Time in Open Source GIS Web-based Visualizations

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The purpose of this project was to develop and evaluate mapping techniques for spatio-temporal data using open-source GIS, graphic, and processing software. Due to breadth of analysis techniques for spatio-temporal data analysis and database storage issues, this project was focused on techniques to address web visualizations and secondarily data manipulation. By identifying the characteristics of the spatial, temporal and attributional dimensions, a spatio-temporal mapping visualization framework was developed to compare and contrast OSGIS techniques for data manipulation and web visualizations of spatiotemporal data. The following paragraph defines the identified key characteristics of spatial, temporal and attributional dimensions.

 Spatio-temporal mapping is the representation of changes in geographical phenomena through time. Spatial change components include: shape, location, presence and size. Temporal change components include: states, rate, duration and intervals. Attributes include qualitative and quantitative descriptors. State changes include spatial and attribute features a moment in time. A rate change is the speed of movement or the speed of change of spatial phenomena. A duration is a length of time of a condition of spatial feature and attributes. A duration has a beginning and an end time period. An interval is an event or a duration repeating in patterns.

Combinations of changes were evaluated in spatial, temporal and attributional dimensional components. For instance the following changes were evaluated: attribute change (i.e. land-use), spatial attribute change (i.e. national boundaries), moving objects (i.e. hurricane paths), rate of change (i.e. populations of invasive species), temporal aggregation (i.e. precipitation) and spatial aggregations (i.e. voting results). In addition, the following map visualization types were explored: static (single and multiple snapshots), dynamic display (animation), symbolic temporal representation and interactive visualizations. Figure 1 shows the spatio-temporal mapping visualization framework. Some of the open source software evaluated included: Weave, timemap.js, Dojo.js, QGIS temporal extension, OpenLayers Tracking, D3 and i2maps (Figure 2).

Figure 1 – Spatial-temporal mapping framework

Figure 2 – OSGeo software evaluated

With static maps presentation is limited to a single image where time's passage is represented by symbols. They may be hard-copy or digital, single or multiple 'pages'. For static maps, two visualizations were identified: to show change from one state to another by the symbol design (census percent change) and to present two or more static maps with each showing a single state. A static map of the population density change for New York State from 1800 to 1810 was developed. The data included shapefiles and data from National Historical GIS (US Census figures). QGIS was used to create the single static map. Each example is categorized using the visualization framework. This example is a "static, single image – two states change - quantitative symbology". In this example symbol color represents change in data value between two states: two decadal censuses. An advantage of this example is that the user can see the change that occurred between two states. Disadvantages are that the static map requires interpretation and the user does not see the original two states (unless three maps are presented) (Figure 3). The next visualization was based on population change over 50 years (static multiple – shape change – multiple states – quantitative change). The software used was QGIS and Gimp. The advantage identified was that static multiple map visualization is good for publication. However, this visualization is dependant upon the viewer's ability to compare images to identify changes that have occurred. One other static map visualization evaluated included a satellite land use change image (static single – size/shape, location, presence changes – multiple states –

qualitative and quantitative changes). Depending on the method used (i.e. difference image, CVA), the land use change image can shows change in land cover, amount of land cover change and direction of change. Limitations of this visualization include spatial, spectral resolution and expert knowledge needed for the analyses and cause of change is not shown in the image.
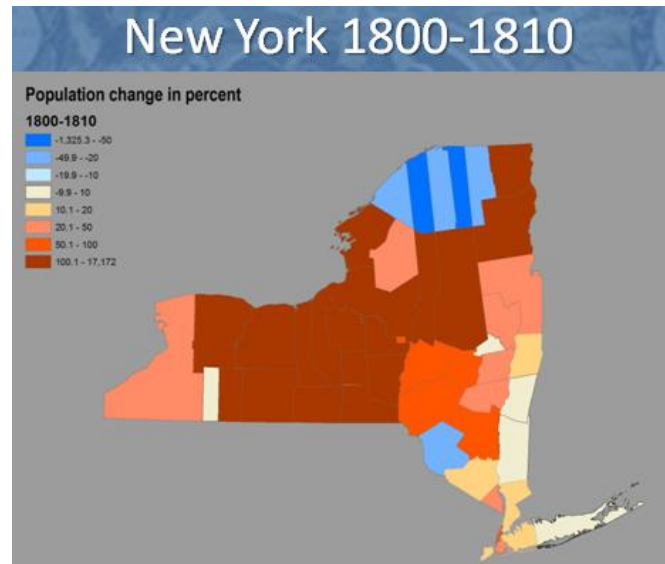

