

## GeoTime Product Evaluation

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Abstract: GeoTime is a stand-alone spatio-temporal browser with built-in queries for analyzing imported datasets containing events with defined spatial and temporal footprints. Events can be viewed as discrete points in a 3D space-time cube (with the the z-value representing the time axis), or can be viewed as entities (which are comprised of multiple location-events). The current version of GeoTime can directly load tables and flat files (including KML), but must be used together with ESRI ArcGIS to load from shapefiles and layers.

Installation: The installation package for GeoTime includes an executable installer (for Windows only), a license file, and a third-party map library application, called MapMan. For GeoTime to run with ESRI files, both ArcGIS 9.2 or 9.3 must be installed, along with .NET, and Excel. Installation on ArcGIS 9.3 worked as expected during testing, but failed to completely integrate with ArcGIS 9.2 (due to an error with ESRI .NET assemblies).

On the ArcGIS 9.3 install, the application worked for the administrator user profile only. It was not clear how to install the application for all user profiles. There are some options for installing the application with a license server, presumably to run as a keyed application over a limited subnet group of machines. However, since we are using the trial-period stand-alone client we don't know the level of difficulty in getting the license server (third-party software) to run.

The MapMan package, included with GeoTime, takes considerably longer than GeoTime to install. Presumably the MapMan package is optional, as it only offers some mapping capabilities for the planar surface map. The 3D rendering engine is contained within GeoTime and should run by itself.

Data Loading: Loading the tutorial samples (Taxicabs in Baghdad) works when following the GeoTime Data Import Tutorial. Shapefiles are opened with ArcMap, then loaded to GeoTime using the commands on an ArcMap GeoTime extension toolbar. In the Date/Time configuration step, values can be read from the shapefile's attribute table either from a plain text field (as interpreted by a drop-down list of possible formats) or as a standard Date format field.

Import from KML: tested using Ming Garrisons KML file, which includes time stamps. The data loaded into GeoTime, though the Chinese Characters (in UTF-8 encoding) were not interpreted correctly. Begin times are indicated as

floating nodes, while the end times (which are mostly the same in this dataset) are shown as little perpendicular feet below the start nodes. A vertical gray bar connecting the begin and end time of each instance represents the "lifetime" of the events, and is referred to in GeoTime as the Location – Vertical Axis. The event node in GeoTime always represents the begin time of the instance. See figure 1.

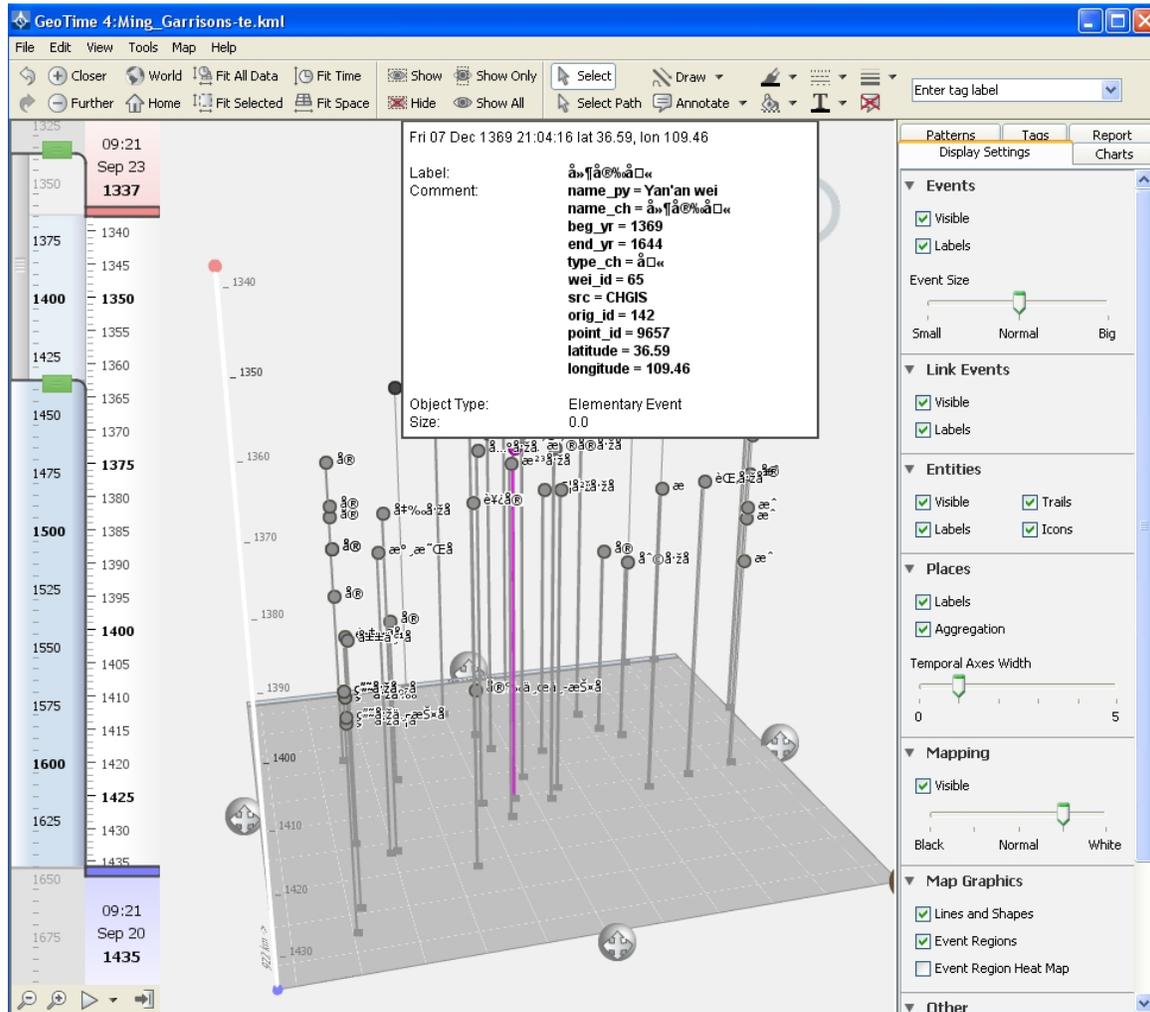


figure 1: Ming Garrisons KML file loaded into GeoTime

Loading from Excel is also fairly simple, using a wizard for selecting the columns that indicate BEGIN TIME, LATITUDE, LONGITUDE, and ENTITY. Entity is used to group together multiple events (time + location nodes) so that they can be visualized as trail that traverses space (across the horizontal grid plane) and time (the vertical linear scale). The data loading configuration is shown in the following figure 2, which is launched by a GeoTime Excel toolbar. Once the configuration settings have been selected, either the "Quick Send" or "Send and Replace" button, will launch the GeoTime application itself.

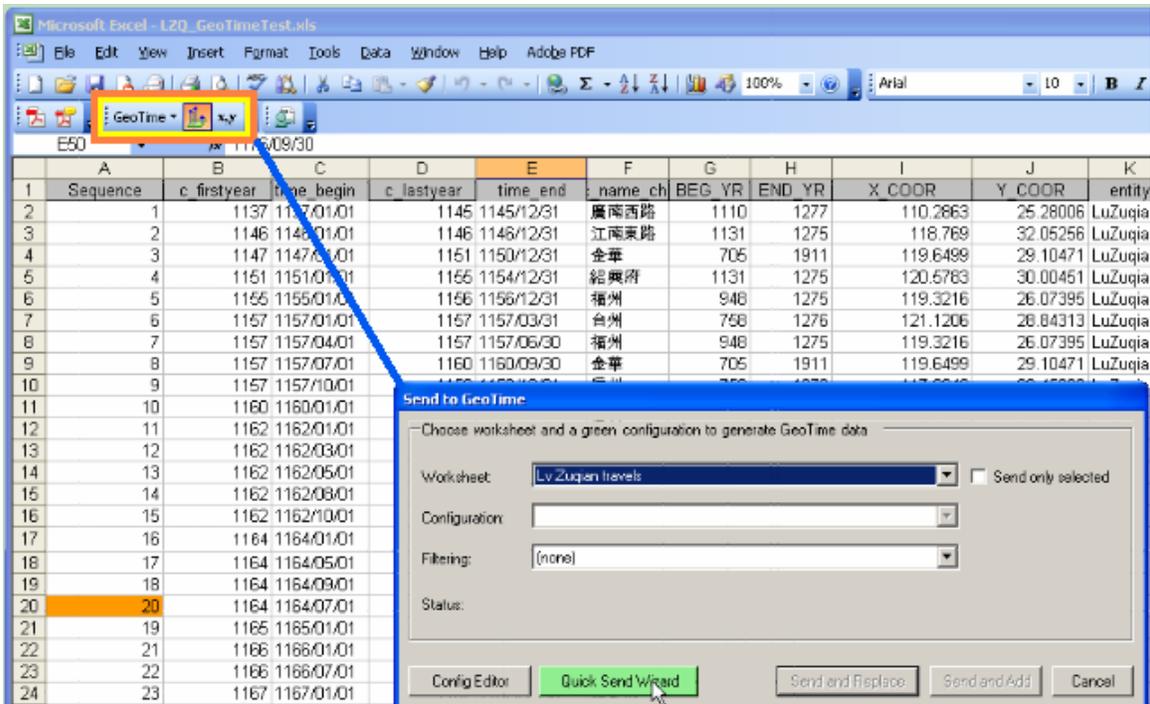


figure 2: loading from Excel configuration dialog

The resulting upload of data from Excel is shown in the following figure, which will be described in greater detail below.

