## HW3: Geospatial data handling

Total points: 6 [plus 1 bonus]

In this homework, you are going to work with **spatial data** - you will create (generate/sample) some data, visualize it, do queries on it, and visualize the query results.. Hope you have fun with this!

The exercise will give you a taste of working with spatial data, use of a spatial file format and spatial query functions, all of which are quite useful from a real-world (or job interview) perspective.

What you need to do is described below in sufficient, but not too much, detail - you'd need to do a bit of reading up and experimenting, to fill in the gaps. Please talk to a TA/grader if you are unable to proceed at any point!

1. You need to create (generate) latitude,longitude pairs (ie. spatial coordinates) for **12 locations.** One of those will be where your home/apartment/dorm room is. The other 11 would have to be spread out - use your judgment, try to span the campus area, choose locations inside and outside, nearby - we don't want to cover a 'huge' region, or at the other extreme, sample just parts of a single building!

If you are on campus, you can obtain the coords of the four corners (Exposition/Vermont, Vermont/Jefferson, Jefferson/Figueroa, Figueroa/Exposition), and get coordinates for other spots inside the campus (classrooms, libraries, labs, offices, restaurants, landmarks..). If you are a DEN student, please get your 12 coordinates from your place of work or your home neighborhood (again, make sure they are not too close to each other or too far apart).

How would you obtain (lat,long) spatial coordinates at a location? You can do so, one of two ways:

• **using the Chrome browser**, simply bring up this (geolocate_mod/geolocate_mod.html) page on your smartphone, and write down the (latitude,longitude) values that get shown when you load/refresh the page :) As you can see, the page shows your location on a map - cool! Be sure to enable cross-site script loading when you run this - click on the shield icon at the right of the URL bar, and click on 'Load unsafe scripts'. Alternately, you can use this (geoloc2/run.html) page to obtain the (latitude,longitude) coordinates - for this to work, be sure that the browser url starts with https:// [type this in, if you need to].

• **using your phone's built-in GPS/compass app**, simply read off the displayed GPS coordinate values (if the coordinate display is in degrees, minutes and seconds, you need to convert the minutes,seconds pair of values into a single fractional degree value - one degree is subdivided into 60 minutes (60'), and one minute is subdivided into 60 seconds (60") - so for example, 30'15", since it is equivalent to 1815", would be eqvt to 1815/3600=0.504 degrees.

Also, be sure to write down the location names as well (you will use them to label your points when displaying). AND, take a selfie (!) that clearly shows the location you're sampling - **this step is to ensure that you're not simply reading off the coords from a map, sitting at home**! You'll lose points if you don't submit selfies.

2. Now that you have 12 coordinates and their label strings (ie. text descriptions such as "Tommy Trojan", "SAL", "Chipotle"..), you are going to create a KML file (.kml format, which is XML) out of them using a text editor. Specifically, each location will be a 'placemark' in your .kml file (with a label, and coords). Here (https://developers.google.com/kml/documentation/kml_tut#placemarks) is more detail. The .kml file with the 12 placemarks is going to be your starter file, for doing visualizations and queries. Here (data/starter_kml.xml) is a .kml skeleton to get you started (just download, rename and edit it to put in your coords and labels). NOTE - keep your labels to be 15 characters or less (including spaces). Here (data/starter_kml.txt) is the same .kml skeleton in .txt format, if you'd like to RMB save it instead and rename the file extension from .txt to .xml. NOTE too that in .kml, you specify (long,lat), instead of the expected (lat,long) [after all, longtitude is what corresponds to 'x', and latitude, to 'y']!

You are going to use Google Earth to visualize the data in your KML file (see #3 below). FYI, as a quick check, you can also visualize it using this (http://display-kml.appspot.com/) page - simply copy and paste your KML data into the textbox on the left, and click 'Show it on the map' to have it be displayed on a map on the right :)

3. Download Google Earth (https://www.google.com/earth/download/ge/agree.html) on your laptop, install it, bring it up. Load your .kml file into it - that should show you your sampled locations, on Google Earth's globe :) Take a snapshot (screengrab) of this, for submitting.

4. Install Oracle 11g+Oracle Spatial, or Postgres+PostGIS on your laptop, and browse the docs for the spatial functions. Here (BigSQL/index.html) is my page that walks you through installing a packaged version of Postgres.

4 (alt). You can also use MySQL (https://dev.mysql.com/doc/refman/5.7/en/spatial-extensions.html) if you want, or even sqlite (http://www.bostongis.com/PrinterFriendly.aspx?content_name=spatialite_tut01); if you are familiar with using SQL Server (https://docs.microsoft.com/en-us/sql/relational-databases/spatial/spatial-data-sql-server), that can also help you do the homework. Even QGIS (https://gis.stackexchange.com/questions/38937/how-to-connect-to-postgres-with-qgis) can be used to do the HW.

