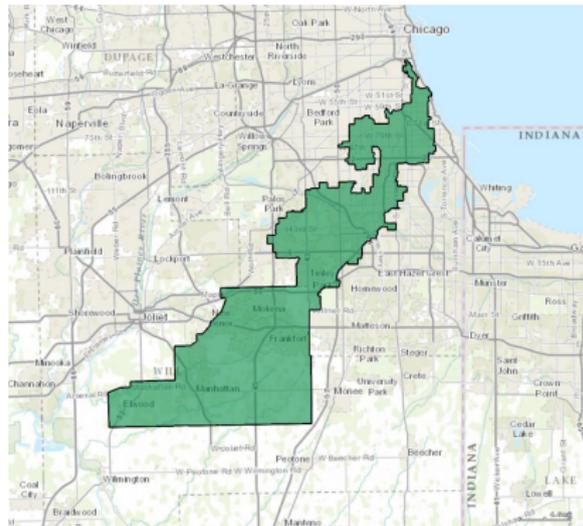


What is gerrymandering?

2000: Obama lost in IL

opponent allowed to
draw maps

...carved Obama's
house out!



Levitt, Justin, The Legal Context for Scientific Redistricting Analysis (March 28, 2011). NEW TECHNOLOGY AND THE OLD PROBLEMS OF REDISTRICTING, Forthcoming; Loyola-LA Legal Studies Paper No. 2011-13. Available at SSRN: <https://ssrn.com/abstract=1798005> or <http://dx.doi.org/10.2139/ssrn.1798005>

Computational Redistricting

humans debate
districting criteria

machines draw
the district
boundaries

open source, don't
get tired



Psychological Perspective

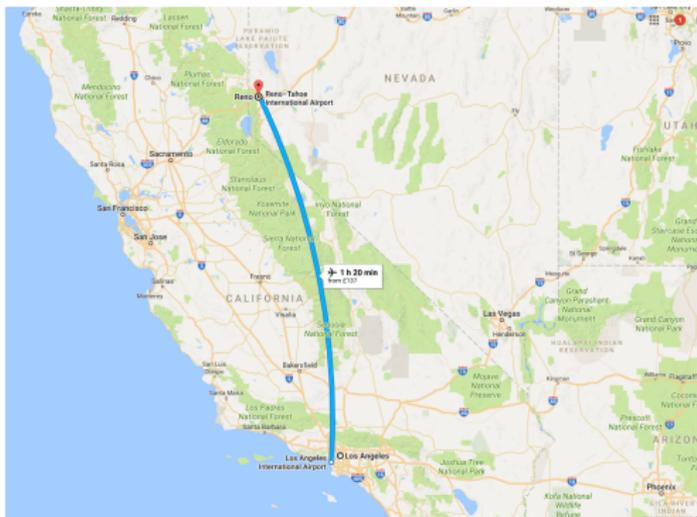
humans get
confused by the
world

Myers, 2002. Intuition: Its Powers and Perils.

Psychological Perspective

humans get
confused by the
world

Reno east of LA



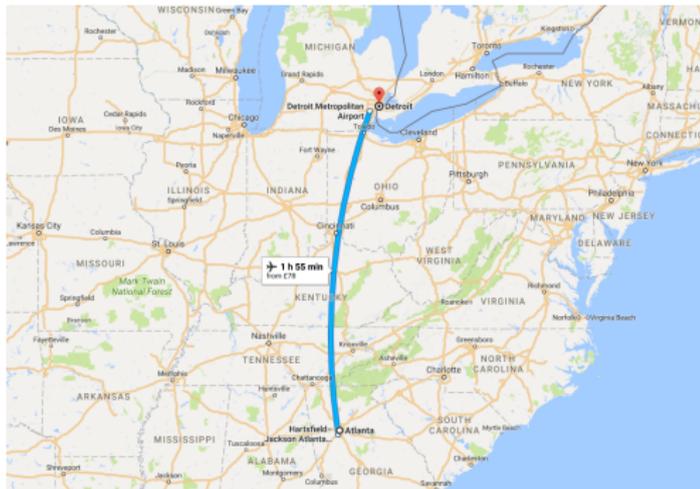
Myers, 2002. Intuition: Its Powers and Perils.

Psychological Perspective

humans get
confused by the
world

Reno east of LA

Atlanta east of
Detroit



Myers, 2002. Intuition: Its Powers and Perils.

Analysis

Improvement as func of number of districts and
(number of districts)²

$$R^2 = 0.550, F(2, 40) = 24.47, p \approx 0$$

Analysis

Improvement as func of number of districts and
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20% improvement per state on average