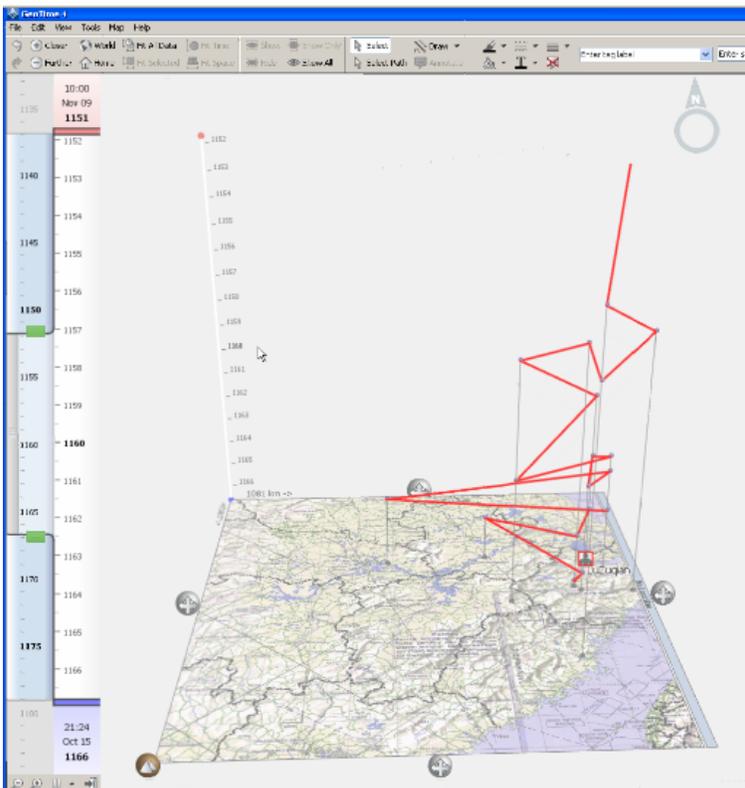


figure 3: Excel data showing the trail of nodes formed by a single entity in GeoTime

## Data Visualization

The figure illustrating the imported Ming Garrisons KML file (figure 1) is a good example showing how the earlier points in time are higher in the 3D visualization, while the current time is the plane at the bottom. Therefore, if we were to animate the dataset, the nodes would appear on the plane exactly when their "begin time" value matched the current time (indicated on the vertical time bar at the left), and the nodes would then continue to rise vertically as time progresses.

If a sequence of nodes is grouped together into one "entity," the visualization method results in a 3D trail. As time progresses the current time location will be shown on the bottom map plane, while the past time nodes will rise up vertically. In the figure below, the nodes represent locations visited during the life of the Song Dynasty philosopher and scholar Lv Zuqian, with a 15 year "visibility window" set on the left hand slider bar (from 1152 at the top to 1167 at the bottom).

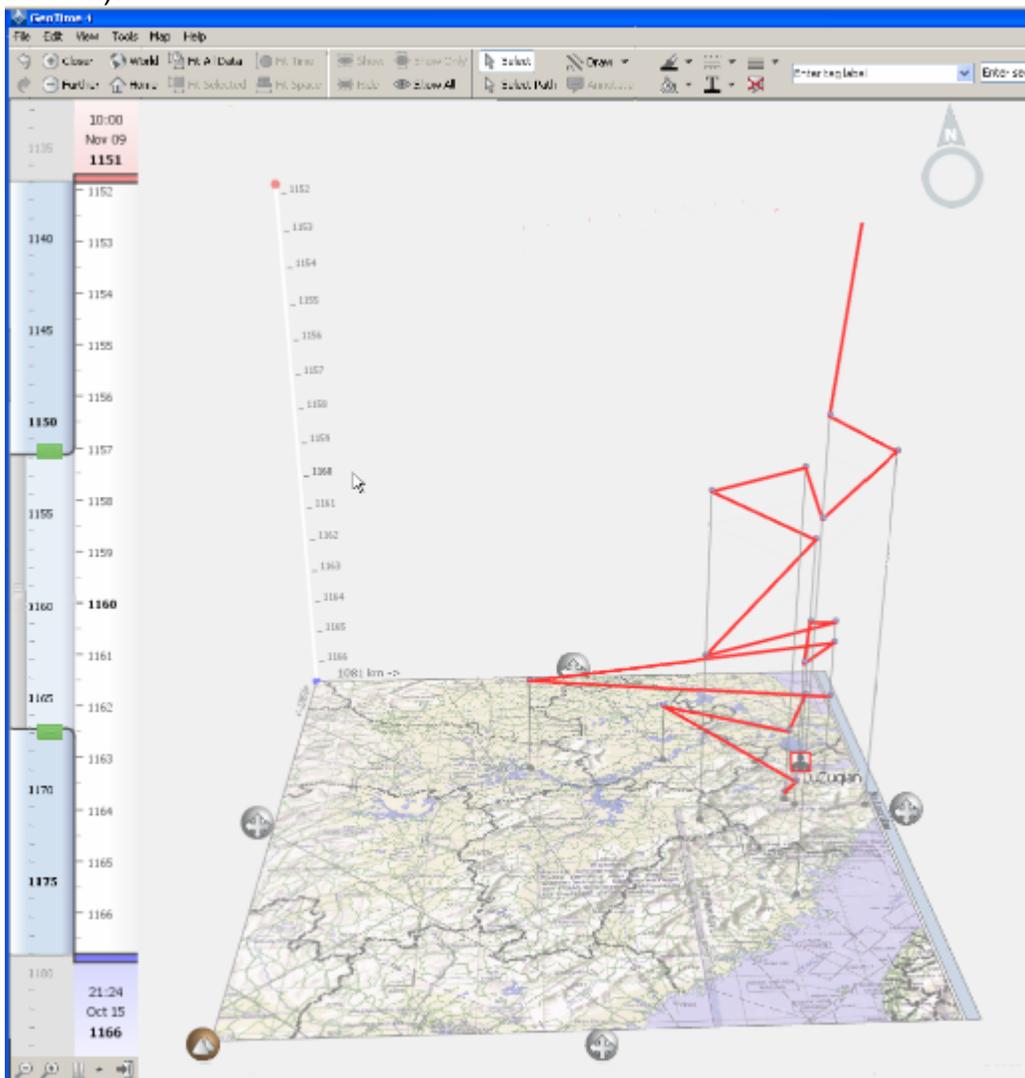


figure 4: GeoTime visualization of an entity (with time as z-axis)

In the preceding image, the nodes are interpreted based on their start times only, and a diagonal is drawn from the start time of any instance directly to the start time of the subsequent instance. If the configuration file is changed to include an end time, the visualization is augmented with an additional **vertical bar** for each event node, indicating its duration.

For example, if we zoom in on several of these nodes, you will see how this is represented in GeoTime. In the following figure 5, the vertical pink lines show the duration of the event record, from begin time to end time. The diagonal blue lines show the spatial transition from one event node to the next.

