Persistence or Transience?
Tracking the evolution of places over time with historical Geographic Information Systems (GIS)

by Merrick Lex Berman

Numerous implementations for modeling geographic information across time have been developed, many of them specifically tuned to a particular kind of data or analysis. In the field of historical geography, several large-scale national projects have been undertaken, and each of these has demonstrated the sharp contrast between scientific solutions for handling time series datasets and the ad-hoc methods created to deal with amorphous objects known as "historical places." This paper examines the nature of those "historical places" as they change over time and whether they should be defined as persistent historical entities or as transient entities formed from an interconnected series of historical instances.

Time Series in GIS

The appearance of theoretical models for dealing with change over time in GIS began to accelerate in the early 1990s[1] and showed no sign of slowing down ten years later.[2] Even today, there are more theoretical models and experimental implementations than there are practical tools for time-variant data in GIS. Indeed, the leading GIS software companies still do not provide any out-of-the-box solutions for dealing with the storage or visualization of time-variant geographic data. For example, ESRI Corporation offers a means of versioning complete layers, or the ability to track histories of revisions for individual features stored in a geodatabase. How-

1 Langran, Gail, Time in GIS, New York 1992.
2 Ott, Thomas; Swiaczny, Frank, Time-Integrative GIS, Berlin 2001.

ever, the visualization of time series data in ESRI products relies on a Temporal Analyst extension from another vendor.[3]

During the same period of time, other types of applications that can display time series of data across space have been quite well developed. For example, meteorologists and physicists make use of the Unidata netCDF standard (first released in 1990), which provides a generic multi-dimensional format for modeling any type of data.[4] The analysis and visualization tool, GEMPAK[5], is widely used for processing meteorological instrument readings into colorful animated weather maps. And the TimeMap project, based at the University of Sydney, provides a means of easily navigating GIS objects that have unique time extents.[6] With such tools available, why is it difficult to create time-variant GIS for capturing and displaying data related to human history?

To put it plainly, human history is neither experienced nor recorded with any degree of measurable accuracy. Unlike the instruments of meteorologists and nuclear physicists, which can be tuned to particular frequencies and can be recorded at known intervals, historians need a fundamentally different kind of data-collecting apparatus. Historians create narratives of history out of the available evidence, and with no small amount of interpolation for gaps in their sources.

Consequently, when we reconstruct the geographies of the past, we are working from various kinds of historical evidence but with no reliable gauge of their accuracy or consistency. In more recent times, this evidence may include accurate maps, census and statistics, government documents, and so forth, all of which can be utilized to demarcate particular areas on the ground and to associate those spatial extents with jurisdictional relationships and other useful attributes. When we have such good evidence available, the construction of historical GIS appears at first to be a very

3 Temporal Analyst for ArcGIS. DHI Software, see: <http://www.dhisoftware.com/time/>.

4 netCDF (network Common Data Format). Unidata, see: <http://www.unidata.ucar.edu/software/netcdf/>.

5 GEMPAK (General Meteorology Package). Unidata, see: <http://www.unidata.ucar.edu/software/gempak/>.

6 TimeMap. University of Sydney, see: <http://www.timemap.net>.

practical endeavor. Nonetheless, even when working from fairly complete and reliable sources, the correlation and digitization of map data is highly labor-intensive, while the construction of jurisdictional relationships among the objects in the database proves to be an equally daunting challenge. For example, the construction of the Great Britain Historical GIS, built up from official statistics and with voluminous documentation about the districts involved, took nearly a decade to complete – and that was only for the period of two hundred years for which the source materials existed.[7]

Whenever historical GIS attempts to delve farther into the past, that is to say into the period for which maps are less accurate and incomplete, into the times when official statistics were sporadic or have since been lost, a whole new crop of problems arises. In this case, historical GIS must bring the conclusions of historians past and present into their data collection process, and it becomes obvious that the degree of accuracy and completeness that is inherent to GIS applications founders in a morass of uncertainties, conflicting interpretations, and scarcity of primary sources.