Analysis

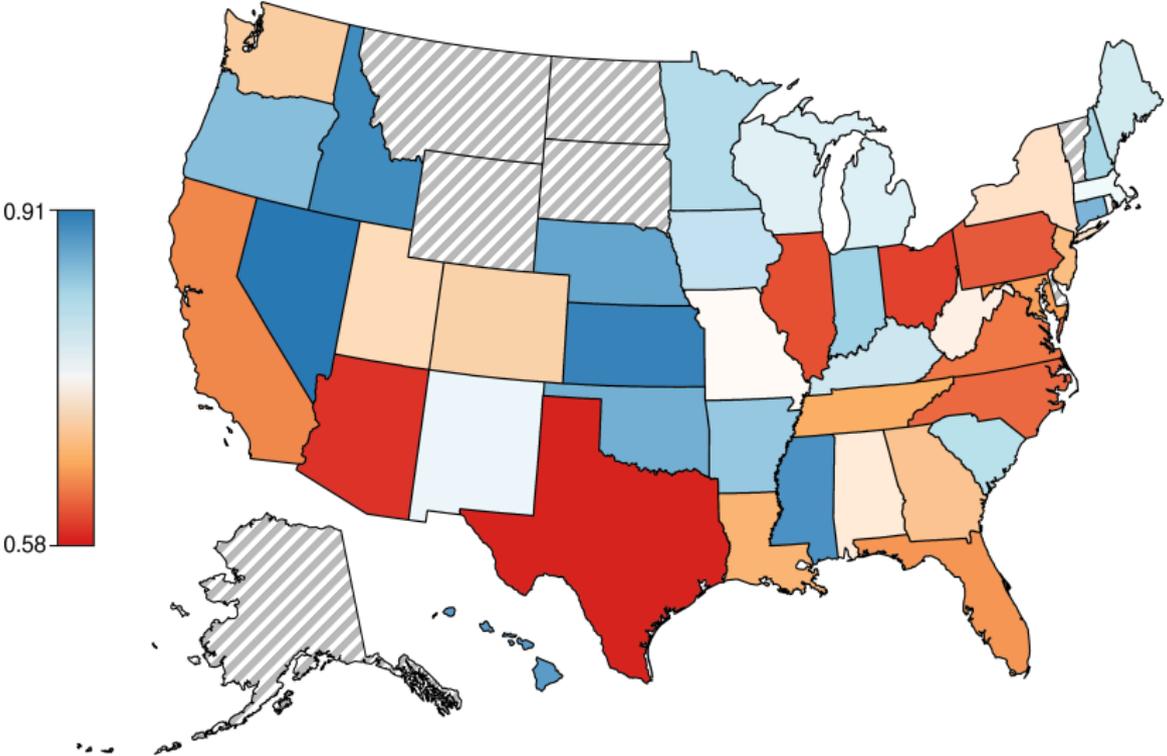
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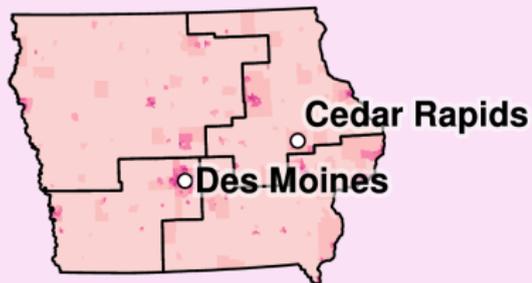
cognitive demands may tax humans