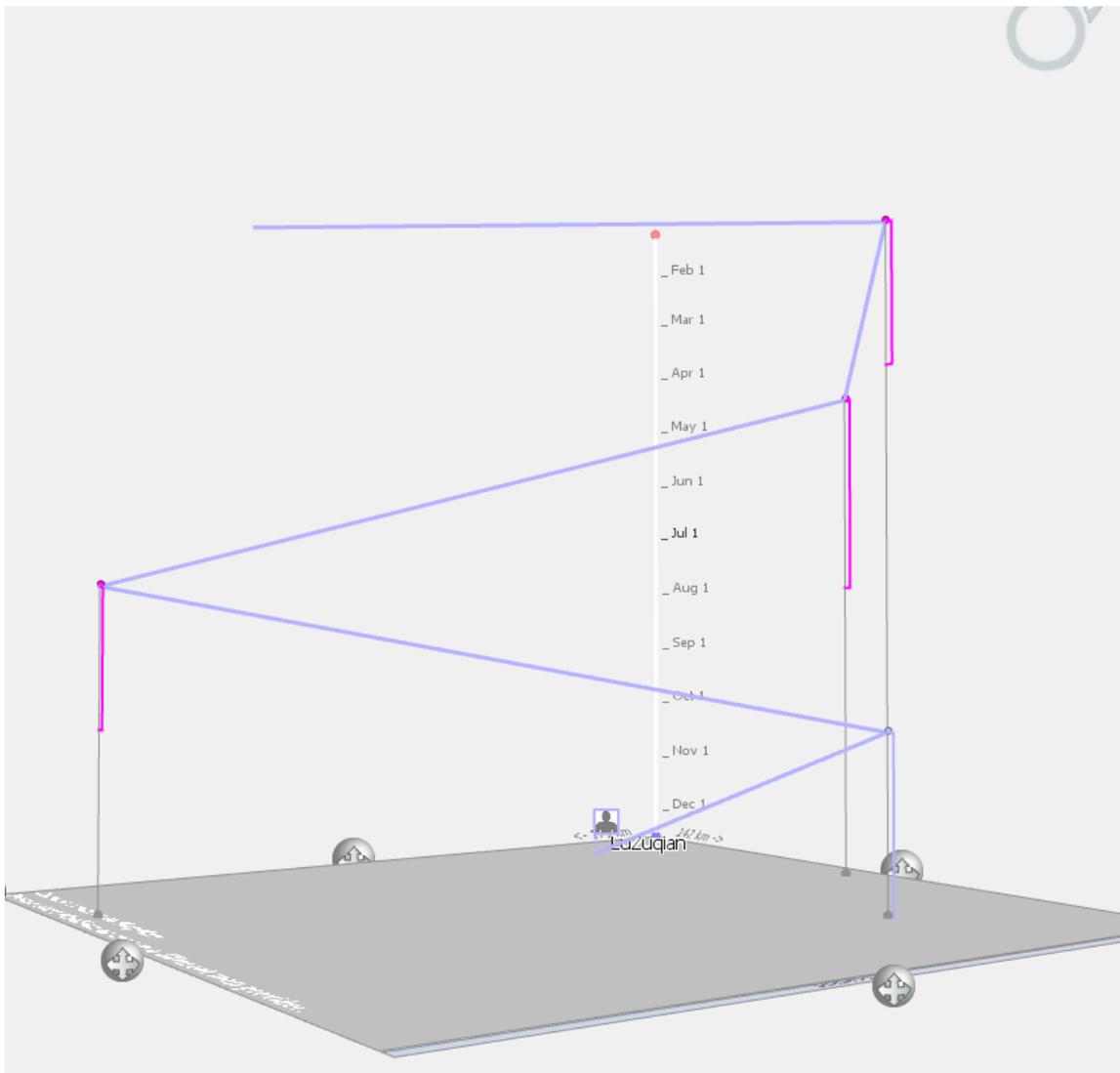


figure 5: GeoTime entity with **END TIMES** set for each event in the configuration file (resulting in a vertical pink bar for the duration of each event record).

This representation is best for keeping the semantic definition of an event separate from movement between events. However, it is a departure from the concept of events as a series of discrete instances (which have fixed locations and attributes for a specified period of time). In the latter case, it might make more sense for the transitions (the diagonals that connect instances) to join the END of one instance to the BEGIN of the subsequent instance. This type of historical instance is not explicitly defined in GeoTime, but can be visualized if need be by splitting each instance into two different event records (the first of which has only one time value equal to the instance's BEGIN time, and the second of which has a time value equal to the instance's END time.) The result should approximate the example annotated on the following figure, where the fixed instances are shown as vertical blue bars, and the transition between instances is shown as a diagonal pink line.

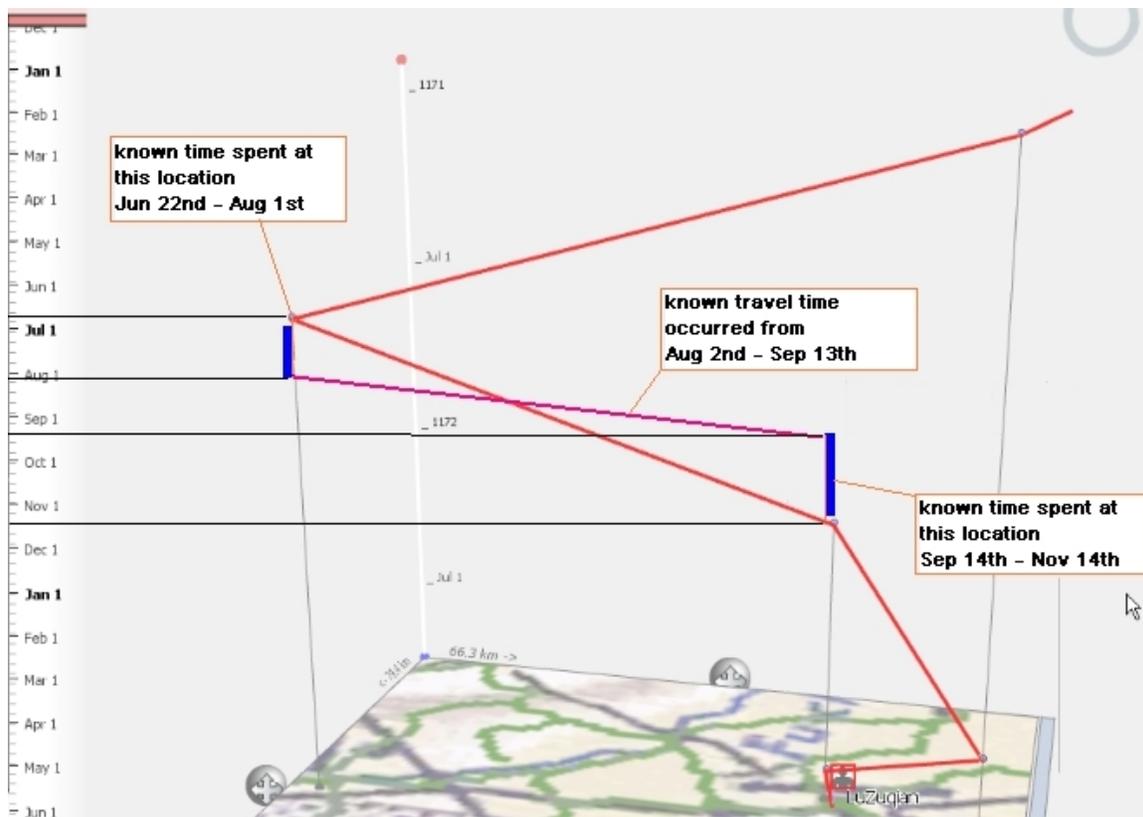


figure 6: workaround to represent instances at fixed locations for specific periods of time

### 3D Rotation

One of the primary selling points of GeoTime is the ability to easily manipulate the entire 3D visualization, which is always "live." Manually this is done by right-clicking the mouse on one of the four handle objects (gray spheres located halfway along each edge of the map plane), then dragging the handle in the desire rotation direction. This will drag the model at any possible rotation angle,

including bird's eye view directly down at the map plane, or nadir view directly up at the map plane, if so desired. The real time handling capabilities of GeoTime allow the user to explore the space-time configurations visually, revealing gaps, patterns or proximities that are obvious to the human eye, but might not be as easily detected in tabular data relationships. [https://cga-download.hmdc.harvard.edu/publish\\_web/GeoTime/](https://cga-download.hmdc.harvard.edu/publish_web/GeoTime/)