4 (alt alt). IF YOU ARE FEELING ADVENTUROUS: as an alternative to installing Oracle or Postgres (or MySQL or sqlite or SQL Server...) on your machine, you can use Postgres or Oracle on the AWS cloud platform (ie. without installing anything on your laptop!) - eg. see this (https://aws.amazon.com/free/?) page, and this (https://aws.amazon.com/rds/postgresql/) one. **Be sure to not leave your DB instance running, when you aren't working on the hw!**

4 (alt alt alt). Last but not least, do feel free to use GCP for this! Here are some relevant resources:

* https://cloud.google.com/sql/docs/postgres/quickstart (https://cloud.google.com/sql/docs/postgres/quickstart)

* https://medium.com/google-cloud/postgres-is-incredibly-awesome-c54353b88655 (https://medium.com/google-cloud/postgres-is-incredibly-awesome-c54353b88655)

* https://cloudplatform.googleblog.com/2017/03/Cloud-SQL-for-PostgreSQL-managed-PostgreSQL-for-your-mobile-and-geospatial-applications-in-Google-Cloud.html (https://cloudplatform.googleblog.com/2017/03/Cloud-SQL-for-PostgreSQL-managed-PostgreSQL-for-your-mobile-and-geospatial-applications-in-Google-Cloud.html)

* https://cloudplatform.googleblog.com/2017/08/Cloud-SQL-for-PostgreSQL-updated-with-new-extensions.html (https://cloudplatform.googleblog.com/2017/08/Cloud-SQL-for-PostgreSQL-updated-with-new-extensions.html)

5. You will use the spatial db software to execute the following two spatial queries that you'll write:

• **compute the convex hull** for your 12 points [a convex hull (http://mathworld.wolfram.com/ConvexHull.html) for a set of 2D points is the smallest convex polygon that contains the point set]. If you use Oracle, see this (https://docs.oracle.com/cd/A97630_01/appdev.920/a96630/sdo_aggr.htm) page; if you decide to use Postgres, read this (http://postgis.net/docs/ST_ConvexHull.html) and this (http://stackoverflow.com/questions/10461179/k-nearest-neighbor-query-in-postgis) instead. Use the query's result polygon's coords, to create a polygon in your .kml file (edit the .kml file, add relevant XML to specify the KML polygon's coords). Load this into Google Earth, visually verify that all your points are on/inside the convex hull, then take a screenshot. Note that even your data points happen to have a concave perimeter and/or happen to be self-intersecting, the convex hull, by definition, would be a tight, enclosing boundary (hull) that is a simple convex polygon. The convex hull is a very useful object - eg. see this (https://www.quora.com/What-are-the-real-life-applications-of-convex-hulls) discussion.. Note: be sure to specify your polygon's coords as '...-118,34 -118,34.1...' for example, and not '...-118, 34 -118, 34.1...' [in other words, do not separate long,lat with a space after the comma, ie it can't be long, lat].

• **compute the four nearest neighbors** of your home/apt/dormroom location [look up the spatial function of your DB, to do this]. Use the query's results, to create four line segments in your .kml file: line(home,neighbor1), line(home,neighbor2), line(home,neighbor3), line(home,neighbor4). Verify this looks correct, using Google Earth, take a snapshot.

Note - it *is* OK to hardcode points, in the above queries! Or, you can create and use a table to store your 12 points in it, then write queries against the table.

Here is what you need to **submit** (**as a single .zip file**):

* your .kml file from step 5 above - with the placemarks, convex hull and nearest-neighbor line segments (1 point)

* your selfie pics that 'prove' you actually collected the point locations on site (.jpg or .png) (no points for selfies submission, but, -2 points IF YOU DON'T SUBMIT ALL OF THEM)

* a text file (.txt or .sql) with your two queries from step 5 - table creation commands (if you use Postgres and directly specify points in your queries, you won't have table creation commands, in which case you wouldn't need to worry about this part), and the queries themselves (2+2=4 points)

* screengrabs from steps 3,5 (1 point)

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BONUS QUESTION! [1 point]

Using SGM 123 as the center, **compute** (don't/can't use GPS!) a set (sequence) of lat-long (ie. spatial) co-ordinates that lie along a pretty Spirograph(TM) curve (https://www.google.com/search?q=Spirograph+curve&num=100&source=lnms&tbm=isch) :)

Create a new KML file with Spirograph curve points [see below], convert the KML to an ESRI 'shapefile', visualize the shapefile data using ArcGIS Online, and submit these four items (**as a separate, bonus.zip file**): your point generation code (see below), the resulting .kml file ("spiro.kml"), shapefile (this needs to be a .zip) and a screenshot ("spiro.jpg" or "spiro.png").

DEN students: you can use as the center, a different spatial coordinate (eg. that of your home).