Our Results



Our Results

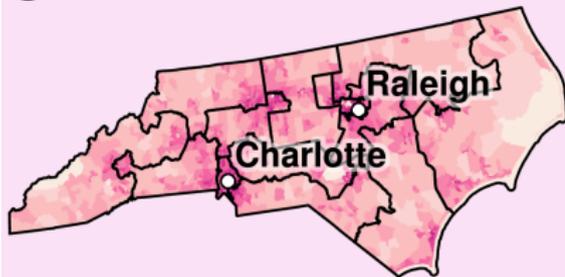
a



b



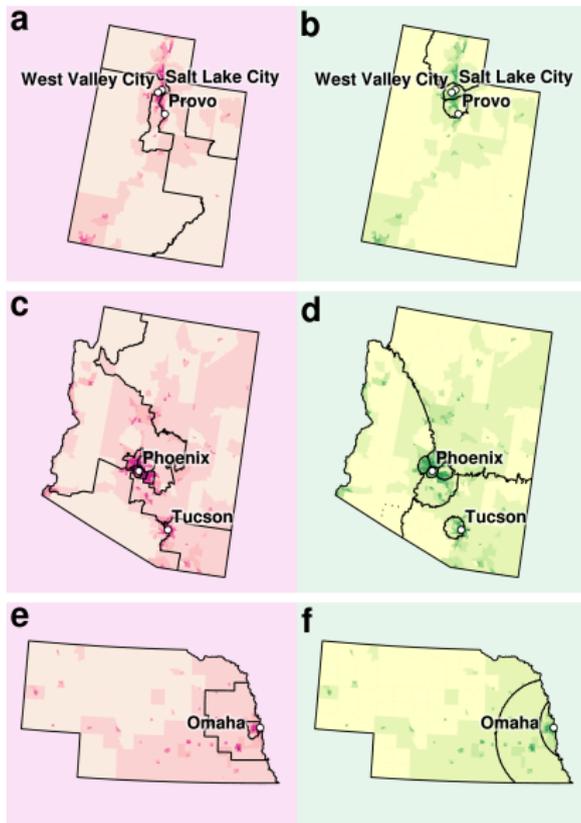
c



d



Our Results



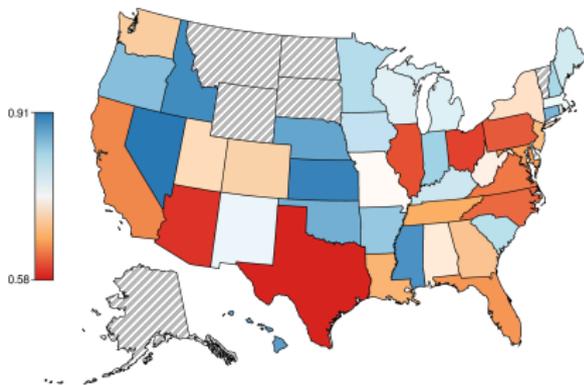
More Results

larger states → more improvement

complex for humans

gerrymandering may be accidental

Arizona is worst state



Discussion

political, legal, academic debate on criteria

Discussion

political, legal, academic debate on criteria

computers do the grunt work

Discussion

political, legal, academic debate on criteria

computers do the grunt work

open source software for transparency

Discussion

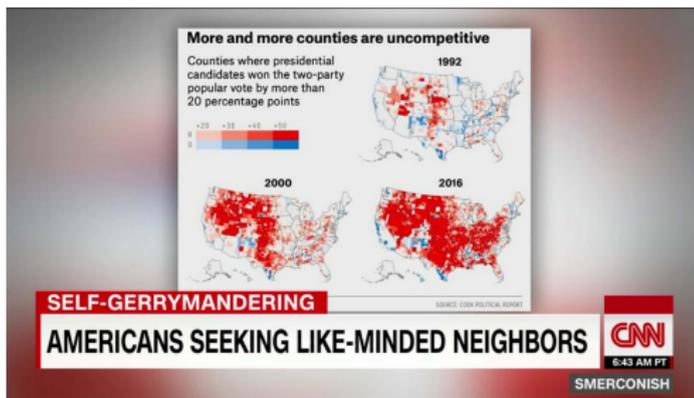
travel time not
just geo distance

communities can
be respected



Discussion

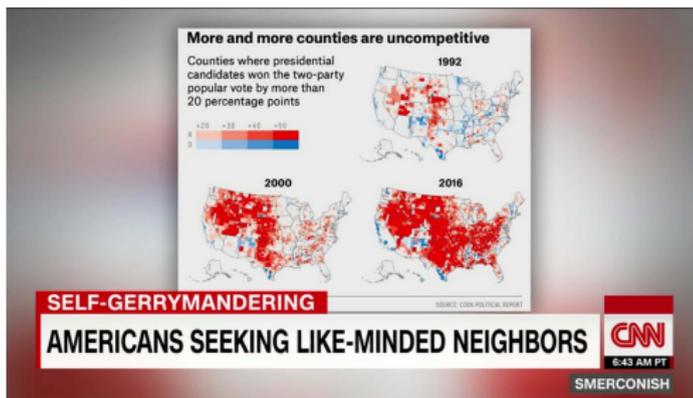
people
self-gerrymander



Discussion

people
self-gerrymander

but it's
empowering to
representatives

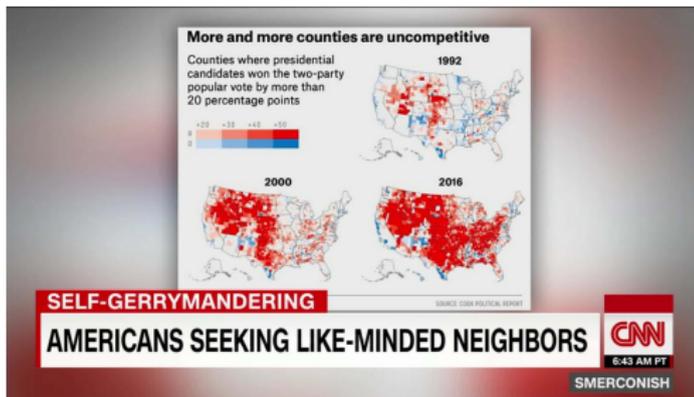


Discussion

people
self-gerrymander

but it's
empowering to
representatives

Civil Rights &
LGBT movements
not initially
mainstream



End of Part 1

Conceptual Challenges

understand US:
legal system,
politics

Conceptual Challenges

understand US:
legal system,
politics



Conceptual Challenges

understand US:
legal system,
politics

other research:
disparate,
unconsolidated



Conceptual Challenges

understand US:
legal system,
politics

other research:
disparate,
unconsolidated

algorithm
development***



Our Algorithm

Weighted k-means:

clusters = districts, points = census blocks

The weight for cluster i is

$$w_i = \frac{|C_i|^\alpha}{\sum_{j=1}^K |C_j|^\alpha}$$

Weighted k -means

The screenshot shows the GitHub repository page for 'oliviaguest / weighted_k_means'. At the top, there are navigation links for Code, Issues, Pull requests, Projects, Wiki, Insights, and Settings. The repository description is 'A weighted k -means implementation. <http://redistrict.science>'. Below this, there are statistics: 36 commits, 1 branch, 0 releases, and 1 contributor. A list of files is shown, including tests, .gitignore, .travis.yml, Makefile, README.md, __init__.py, example.py, requirements.txt, and wkmeans.py. The README.md file is selected and its content is displayed below, featuring a 'build: passing' status and instructions on how to run the weighted k -means algorithm.

oliviaguest / **weighted_k_means** Unwatch 1 Star 0 Fork 0

<> Code Issues Pull requests Projects Wiki Insights Settings

A weighted k -means implementation. <http://redistrict.science> Edit

Add topics

36 commits 1 branch 0 releases 1 contributor

Branch: master New pull request Create new file Upload files Find file Clone or download

oliviaguest more tests Latest commit ee31788 11 days ago

tests	more tests	11 days ago
.gitignore	Create .gitignore	9 months ago
.travis.yml	test	19 days ago
Makefile	test	19 days ago
README.md	Update README.md	20 days ago
__init__.py	So much tidying	9 months ago
example.py	tests!	20 days ago
requirements.txt	tidy	a month ago
wkmeans.py	more tests	11 days ago

README.md

Weighted k -means

build: passing

To run your own weighted k -means use `example.py` which has step-by-step instructions. For more detailed information regarding the implementation, please refer to `wkmeans.py`'s source code which is fully commented.