At first it may seem that GIS is simply the wrong tool for the task. How can a software which demands to know the planimetric accuracy of a dataset measured in meters, be used to depict locations only vaguely described in the source materials? What can be done with measures of distance and direction that are at best dubious, and quite possibly hopelessly adrift? And yet, as long as each spatial object is adequately documented with some kind of historical justification for its location or extent, GIS is a perfectly suitable tool. In other words, we may never be able to say that a particular historical location is accurate within 500 meters, but we can provide a full citation of the historical source and a note on how the evidence in that source justified the spatial object created to depict it. As long as the historical GIS is internally consistent in showing the sources of its spatial objects, incompleteness and hypotheses expressed in the sources and commentaries are plain for all to see. New evidence or interpretations

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7 Gregory, Ian N.; Bennett, Chris; Gilham, Vicki L.; Southall, Humphrey R., The Great Britain Historical GIS Project. From Maps to Changing Human Geography, in: Cartographic Journal 39 (2002), p. 37-49.

can justify moving or editing the spatial objects, so there is no harm in asserting hypothetical locations, testing them, then revising them as our knowledge is advanced. By contrast, it should be obvious that any historical GIS which lacks some textual notes and citations about how each of the historical locations was derived is both incomplete and impossible to evaluate.

If we accept that GIS can in fact be a useful means to represent individual historical places, what then shall we do to model those places as they change over time? Let us return to the existing scientific models for time series data, which are essentially a defined set of variables, for which unique values exist at specific moments in time. Such data can be represented with multivariate time series graphs, for example (Figure 1).

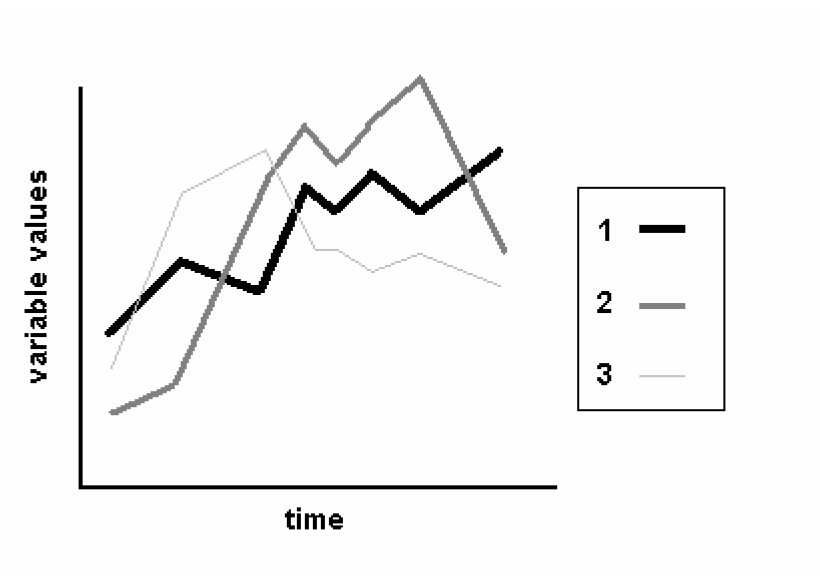

Figure 1: time series graph

Time series graphs typically represent cross-sectional values collected at the same time for a group of variables. In historical GIS, if each variable was to represent an historical place, the variables might or might not change at the same time. Instead, the variables are essentially asynchronous, each one having an independent series of changes over time. In a graph showing historical places, the break points would represent the times of change, and they would not necessarily align with any of the other historical places' break points. For example, Place 1 might be created at Time 1, then have subsequent changes at Time 4 and 5, then cease to exist at Time 7. Meanwhile Place 2 could have its own unrelated history, a creation at Time 3, no changes at all, then abolition at Time 8. If we used the same sort of graph to represent the changes for historical places the results would be markedly different (Figure 2).