Figure 3 – Multiple state static change map

The second type of map visualization examined was animation maps. These maps present sequential static images in a structured time frame. A movie is a good example. The designer sets the content and the frame rate of the animation. The viewer only controls the start, stop, and sometimes pause of the flow. The sequence may be looped (repeating until a control ends the play). Animations are unidirectional. All information is presented on the frames, no querying beyond the presentation is possible. One of the example animations created was a track map of the voyage of the HMS Beagle. The color of symbols were coded for air temperature sampled at each stop. The data for this example were processed in Excel and Q-GIS. Animation frames were from Q-GIS plugin Time Manager. An AVI movie of the frames were made in VirtualDub. This animation is a great visualization for vector data within QGIS for data after 1970. Several limitations were identified. For instance, it was found that database requirements for data formatting were incompatible with data for the example. These problems occurred in both GIS animation and data preparation software. Specifically, dates in Excel are limited to 1900 and after. Hence, all dates were converted from 19th c. to 20th c. (i.e. 1831 to 1931) to access the date as a time stamp. Dates in Time Manager are limited to 1970 and after; all values were shifted 40 years to make the animation. A second animation example was created using population density change data in New York counties, 1623-2010 (Figure 4). Data were managed in Excel and Q-GIS. Annual map frames were exported and converted to an AVI movie in VirtualDub. With this example, users can see the changes over time in size and shape easily. The quantity change is harder to see, requires interpretation. One major limitation are changes in areal units. Attribute values were associated with original areal unit (county boundaries). Areal units change over time which requires a method (i.e. weighted average) to estimate the changes.
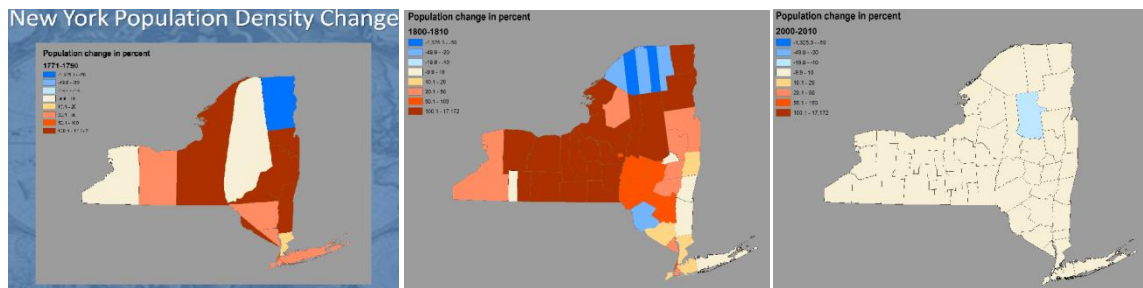
Figure 4 - Animation – size/shape and location change – multiple states – quantitative change

The next map type evaluated was interactive animations. The first example of this type is an example showing the Light rail train line through downtown Portland. The software used included: Open Plans Leaflet Animated Marker Plugin and the Leaflet map client. This visualization showed an automated track animation upon opening and allowed the user to interact with preprogrammed fields / information from database along the track. Although the software visualization implies a known travel rate, there is only a single rate for a given map. Additionally, various browser clients have limitations with the number of vertices/points that can be shown in json format- the more points, the slower the load time. A second interactive animation was created using data from the spread of Influenza in the epidemic of 1918 (interactive animation – size/shape and location change – rate of spread – qualitative and quantitative change) (Figure 5). The software components evaluated included: QGIS (for creating the map frames) and the Jquery timeline slider. This visualization allowed the view to interact with slider to see each time stamp or use the play button for automated play back. With this visualization there were no additional attribute information via popup, tables or queries.
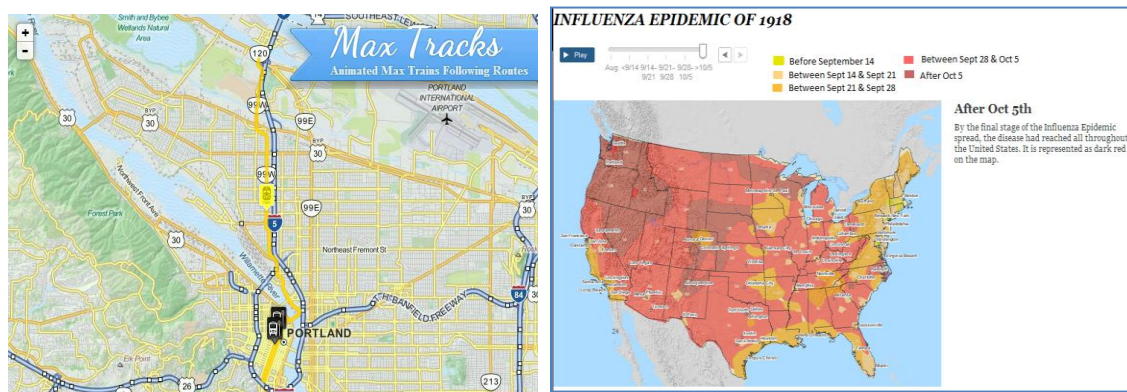