Our Metric

$$\text{Improvement Ratio} = \frac{\text{pairwise distances clusters}}{\text{pairwise distances districts}}$$

Our Metric

$$\text{Improvement Ratio}_{\text{SC}} = \frac{50 \text{ km}}{60 \text{ km}} = 0.833$$

Our Metric

$$\text{Improvement Ratio}_{\text{TX}} = \frac{60 \text{ km}}{100 \text{ km}} = 0.6$$

Pairwise Distances Metric

The screenshot shows the GitHub repository page for 'oliviaguest / pdist'. At the top, there are navigation buttons for 'Unwatch' (1), 'Star' (8), and 'Fork' (1). Below this is a navigation bar with links for 'Code', 'Issues' (0), 'Pull requests' (0), 'Projects' (0), 'Wiki', 'Insights', and 'Settings'. The repository description reads: 'Calculate mean of pairwise weighted distances between points using great circle metric.' Below the description are tags for 'geographical-information-system', 'pairwise-distances', 'pairwise-weighted-distances', 'python', 'cython', and 'big-data', along with a 'Manage topics' button. A progress bar shows 70 commits, 1 branch, 0 releases, and 2 contributors. Below the progress bar are buttons for 'Branch: master', 'New pull request', 'Create new file', 'Upload files', 'Find file', and 'Clone or download'. The file list shows the following files and their last commit dates:

File	Description	Latest commit
tests	renamed module to pdist	20 days ago
.gitignore	gitignore	12 days ago
.travis.yml	Update .travis.yml	14 days ago
LICENSE	Create LICENSE	a month ago
Makefile	Update Makefile	14 days ago
README.md	Update README.md	14 days ago
__init__.py	working!	7 months ago
cdist.c	tidy	21 days ago
cdist.h	working!	7 months ago
compare.py	renamed module to pdist	20 days ago
pdist.c	renamed module to pdist	20 days ago
pdist.pyx	renamed module to pdist	20 days ago
requirements.txt	updated requirements.txt	21 days ago
setup.py	renamed module to pdist	20 days ago

Pairwise Distances Metric

README.md

pdist

build passing codecov 100% license CC0 Follow @o_guest

Calculate the mean of the pairwise weighted distances between points using the great circle metric 🌐 for a very big dataset without running out of RAM 🤖 and/or waiting till the end of the universe. 🤪

Usage

Mean of Pairwise Weighted Distances Using Great Circle

This code takes a set of 2D data points `x` and calculates the mean of the pairwise weighted distances between points using the great circle metric. It offers extensive speedup over Python-only implementations, so it is useful when dealing with *big data*.

To call use:

```
mean_distances = c_mean_dist(X, weights)
```

where `x` are your data points, and `weights` are the weights or counts (depending on how you want to conceptualise them). Weights affect the mean of the pairwise distances in the same as including more of the point which the weight corresponds to. So if a data point with value `(0, 1)` has a weight of 2, the average pairwise distances will be affected in the same way as if you had added another data point with value `(0, 1)` to `x` and had set both their weights to 1.

Great Circle Distance

It also implements great circle, also known as orthodromic or geodesic, distance metric faster than GeoPy in `cdist`.

Example

For an example of both functions see `compare.py`.

Software Challenges

US Census Bureau
GIS data, API



Software Challenges

US Census Bureau GIS data, API

The screenshot shows the US Census Bureau's website, specifically the 'Geography' section. The page features a navigation menu with options like 'Topics', 'Geography', 'Library', 'Data', 'Surveys/Programs', 'Newsroom', and 'About Us'. The main content area is titled 'Census Data Mapper' and includes a description of the application, a map of the United States, and a list of application requirements.

U.S. Department of Commerce | Blogs | Index A-Z | Glossary | FAQs

U.S. Census Bureau

Topics: Population, Economy, Geography: States, Territories, Library: Integrations, Publications, Data: Table Downloads, Surveys/Programs: Research, Survey Data, Newsroom: News, Blogs, About Us: Our Research

Geography

Main | About | Maps & Data | Reference | Partnerships | Education | Research | GIS1 | Contact Us

Maps & Data

- Maps & Data Main Page

Maps

- Census Data Mapper
- Reference
- Thematic
- Maps Available for Purchase

Data

- TIGER Products
- Census Geocoder
- Geographic Shapefiles
- Relationship Files
- Geoserver Files
- Block Assignment Files
- Name Lookup Tables
- Tables
- Landfiles

Census Data Mapper

The Census Data Mapper is a web mapping application intended to provide users with a simple interface to view, save and print county-based demographic maps of the United States. The data are from the 2010 Census.

Please click on the image or link below to launch the application.

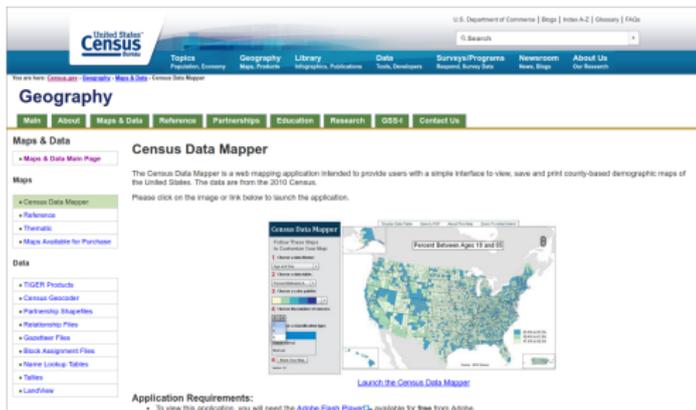
Application Requirements:

- To view this application, you will need the [Adobe Flash Player](#), available for free from Adobe.

Software Challenges

US Census Bureau
GIS data, API

equations into
code



The screenshot shows the US Census Bureau's "Census Data Mapper" web application. The page features a blue header with the "United States Census Bureau" logo and navigation links for Topics, Geography, Library, Data, Surveys/Programs, Newsroom, and About Us. Below the header is a "Geography" section with sub-links for Main, About, Maps & Data, Reference, Partnerships, Education, Research, GIS1, and Contact Us. The "Maps & Data" section includes a "Census Data Mapper" link. The main content area is titled "Census Data Mapper" and contains a description: "The Census Data Mapper is a web mapping application intended to provide users with a simple interface to view, save and print county-based demographic maps of the United States. The data are from the 2010 Census." Below this is a "Please click on the image or link below to launch the application." instruction and a thumbnail image of the application interface. The thumbnail shows a map of the United States with a legend and various controls. Below the thumbnail is a "Launch the Census Data Mapper" link. At the bottom, there are "Application Requirements:" which state: "To view this application, you will need the [Adobe Flash Player](#) available for free from Adobe."