To convert your .kml into a shapefile, use this online converter: https://mygeodata.cloud/converter/kml-to-shp (https://mygeodata.cloud/converter/kml-to-shp) - the result will be a .zip [which is what we call 'shapefile'], which will contain within it, shape data (.shp), a relational table (.dbf), and other optional files (.shx, .prj, .cpg). Here (http://desktop.arcgis.com/en/arcmap/10.3/manage-data/shapefiles/what-is-a-shapefile.htm) is a page on shapefiles, and this (http://desktop.arcgis.com/en/arcmap/10.3/manage-data/shapefiles/shapefile-file-extensions.htm) talks about the various components (.shp, .dbf etc) of a shapefile.

Once you have your shapefile, you can upload it to ArcGIS' online map creator to view your Spirograph curve-shaped points. To do so, log on to ArcGIS [after creating a free 'public' account], at https://www.arcgis.com/ (https://www.arcgis.com/), then use the 'Map' tab - https://www.arcgis.com/home/webmap/viewer.html?useExisting=1 (https://www.arcgis.com/home/webmap/viewer.html?useExisting=1). Do 'Add -> Add Layer from File', and upload your shapefile .zip, you should see your data overlaid on a map. Here (spiro/ArcGIS_spiro.png) is a screenshot of roughly what to expect, and here (https://www.arcgis.com/home/webmap/viewer.html?webmap=2b8d27c576154fbe89f1140dfcab35df) is a live link.

For the Spirograph curve point creation, use the following parametric equations (with R=8, r=1, a=4):

```
x(t) = (R+r)*cos((r/R)*t) - a*cos((1+r/R)*t)
y(t) = (R+r)*sin((r/R)*t) - a*sin((1+r/R)*t)
```

Using the above equations, loop through t from 0.00 to n*Pi (eg. 2*Pi; note that 'n' might need to be more than 2, for the curve to close on itself; and, t is in radians, not degrees), in steps of 0.01. That will give you the sequence of (x,y) points that make up the Spiro curve, which would/should look like the curve in the right side of the screengrab below, when R=8, r=1, a=4 (my JavaScript code for the point generation+plotting loop is on the left):

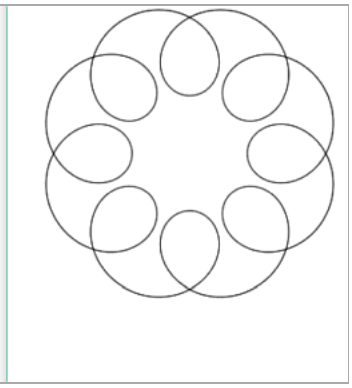
```
var canvas = document.getElementById('canvas');
if (canvas.getContext){
  var ctx = canvas.getContext('2d');

  ctx.beginPath();

  //x(t) = (R+r)*cos((r/R)*t) - a*cos((1+r/R)*t)
  //y(t) = (R+r)*sin((r/R)*t) - a*sin((1+r/R)*t)

  var R=8, r=1, a=4;
  var x0=R+r-a, y0=0;
  ctx.moveTo(150+10*x0,150+10*y0);

  var cos=Math.cos, sin=Math.sin, pi=Math.PI, nRev=16;
  for(var t=0.0;t<(pi*nRev);t+=0.01) {
    var x=(R+r)*cos((r/R)*t) - a*cos((1+r/R)*t);
    var y=(R+r)*sin((r/R)*t) - a*sin((1+r/R)*t);
    ctx.lineTo(150+10*x,150+10*y);
     //document.write(x+", "+y);
  }
 ctx.stroke();
```



Note - your figure MUST resemble the above, ie. it MUST have 8 loops.

In order to center the Spirograph at a given location [SGM123 or other], you need to ADD each (x,y) curve point to the (lat,long) of the centering location - that will give you valid Spiro-based spatial coords for use in your .kml file. You can use any coding language you want, to generate (and visualize) the curve's coords: JavaScript, C/C++, Java, Python, SQL (https://docs.oracle.com/cd/B28359_01/server.111/b28285/sqlqr02.htm), MATLAB, Scala, Haskell, Ruby, R.. You can also use Excel, SAS, SPSS, JMP etc., for computing [and plotting, if you want to check the results visually] the Spirograph curve points.

Payoff - what you'll see is the Spirograph curve, superposed on the land imagery - pretty!

PS: Here (https://www.google.com/search?q=Spirograph+curve&ie=utf-8&oe=utf-8) is MUCH more on Spirograph (hypocycloid and epicycloid) curves if you are curious. Also, for fun, try changing any of R, r, a in the code for the equations above [you don't need to submit the results]!

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HAVE FUN! From here on out, you know how to create custom overlays (via KML files containing vector symbols constructed from points, lines and polygons, and its shapefile equivalent) on a map, and perform spatial queries on the underlying data :)

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