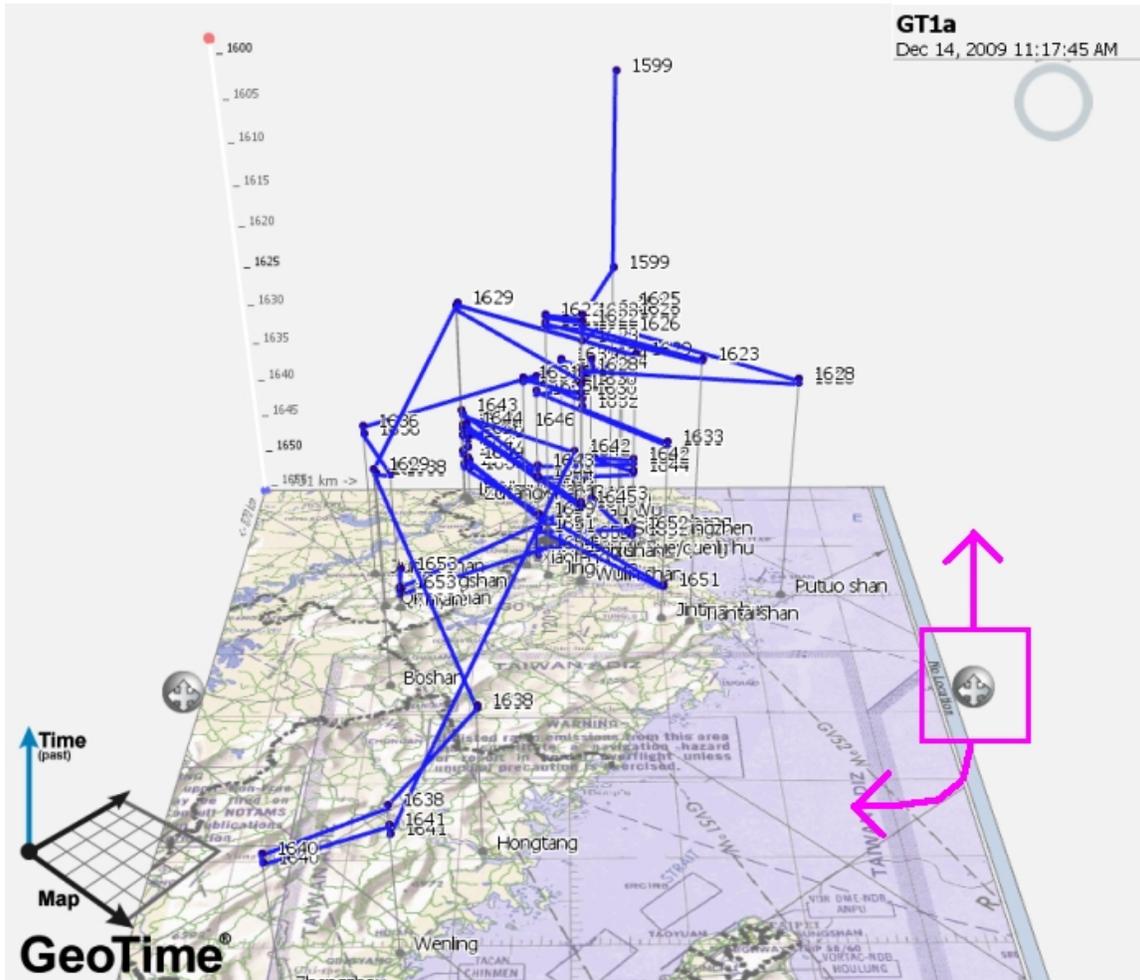


figure 7: manual 3D rotation of current view

### Time Bar and Animation over Time

The time bar control is a vertical measure along the left hand side of the screen with two important control parameters. One control is the total temporal span of the data shown in the current visualization. That is to say, if all the nodes of an entity that had a begin time of 1964/08/02 and an end time of 1975/04/30 are loaded into the current view, the timeline will extend for about twelve years, from 1963 at the top to 1975 at the bottom. These begin and end times are shown on the overall time scale using red (begin) and blue (end) time indicators.

Setting the extent of the data that is visible in the current view is done with the second time control, which is a time window parameter that is set using the top and bottom green tabs. The readings on the time bar are shown in two vertical scales on the left side of the screen. On the far left (in a sky blue tone) is the overall time scale. On the right (white background color) is the current view window time scale, expanded to show the range that has been set with the green tabs.

The example in Figure 8 shows a selection from the travels in China of a 17<sup>th</sup> Century Buddhist monk, Ouyi Zhixu. His lifespan (the overall timespan of the dataset) was from 1599 to 1655, as seen in the blue scale. The visible window of time has been set to 5 years, and is currently showing the event nodes that occurred between 1618 and 1623, seen in greater detail on the white scale.

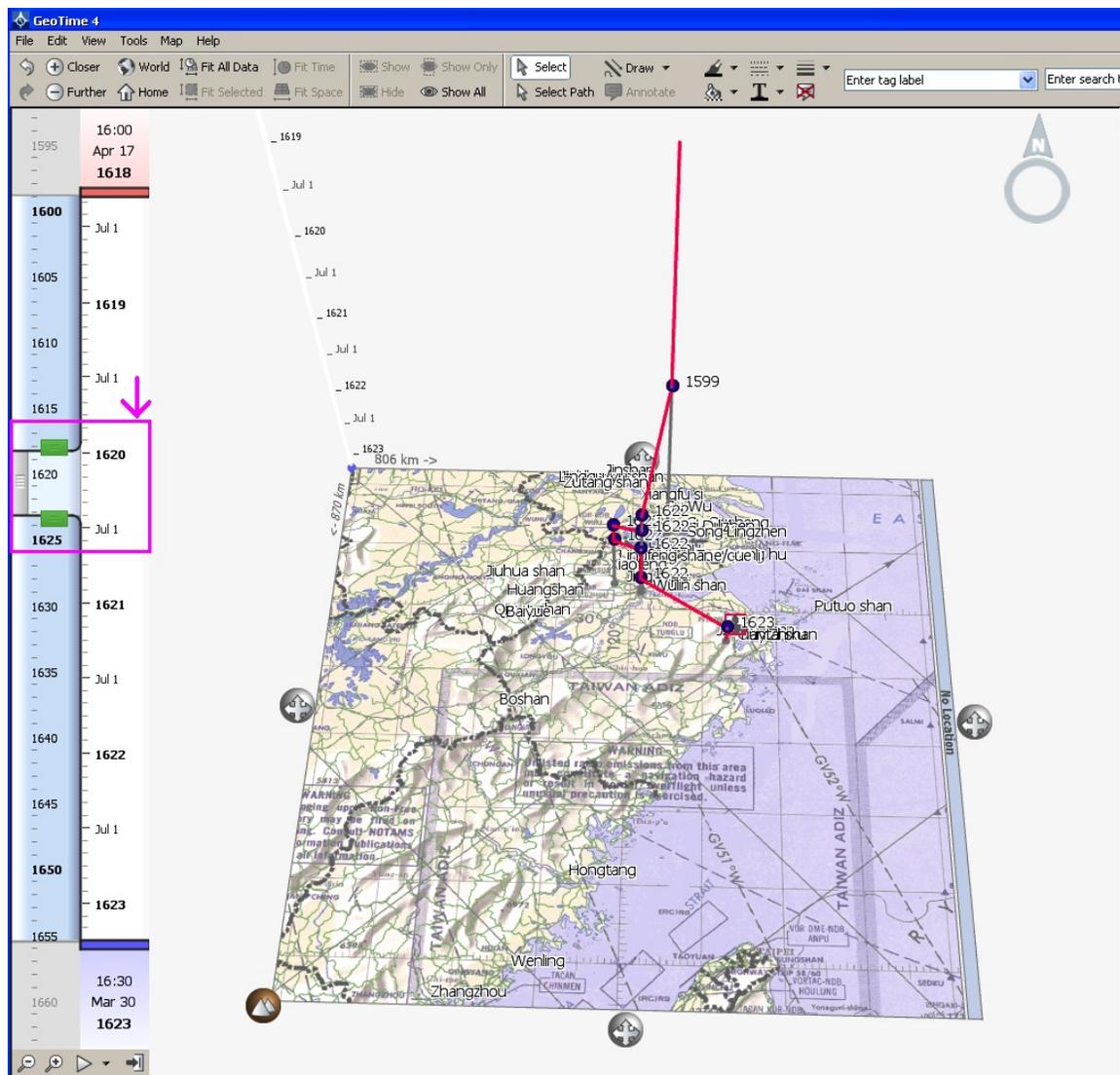


figure 8: time bar adjustment

Dragging the visible window frame up and down the blue overall time scale, will dynamically cause the 3D visualization to update. In this way the events will appear on the map plan at the moment of occurrence, then rise up along the vertical axis as they become past events.

### Selection of nodes, entities, and setting display values

In addition to setting the overall parameters of the time bar, which will constrain the visualization to the subset of the data, the user can use the mouse to drag a zoom box over the 3D clusters of event nodes to select a group of nodes. The "Fit to selected" command will then zoom into the subset area in time and space. Alternatively the user can drag a box on the map plane at the bottom of the 3D cube, to select all the events that occurred within a certain spatial bounding box.