Software Challenges

US Census Bureau
GIS data, API

equations into
code

11 million census
blocks (geometry
and population)

The screenshot shows the US Census Bureau's website with a search bar at the top right. The main navigation bar includes links for Topics, Geography, Library, Data, Surveys/Programs, Newsroom, and About Us. A secondary navigation bar under 'Geography' includes links for Main, About, Maps & Data, Reference, Partnerships, Education, Research, GSD-1, and Contact Us. The 'Maps & Data' section is active, displaying a 'Census Data Mapper' page. The page title is 'Census Data Mapper' and it includes a description: 'The Census Data Mapper is a web mapping application intended to provide users with a simple interface to view, save and print county-based demographic maps of the United States. The data are from the 2010 Census.' Below the description is a 'Please click on the image or link below to launch the application.' section featuring a thumbnail of the 'Census Data Mapper' application interface, which shows a map of the United States with a legend and various controls. A 'Launch the Census Data Mapper' link is provided below the thumbnail. At the bottom, there are 'Application Requirements:' which state: 'To view this application, you will need the [Adobe Flash Player](#) available for free from Adobe.'

Software Challenges

US Census Bureau
GIS data, API

equations into
code

11 million census
blocks (geometry
and population)
OMG!!!

The screenshot shows the US Census Bureau's Census Data Mapper website. The page has a blue header with the US Census Bureau logo and navigation links for Topics, Geography, Library, Data, Surveys/Programs, Newsroom, and About Us. Below the header is a search bar and a navigation menu with links for Home, About, Maps & Data, Reference, Partnerships, Education, Research, GSD-1, and Contact Us. The main content area is titled "Census Data Mapper" and includes a description of the application, a "Launch the Census Data Mapper" button, and "Application Requirements" for Adobe Flash Player.

U.S. Department of Commerce | Blogs | Index A-Z | Glossary | FAQs

U.S. Census Bureau

Topics: Population, Economy, Geography: Maps, Technical, Library: Integrations, Publications, Data: Tools, Downloads, Surveys/Programs: Research, Survey Data, Newsroom: News, Blogs, About Us: Our Research

U.S. Census Bureau

Geography

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Maps & Data

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Please click on the image or link below to launch the application.

Census Data Mapper

County-based Demographic Data

Percent Between Ages 18 and 64

Launch the Census Data Mapper

Application Requirements:

- To view this application, you will need the [Adobe Flash Player™](#), available for free from Adobe.

Software Challenges

interactive map

collect data on our solutions vs reality

share 10s of gigs of data

Gerrymandering and Computational Redistricting

Olivia Guest  , Frank J. Kanayek  and Bradley C. Love  

 Share  Tweet

Welcome

Partisan gerrymandering poses a threat to democracy. One solution is using computers to draw the district lines instead of relying on politicians. To learn more about gerrymandering and our computer-based solution, please read "[Gerrymandering and Computational Redistricting](#)" by [Olivia Guest](#), [Frank J. Kanayek](#), and [Bradley C. Love](#). This interactive website accompanies that paper and shows how computers can improve the districting process.

The data and code used for these simulations can be found on the OSF repository [osf.io/5fepu](#) and the [redistrict](#) github repository.

Existing Solution



Maps

Below are two interactive maps showing the existing districts (left column) and the results from our weighted k -means algorithm (right column). The colors used are to facilitate viewing and are randomly assigned to each congressional district — except in the case of states with at-large districts (i.e., a single district, which have no color).

Moving your cursor over a state highlights its border in black. Clicking on a state zooms both maps in, allowing you to see the state's districts close up for both reality and our solution. To find a specific location click on the magnifying glass, on the top left of both maps, to open up a search box.

Clustering Solution



Skills I Sharpened

JavaScript, JSON, Topo/GeoJSON, JSON-APIs in Python, geopandas, pandas, Cython, parallelising code in Python,

brushing up on my C which I hadn't used since 2014 (aka why I stopped using C)

Travis Continuous Integration, Codecov

GIS and when to use QGIS over Python/code

US Census Bureau GIS data, API



Logan



Logan @logantpowell
you are new to working with Census data?

Mar 13 16:30



Olivia Guest @oliviaguest
100% new yes

Mar 13 16:30



Logan @logantpowell
what kind of experience do you have with GIS?

Mar 13 16:30



Olivia Guest @oliviaguest
I am also not American so I had to learn all your vocabulary words 😊
zero except I opened QGIS up today and managed to plot the block in Alabama blocks*

Mar 13 16:30



Logan @logantpowell
ok
let's start with what you're trying to accomplish with the data
what are you trying to prove/do?

Mar 13 16:31



Olivia Guest @oliviaguest
I would like to have the long and lat for each block and the population

Mar 13 16:32



Logan @logantpowell
you say you already have that though right?

Mar 13 16:32



Olivia Guest @oliviaguest
yes
except it's wrong given that I want to associate each block with the correct 2017 cong dist

Mar 13 16:32



Logan @logantpowell
the data are associated with specific boundaries, which change over time

Mar 13 16:33



Olivia Guest @oliviaguest
I assume they somehow used the census population estimation to update e.g. nevada into 4 cong dists from 3 though
so they must have some estimated data somewhere for the population of nevada?