Figure 5 - Interactive animation and location change. Inflenza map is also size shape change, rate of spread and qualitative and quantitative change

A third interactive animation map with multiple states were created with a software package entitled Weave. Weave animations use Flash animation and data from a SQL database (MySQL or POSTGIS). Two interactive animations were created using estimated adult wild steelhead return by population group and Oregon counties' vineyard acres by year (Figure 6). The viewer of the two Weave visualizations can interact with the data, create subsets of the data and control the animation. The visualizations include graphs/charts linked with map and the data are easily

downloadable. Flash is required for these visualizations. The visualization can be slow loading. Weave can only be used with vector data to create choropleth maps.
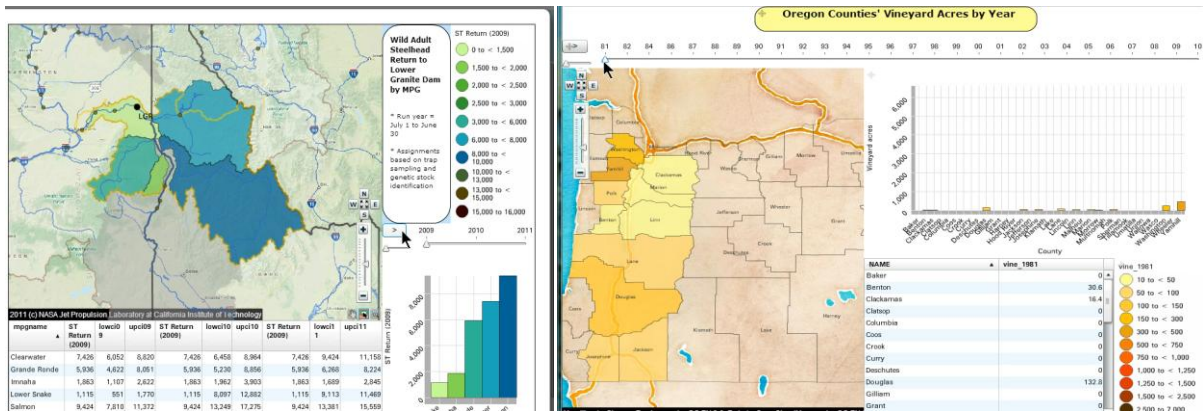

Figure 6 - Interactive animation – spatial presence change – multiple states – qualitative and quantitative change

Several examples were evaluated using Timemap.js, including an interactive 2011 flood duration map (Interactive – presence change – duration – qualitative and quantitative). The viewer can interact with site information via popups. Several types of data can be included on timemap.js including graphics and charts, proportional symbols, points, polygons, lines, routes, raster, and polygon boundary changes. The viewer has control over timeline and the viewer can select filtered subsets of data to display. However, various browser clients have limitations with the number or vertices/points that can be shown. With some browsers, the more points, the slower the load time. Another limitation is that the designer must create the legend outside of Timemap.js (Figure 7). Several other interactive spatio-temporal visualizations were evaluated. The software used in creating these visualizations included: OpenLayers Control TimeSliderBar and OpenLayers Layer TimedPointTrack, OpenLayers map client, Kartograph.js, JQueryGeo, OpenLayers WMS-t Animated controls and scripts, Dojo Toolkit, D3.js and I2maps.
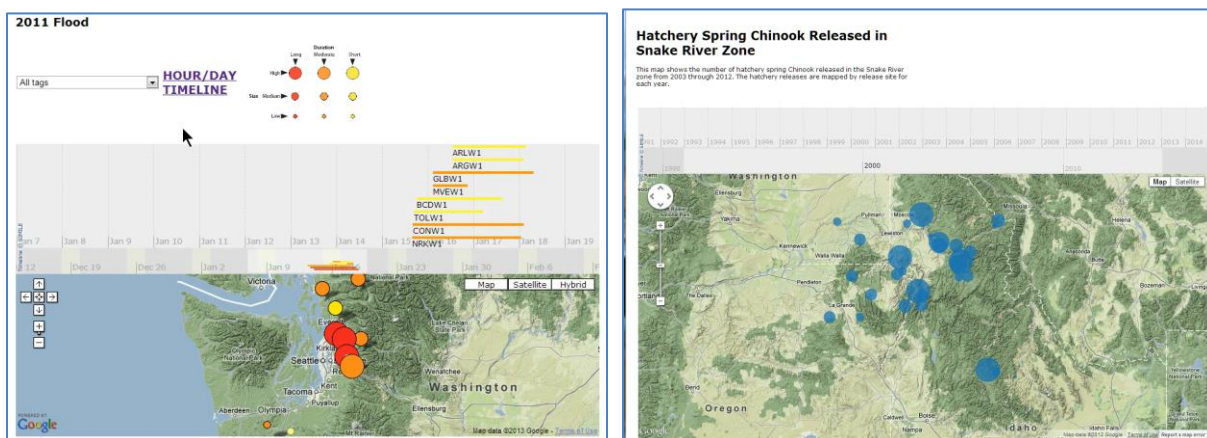