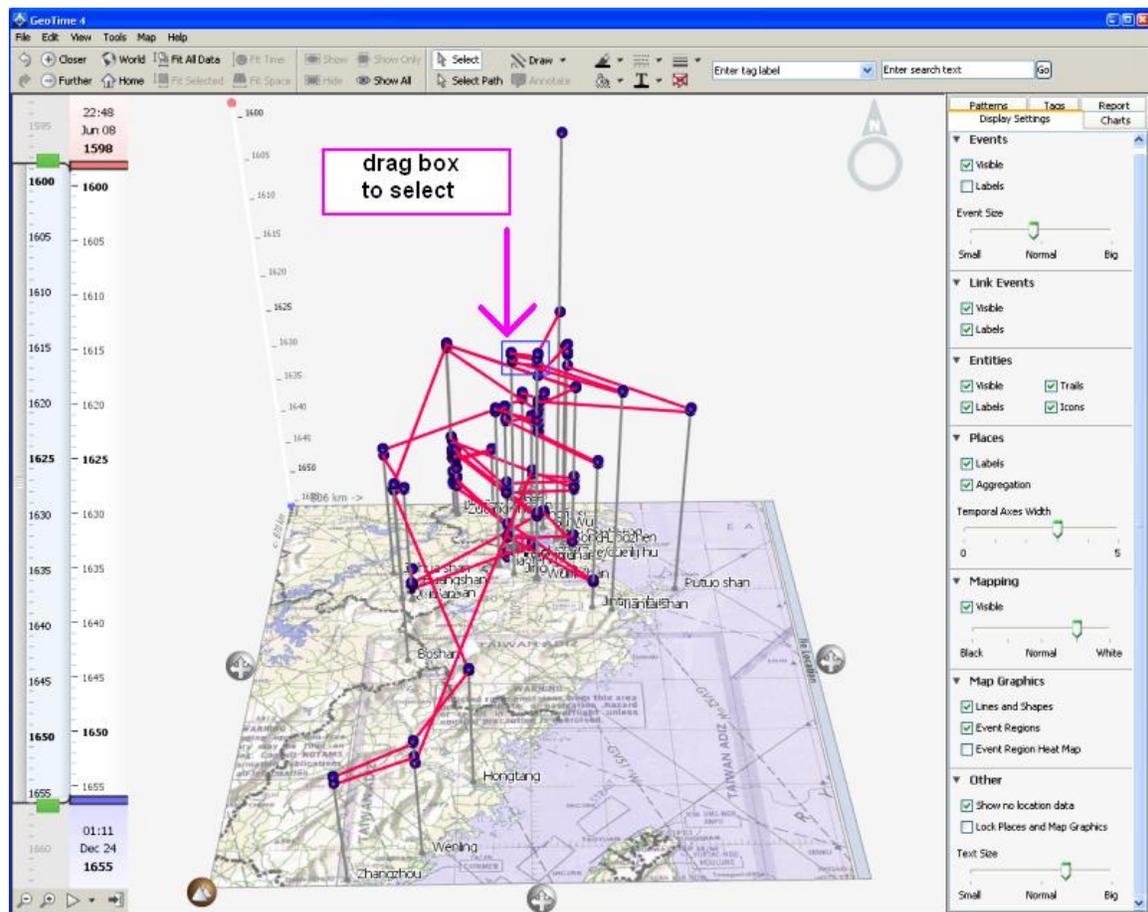


figure 9: selection of nodes with drag box

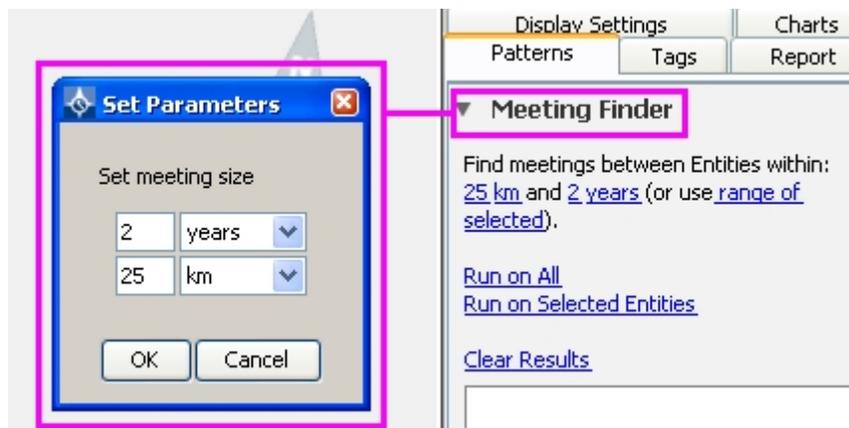
Entities, that is to say the entire trail designated at the time of loading data by having the same value in a specified entity field, can be manually selected by clicking on the trail that connects any two events within the entity.

Display settings, found in a tab along the right side of the screen, control the visibility and labeling of event nodes, in addition to their size. None of the display settings are open variables, but are all constrained within a certain fixed range (such as small – normal – big). Visibility and/ or labeling of link events, trails, entities, places, and graphics are all controlled in the same tab area. It is also possible to hide or make thicker the vertical axes that create a visual link between the event nodes and their location on the ground.

### Built-in Analytical Tools

GeoTime is not designed in a way that allows for users to design and implement their own algorithms to analyse data loaded into the system. Instead there are a series of generalized analytical tools, found under the Patterns tab on the right side of the screen. In the version of GeoTime 4 being tested, these included Meeting Finder, Gap Finder, Speed Finder, Connection Filtering, Paths between Objects, Link Analysis, Links between Entities.

During the testing phase, only the first three seemed to work for the datasets being tested, so let's look at how those function. The Meeting Finder essentially is a tool that places both a spatial distance and temporal span constraint on the objects in the 3D view. For example, in the supplied hurricanes dataset, a query to find all the events that were within 25km and 2years from each other can be run (figure 10).



**figure 10: Meeting Finder settings dialog**

The resulting clusters will be listed in the white results window within the Meeting Finder tool section on the right side of the screen. These results can be selectively displayed, or displayed all at once as shown in figure 11.

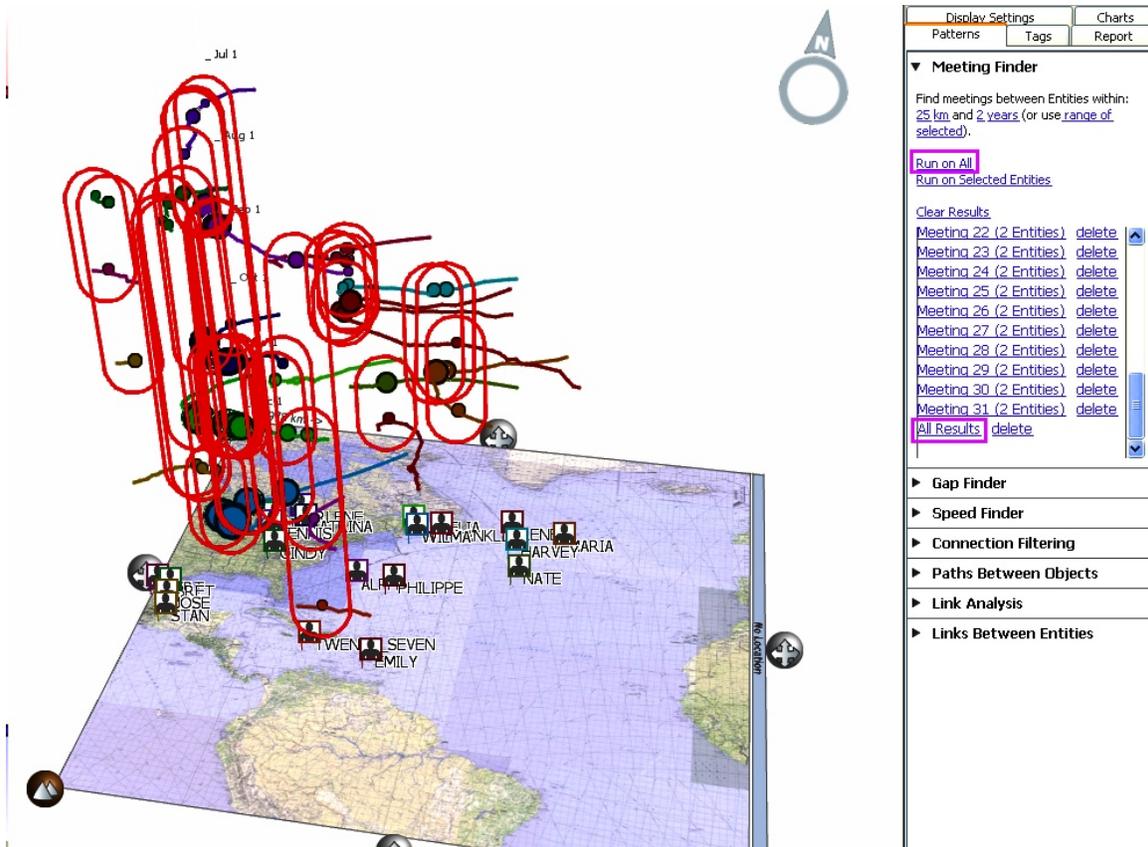


figure 11: Meeting Finder query results

The Gap Finder tool is used to find cases in the dataset where event nodes are separated by minimum gaps in time, which reveals cases where long intervals occurred in between events. The only parameter needed is the gap period.

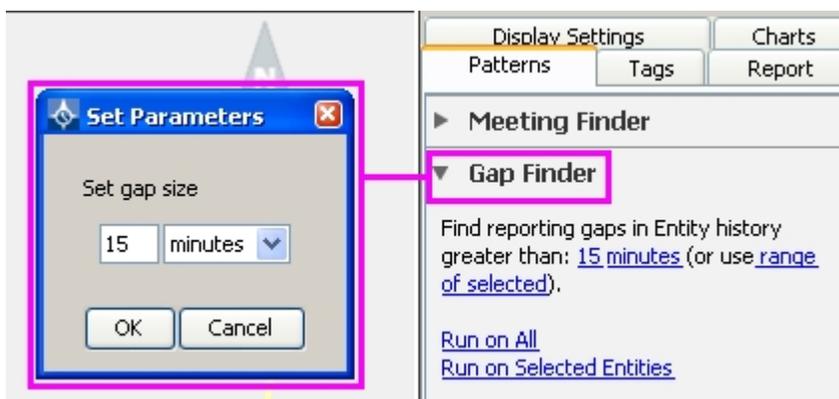


figure 12: Gap Finder settings

The sample dataset for taxicabs driving around the city of Baghdad was used to run the Gap Finder query, with results shown in figure 13.