Mar 13 16:33



Logan @logantpowell
if you want to transform the data into a new boundary, you'll have to grasp how that's going to effect the accuracy of your data (over my head)
congressional districts are arbitrary boundaries defined by politicians

Mar 13 16:34

US Census Bureau GIS data, API



Logan



Logan @logantpowell
sec

Mar 15 14:56

It seems like it should be correct, but...
you were right 😊

<https://geocoding.geo.census.gov/geocoder/geographies/coordinates?x=-071.8263836&y=%2B41.3935288&benchmark=4&vintage=4>

i had the coordinates backwards

I should know this stuff, right?~!

seems like you CAN use these for your purposes



Olivia Guest @oliviaguest
excellent

Mar 15 14:59

so do you know what they are — are they the euclidean centroid?



Logan @logantpowell
idk

Mar 15 14:59



Olivia Guest @oliviaguest
hhahaha

Mar 15 15:00

ok I will calculate some euclidean norms and then compare



Logan @logantpowell

Mar 15 15:01

cool... let me know what you find out and what it's called... it seems to be an esri spec:

https://tigerweb.geo.census.gov/arcgis/rest/services/TIGERweb/Special_Land_Use_Areas/MapServer/layers



Olivia Guest @oliviaguest

Mar 15 15:03

I don't know what that means, I will investigate



Olivia Guest @oliviaguest
hi there

Mar 15 17:43

so I have checked and they are indeed the centroids

I checked this myself with code, I haven't found it written anywhere

I can send you code if need be, but CENTLAT and CENTLON are the coordinates for the centroid for each census block group 😊



Logan @logantpowell
that's good to know 😊

Mar 15 17:52

Thank you

US Census Bureau GIS data, API

data can be plotted as map as well as geopandas

`get_block_groups.py`

`Whole USA figure.ipynb`

Equations into Code

Weighted k-means



Equations into Code

Weighted k-means

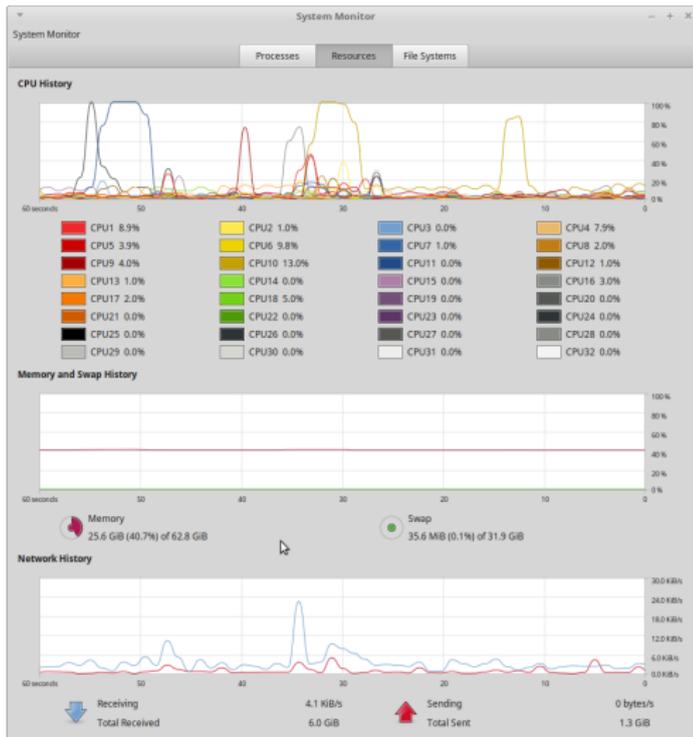
Python but totally
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Cython/C



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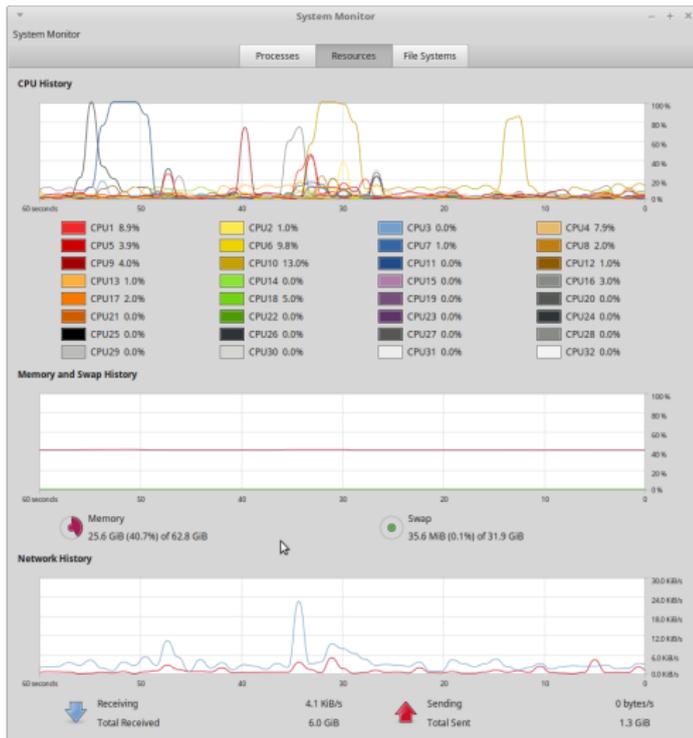
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Equations into Code