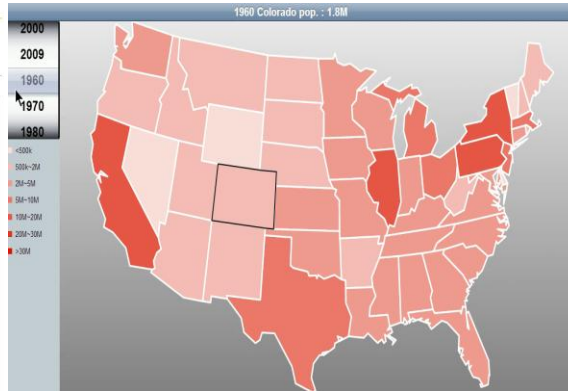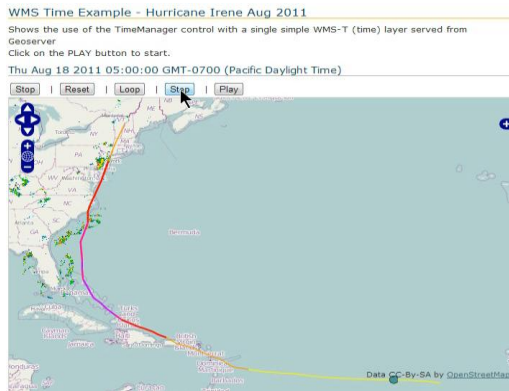**Figure 7 - Interactive – presence change – duration – qualitative and quantitative**
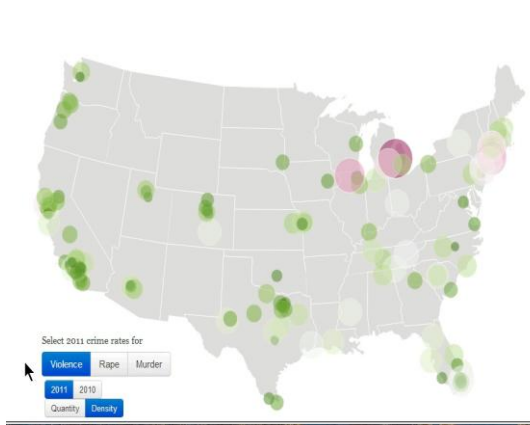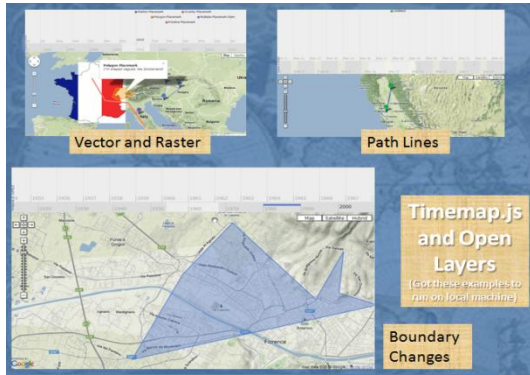
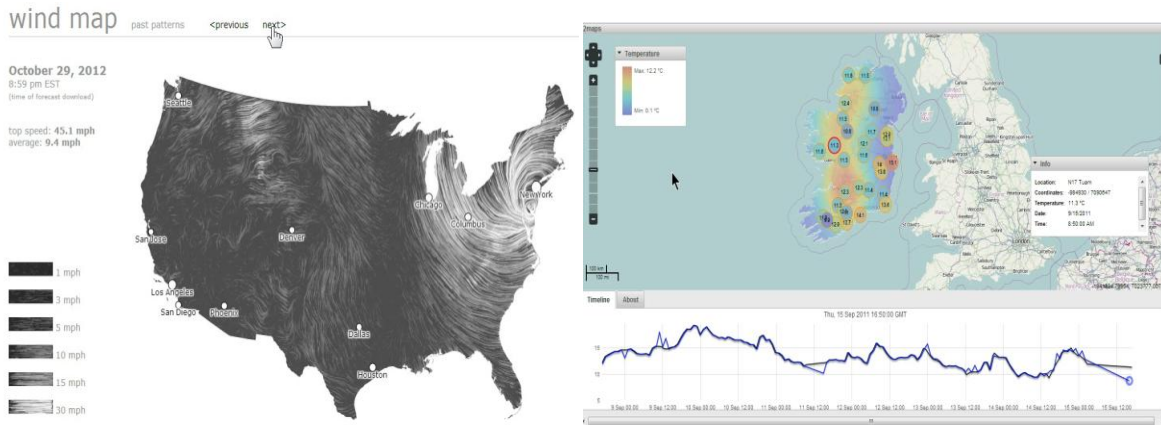**Figure 8 – Other Interactive spatio-temporal visualizations**