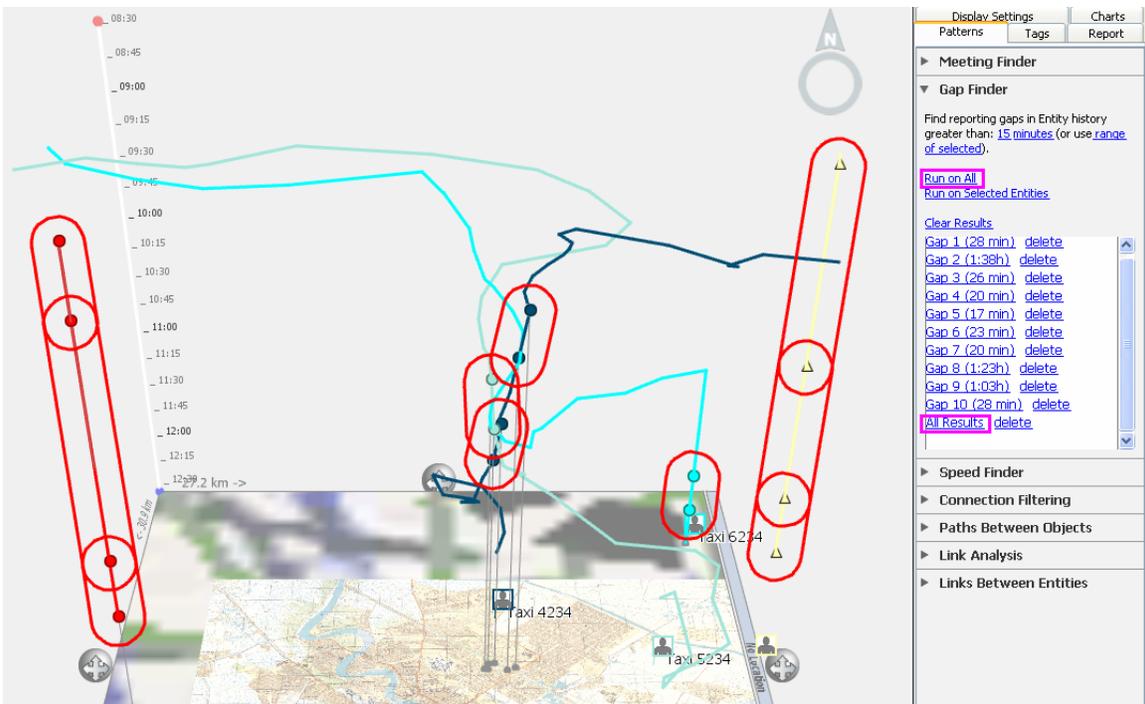


figure 13: Gap Finder query results (showing time gaps in between event nodes)

The Speed Finder computes the approximate speed of the entity in between events (by taking into the account the total time elapsed between the start time of each event and the total distance traveled between the two events). The calculation is based on the parameter of a maximum and minimum velocity setting.

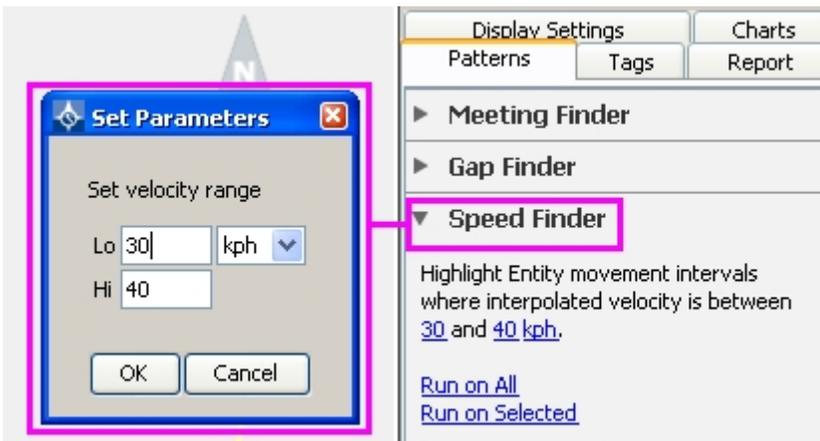


figure 13: query paths of movement where entities travelled between 30 and 40 km/hr

Speed Finder results are shown as black arcs, labeled with the elapsed time, distance traversed, and derived average speed, as shown in figure 14.

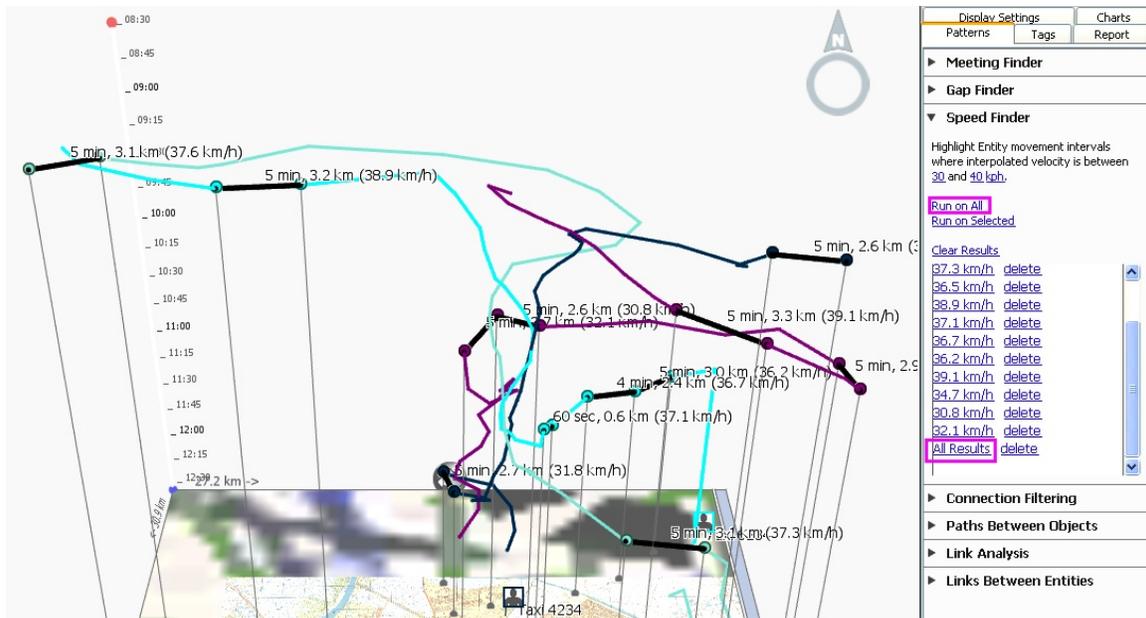


figure 14: Speed Finder results

Although the remaining four analytical tools presumably should work on the sample datasets provided, none of the test cases attempted produced results that could be displayed.

### Annotation and Reporting methods

An interesting feature in GeoTime is an annotation tool that creates a callout balloon that appears on top of the visualization window. This annotation balloon can be filled in with text, or can be populated automatically by a charting tool that reads occurrences or value ranges from a specified column in the dataset. When the user has navigated to the desired rotational angle, temporal window, zoom level, and has displayed all the available events or some query results as needed, the annotation balloon can be added. This balloon will remain visible within the visualization, but can be stored by creating a link, or "snapshot" of the current view (including the annotation balloon) in the Reports tab, also on the right hand side of the screen.

Once the desired view and accompanying annotation have been stored as a snapshot in the Report section, the annotation can be removed from the 3D view. After being removed the annotation will no longer be visible at any zoom level, but can be instantly called back by clicking on the snapshot link in the Report tab. A thumbnail view of the entire snapshot view is seen by hovering the mouse over any snapshot link that has been saved in the Report tab. When a Report is exported to html, the saved text, snapshot images and their related thumbnails are saved as a webpage, an example of which is shown in figure 15.