$O(nkt)$

where n , k , t are
iterations, clusters,
data points

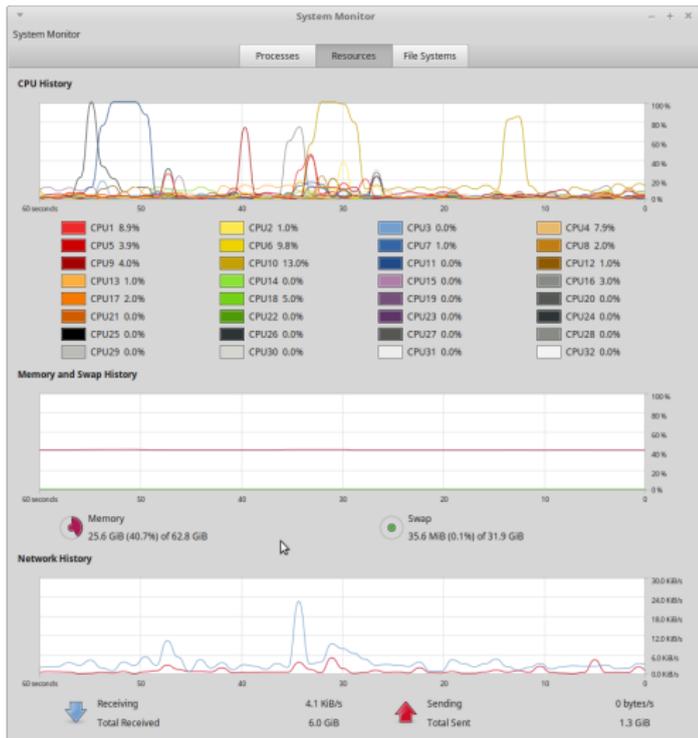


Equations into Code

$O(nkt)$

where n , k , t are
iterations, clusters,
data points

11 million blocks
for param search!



Equations into Code

Pairwise distances

oliviaguest / pdist

Calculate mean of pairwise weighted distances between points using great circle metric.

geographical-information-system pairwise-distances pairwise-weighted-distances python cython big-data Manage topics

70 commits 1 branch 0 releases 2 contributors

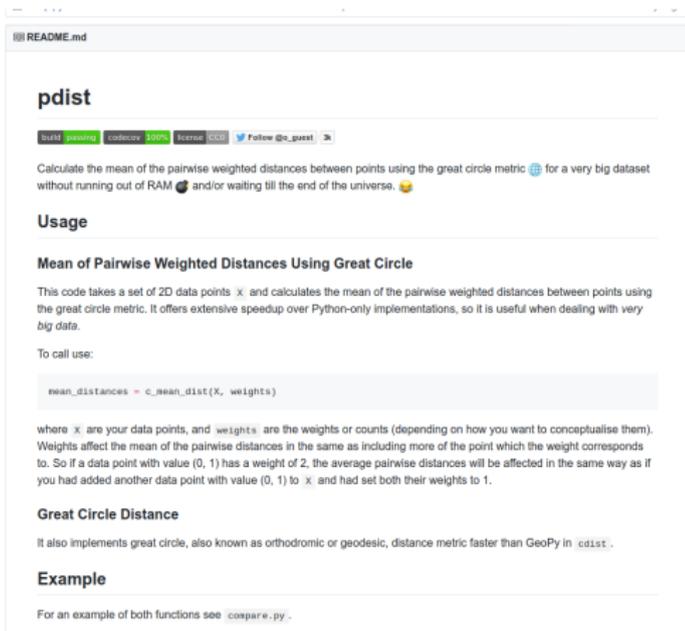
Branch: master New pull request Create new file Upload files Find file Clone or download

File	Commit Message	Time Ago
tests	renamed module to pdist	20 days ago
gitignore	gitignore	12 days ago
.travis.yml	Update .travis.yml	14 days ago
LICENSE	Create LICENSE	a month ago
Makefile	Update Makefile	14 days ago
README.md	Update README.md	14 days ago
__init__.py	working!	7 months ago
cdist.c	tidy	21 days ago
cdist.h	working!	7 months ago
compare.py	renamed module to pdist	20 days ago
pdist.c	renamed module to pdist	20 days ago
pdist.pyx	renamed module to pdist	20 days ago
requirements.txt	updated requirements.txt	21 days ago
setup.py	renamed module to pdist	20 days ago

Equations into Code

Pairwise distances

C with a bit of Cython and Python



README.md

pdist

Build [passing](#) [coverage 100%](#) [license CC0](#) [Follow @o_guest](#)

Calculate the mean of the pairwise weighted distances between points using the great circle metric 🌐 for a very big dataset without running out of RAM 🤖 and/or waiting till the end of the universe. 😊

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Mean of Pairwise Weighted Distances Using Great Circle

This code takes a set of 2D data points `X` and calculates the mean of the pairwise weighted distances between points using the great circle metric. It offers extensive speedup over Python-only implementations, so it is useful when dealing with very big data.

To call use:

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mean_distances = c_mean_dist(X, weights)
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Example

For an example of both functions see `compare.py`.

Equations into Code

Pairwise distances

C with a bit of Cython and Python

tweeps pointed me to tutorial here

Weights affect the mean of the pairwise distances in the same as including more of the point which the weight corresponds to. So if a data point with value (0, 1) has a weight of 2, the average pairwise distances will be affected in the same way as if you had added another data point with value (0, 1) to `x` and had set both their weights to 1.

Great Circle Distance

It also implements great circle, also known as orthodromic or geodesic, distance metric faster than GeoPy in `cdist`.

Example

For an example of both functions see `compare.py`.

Information

The C and Python code were written by Olivia Guest — using [this tutorial](#) by Dmitrii V Pasechnik to call C functions from Python using Cython, and using the [haversine function](#) from Rosetta Code.

Installation

Make sure you have Cython and its dependencies installed (refer to `requirements.txt`). Run `make`. Subsequently, run `python compare.py` to confirm compilation, and to see the comparison between using the C version and using a Python-only way. See `requirements.txt` in case you need to install GeoPy, etc.