Figure 9 - Interactive – all spatial changes – multiple states – qualitative and quantitative

After evaluating the aforementioned spatio-temporal visualizations, the following data manipulation issues, map design issues, spatial boundary issues and data classification issues were identified. Formatting dates in Excel is a problem as it does not recognize dates earlier than 1900. QGIS Time Manager plugin does not recognize dates earlier than 1970. When converting dates from Julian to Gregorian calendars, different regions converted at different times. Time zones and leap years may affect data usability. Additionally, date formats are different for every parser. Dates must usually be converted into requested format for each software package. Getting data into a format that the software stack can use can be time consuming and there are many types that are used. Each software recognizes only a few formats. Some of formats used were Google spreadsheet, Geojson, Postgres/PostGIS WMS from GeoServer/MapServer, text file, raster image (GeoTiff), ESRI shapefile, Excel spreadsheet, CSV, SVG. Big data (many date/time states) can significantly slow down processing and map rendering. A one-minute animation at 20 frames per second has 1200 images. It is important to note that other online mapping options may assist with this (i.e. Cartodb). At times, parsers can miss some characters that prevent data from being read correctly. Small, almost invisible characters can stop the program. There are missing intervals in some data sequences. It is hard to determine how to code non-data areas so they'll draw up as something. Sometimes geographic images are not georeferenced (GOES). When using track data it is important to be aware that just because you have coordinates in a track it does not mean that it won't make an impossible path (i.e. ship coordinates crossing land.)

It was found that some software components do not have included legends, scales or other title/notes/text. The designer is required to develop them separately. Additionally, some freely available map backgrounds (Google Maps, OpenStreetMap) can't be projected on-the-fly in the software. The designer can project them externally and then time them otherwise the visualization must use spherical Mercator for the map display.

Boundaries from different sources may not line up and can create slivers and gaps. Boundaries of administrative/political entities change over time, again you have different polygons, and sliver/gaps. Additionally, there are areal unit change problems. Attribute values are associated with original areal unit (county boundaries). Areal units change over time which requires a method (i.e. weighted average) to estimate the changes.

Data classification include: Data described in two eras may have different parameters, level of detail, inclusion or elimination, accuracy/precision. One example is habitat inventories. Categories are dependent on the purpose of the inventory and the researchers. Between two temporal states new habitat classes may be identified and old classes need to be reconciled to newer ones. Habitat studies are constrained also by the varying boundaries of old and new classes. A second example is the decadal Census information. Decade by decade, the information collected has changed with new categories added, old ones removed or definitions altered, so that comparing two states can be difficult.

Overall, it was concluded that Open source is, for the most part, a competent and even excellent substitute for commercial software. It's getting better all the time. Although open source software is comparable to propriety software, finding the software takes some searching and testing. It is recommended that the user start at SourceForge.net and GitHub.com. The open source online community of users is the best part. Someone, somewhere has done it and posted the solution. (Or at least a hint.) However, documentation is highly variable. Processes you're familiar with will take much longer (at least the first time). There is no 'all-in-one' package; you will cobble together a collection of components. You will be programming or rewriting existing programs at some point. Data processing will take the majority of your time. The software that was evaluated is capable of visualizing almost all of the categories in the spatial-temporal visualization framework. However, both interval data and variable movement data (i.e. animal motion) were not evaluated.

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