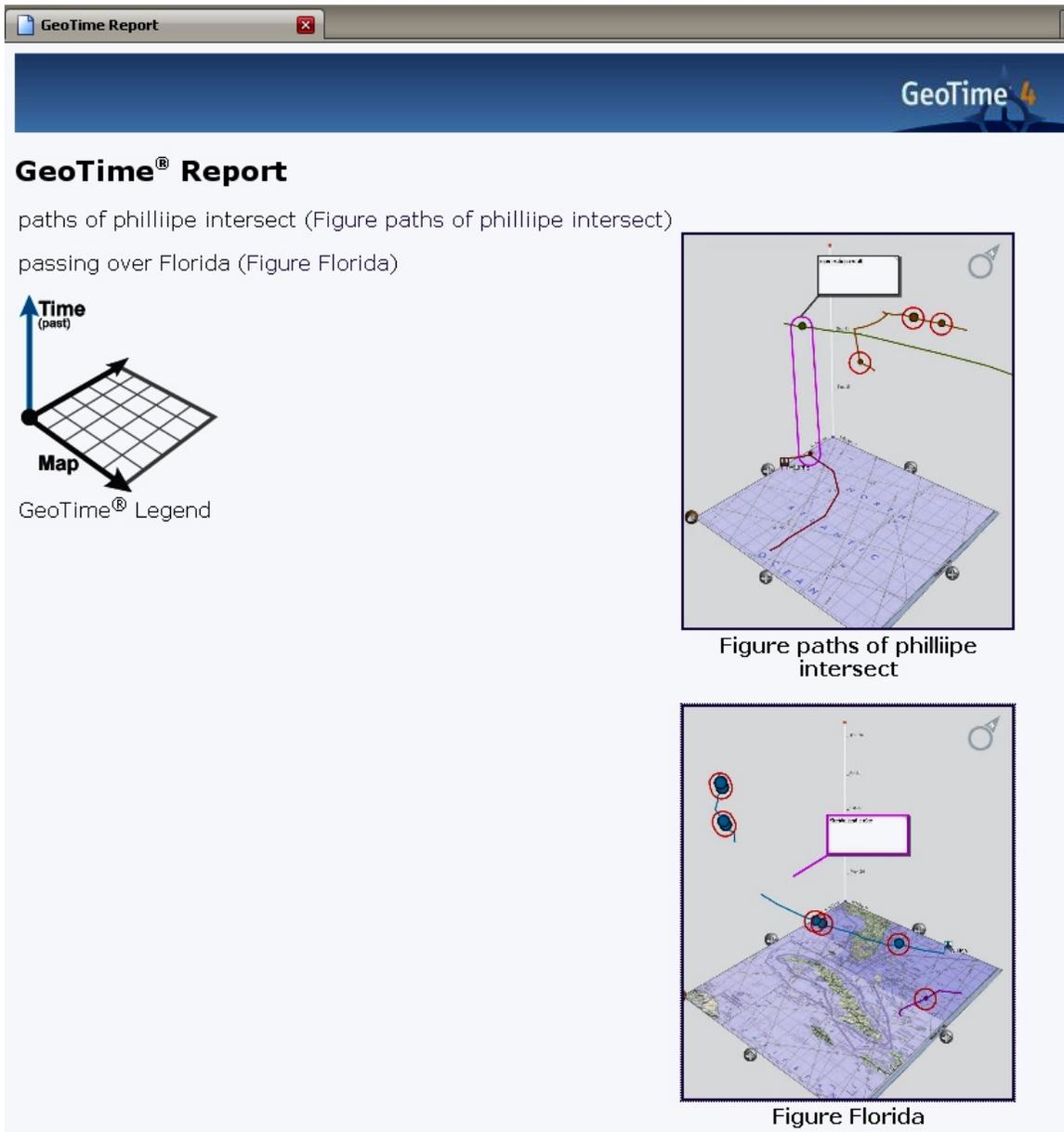
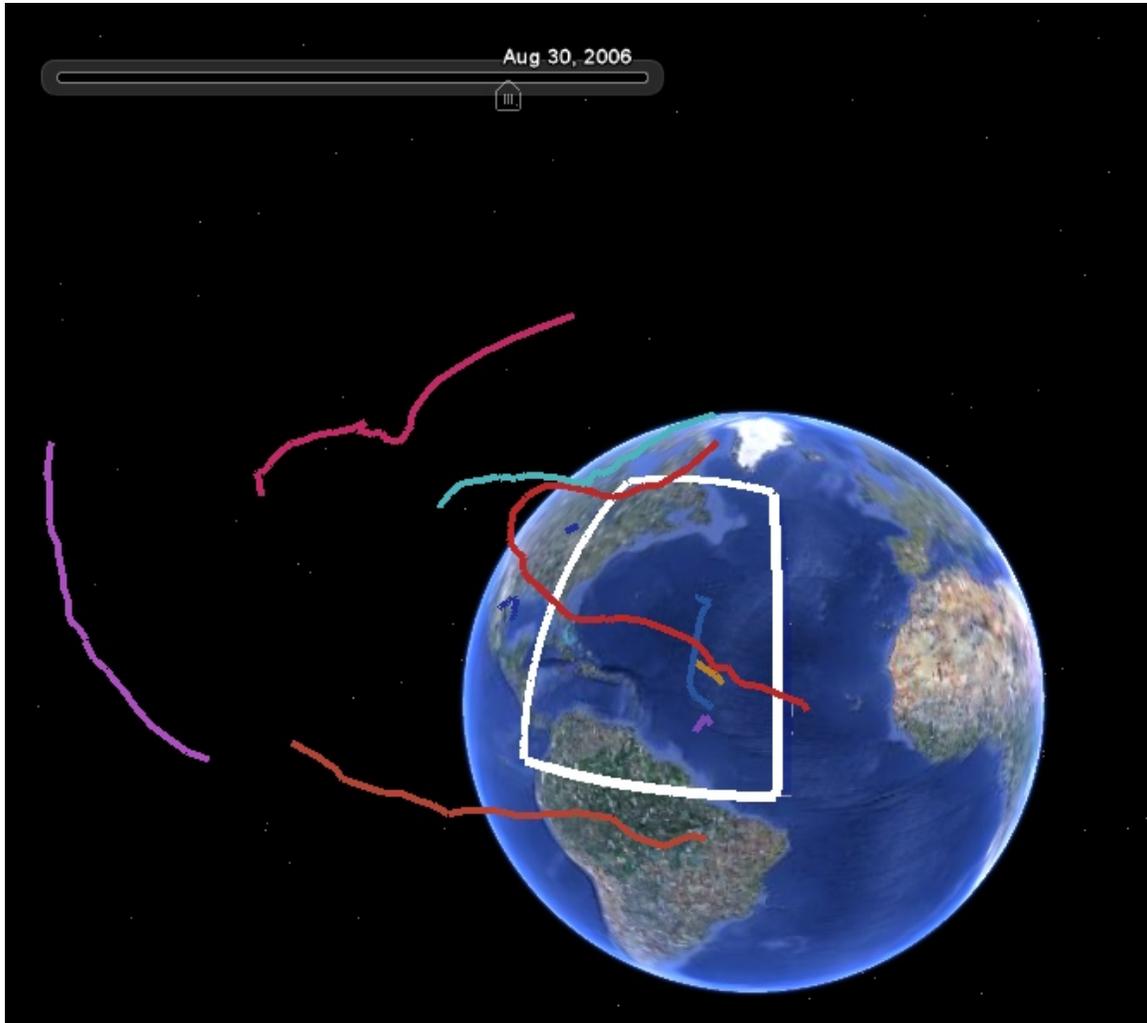


figure 15: exported HTML report

### Data Export to KML

The only data export option found in the tested version of GeoTime 4, was the ability to save the dataset (or selection from the dataset) into KMZ format for Google Earth. Note, the option is called Export to KML, but the format is actually the compressed KMZ file format. Also, when exporting the data to KML, there is no indication as to how the temporal axis values are assigned to GoogleEarth's z-axis value (which by default is a setting in meters of elevation). Therefore, the objects that have been extruded along a readable time scale within the GeoTime

visualization, are extruded into unusual snakes floating through the skies as seen in Google Earth. See, for example the export of the sample hurricane data as viewed in Google Earth, shown in figure 16.



**figure 16: hurricane data sample exported into KML (KMZ) as viewed in GoogleEarth**

The export of our own test data for a single entity (based on the biography of a 12<sup>th</sup> century philosopher, Lv Ziqian) was more understandable in visual terms, since the trail only had to include a single connected series of nodes in the vertical range. Still, the intrepid wanderings of Lv Ziqian, seemed to have taken him well beyond the atmosphere of planet earth and into outer space, where the Google Earth time bar succeeded in animating the event nodes as a sequence of self-illuminating orbs as he followed a trajectory back home.