If you want to use this function from outside this directory, e.g., `import`, I have not yet found a way of doing so without adding the path to the library to `LD_LIBRARY_PATH`, e.g., `export LD_LIBRARY_PATH=./local/path/to/this/repo`. For adding it permanently (so you do not have to do this every time) add it to your `~/.bashrc` or whatever your set-up dictates.

Notes

There were [many attempts](#) 🙄 to make this work Python-only. 🙁 Alas — none of them worked out, but feel free to play around with the various Python versions. The main stumbling block was the GIL. 😞 For very huge data sometimes Python-only is not the best idea. 😞

To Do

- Fill in the `setup.py` (template: <https://github.com/uwescience/shablona/blob/master/setup.py>)
- Submit to pypi (<https://github.com/oliviaguest/pdist/pull/2#issuecomment-339713987>)

Interactive Map

Asked on Twitter

Interactive Map

Asked on Twitter

Leaflet & convert
data from
GeoJSON to
TopoJSON



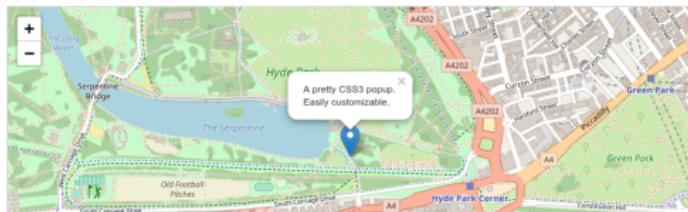
an open-source JavaScript library
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Aug 8, 2017 — [Leaflet 1.2.0](#) has been released.

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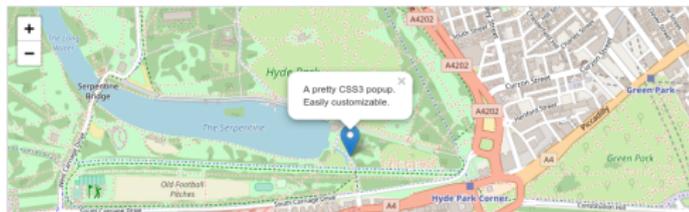
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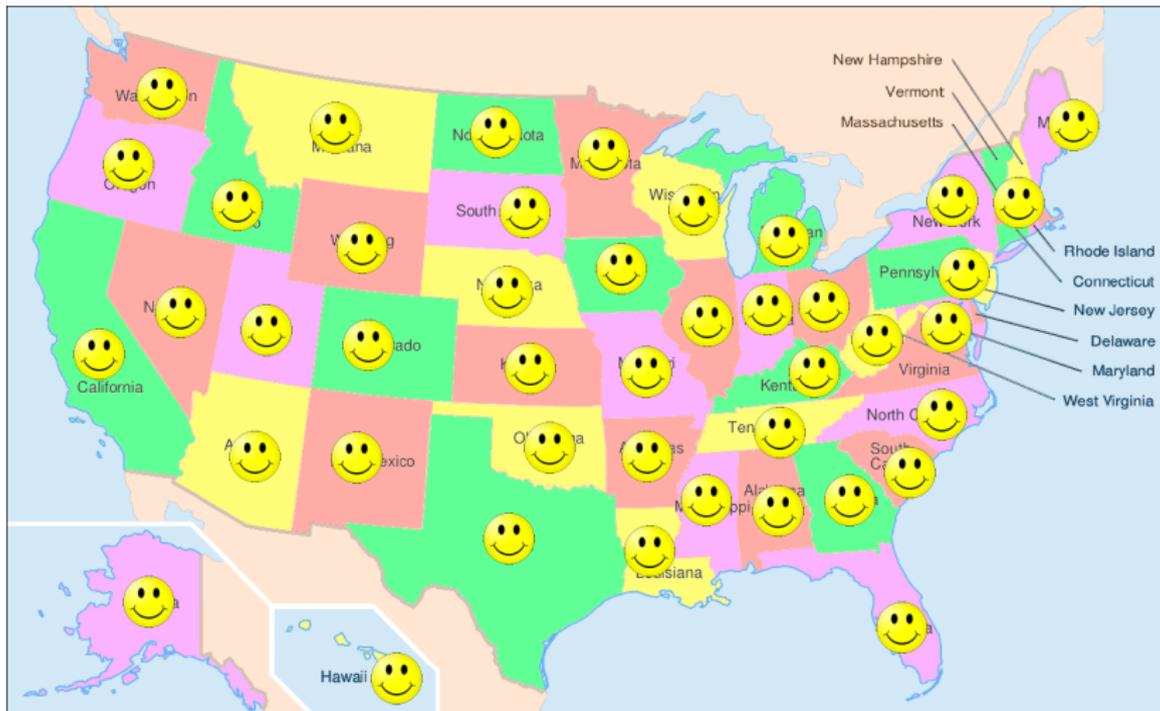
General Lessons

Twitter is amazing

Knowing who to ask

Online communities

The End! Thank you!



The End! Thank you!



Research Software Engineer in Cognitive Neuroscience

University College London - Division of Psychology and Language Sciences
Experimental Psychology

Location:	London	Placed on:	10th November 2017
Salary:	£34,635 to £41,864 per annum, inclusive of London Allowance	Closes:	10th December 2017
Hours:	Full Time	Job Ref:	1688374
Contract Type:	Fixed-Term/Contract		

This Research Software Engineer position is available on a project concerning the neural, psychological, and computational basis of learning and decision making. Core duties include optimising code for numerical simulations, profiling code, parallelising code, preparing software packages to publically distribute (open source) to the wider community through github, conducting simulations of deep learning neural networks using TensorFlow and related packages, and porting code and overseeing analyses and simulations on HPC clusters. Duties will also include other general coding tasks as needed,