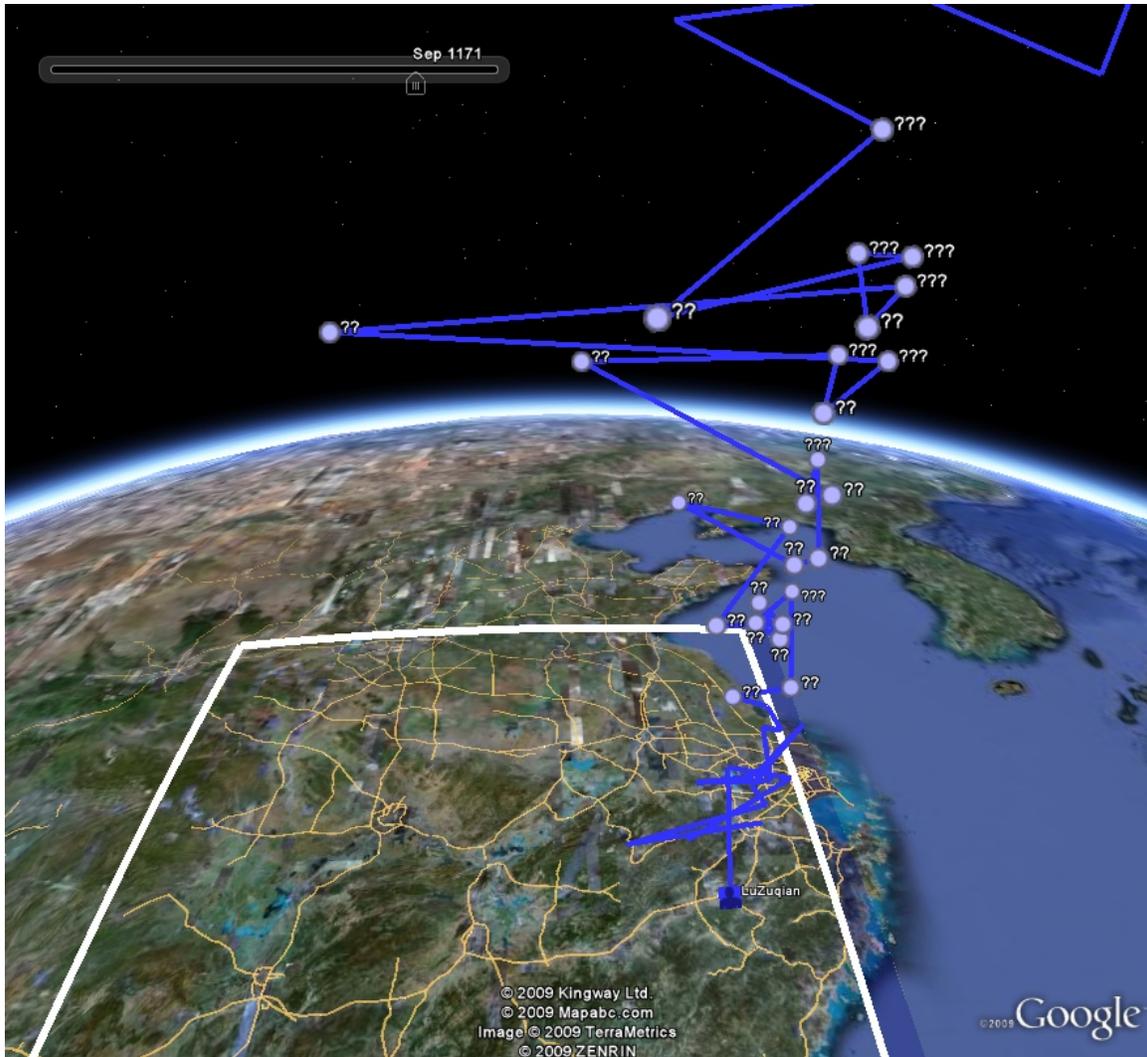


figure 17: biographical events of 12<sup>th</sup> century philosopher, Lv Ziqian, in GoogleEarth

### Static Image Exports

The quality of the static images saved as screenshots (in PNG format) from GeoTime were of decent, medium-quality resolution, sufficient for use as embedded figures in documents or on web-pages. But there were no obvious settings for saving high-resolution images for other purposes. See figure 18 for an example of image export.

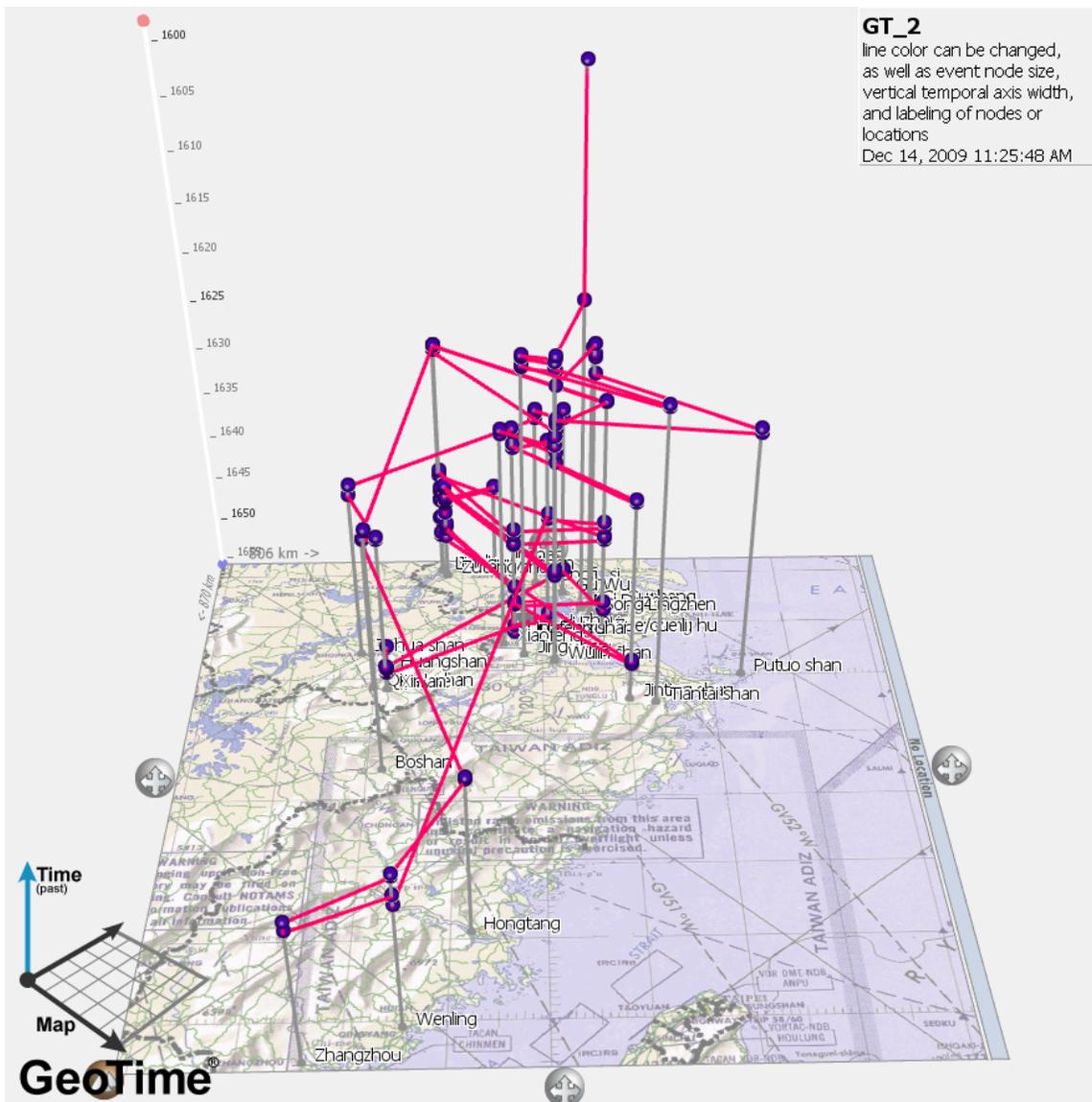


figure 18: image export example

Conclusion: GeoTime's core capability and value is found in the ability to explore a 3D visualization model while simultaneously running queries that reveal relationships in space and time. The relationships that are modeled automatically in GeoTime include the proximity of planar coordinates and proximity of temporal events (along the z-axis), as well as relationships that can be configured between the various entities in the source data, and which are represented as dotted lines between entities based on certain constraints.

The queries available in GeoTime are certainly reproducible in GIS itself (for example, by doing a spatial proximity query constrained to records that fall within a specified date/time range). Indeed, a similar 3D visualization can be achieved

in GIS if the time values are used as the z-axis. What GeoTime adds to the user experience is the ability to adjust the perspective of the 3D visualization by rotating it in any direction, and then to run multiple queries in sequence quite easily with the results shown instantly in the 3D model. The tactile, 3D handling approach enables a much different "hands-on" experience when investigating spatial data that represents groups of moving entities and how they interact.

GeoTime shows some degree of interoperability with GoogleEarth format, but does not allow for either import or export of XML (or other standard interchange formats). The next version of GeoTime is said to include some XML import capabilities, which will be interesting to examine. In the meantime, the current contenders for 3D modeling, such as SketchUp, CityGML, AutoCad, and others are moving more rapidly on the interoperability front. It will be interesting to see how GeoTime adapts to the growing pool of data in those formats, especially since the efficiency and cost-effectiveness of data management is going to drive ever higher levels of interoperability in the future.

GeoTime may be a good tool for descriptive epidemiology data (such as individual tracks within disease cohorts), georeferenced social network models, or exploring historical events and spatio-temporal interactions within groups of historical figures. In short, the user-experience in the way 3D models can be visualized and explored is the primary benefit in using GeoTime, and should be compared with various potential open source options, such as Chris Weaver's visual analytics software, *Improvise*.

(<http://www.cs.ou.edu/~weaver/improvise/examples.html>)

Flash videos demonstrating GeoTime data loading process and visualizations are online here: [https://cga-download.hmdc.harvard.edu/publish\\_web/GeoTime/](https://cga-download.hmdc.harvard.edu/publish_web/GeoTime/)