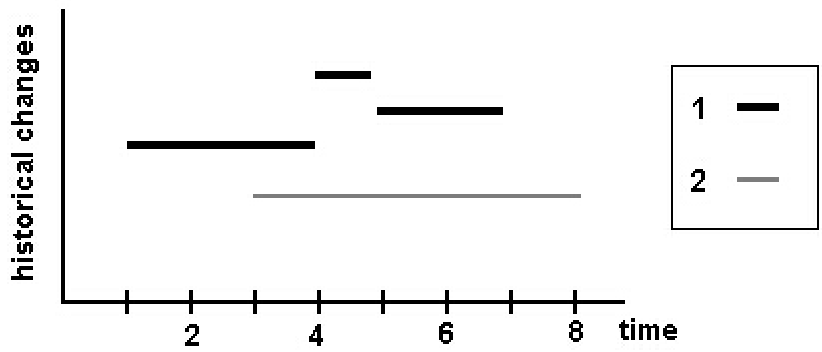

Figure 2: changes in historical places over time

Note that for changes in historical places we are not plotting the vector of change from one value to another over time, instead we are plotting "historical instances," which have known times of origin and conclusion, and which may be followed by a subsequent instance. Think of a practical example for Place 1 in Figure 2: a county seat is established at Time 1; the location of the county seat is moved at Time 4; the county seat is promoted to a municipality at Time 5; the municipality is abandoned due to a flood control project at Time 7. What we are modeling are the "steady states," or the periods of time for which the attributes of the historical place remained constant, and each new instance is created when those basic attributes are changed.

The way historical instances are depicted in Figure 2 is essentially aspatial. Differences are shown as values on the y-axis, but these values have no inherent meaning. A better way to depict the situation for a series of historical instances would be a 3-D graph, showing planar coordinates on the x and y axes, with time depicted as the z-axis (Figure 3).

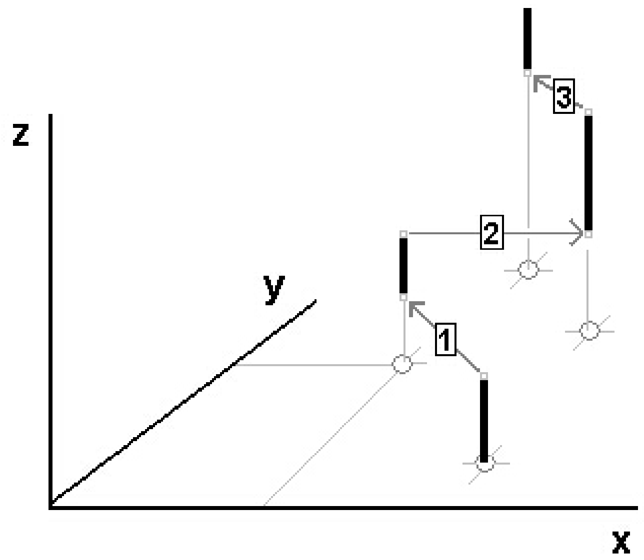

Figure 3: time graph of historical instances as points

In the example shown in Figure 3, there are four geographic locations (shown as circles plotted on a horizontal plane), and each instance has a period of time for which it existed (shown as lengths of the instance vertically). In addition, the graph shows transitions from one instance to another (numbered 1 to 3). This type of graph has been used to show the places of residence of a single individual for their medical history, for example.

Of course, historical instances may not be limited to point objects, in which case the depiction of change over time in a graph becomes more of a challenge (Figure 4).

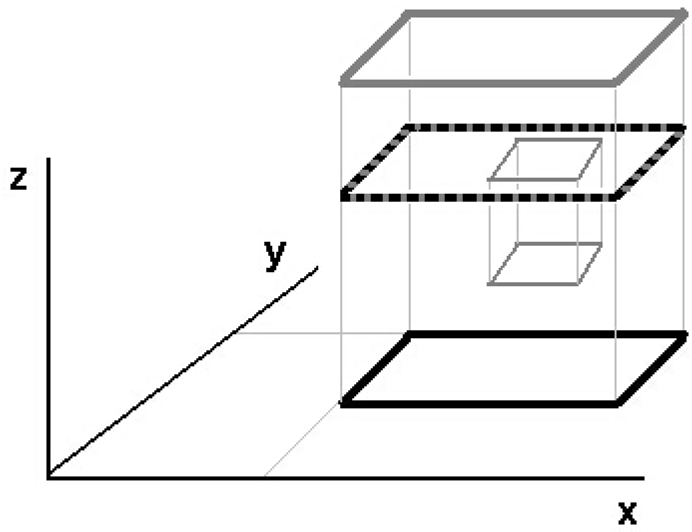

Figure 4: time graph of historical instances as polygons

In Figure 4 an area shown as a black rectangle, is used to represent a parcel which has an extent shown on the horizontal plane and a period of time rising vertically. Let us suppose that at some point during the existence of the parcel, a building was constructed, shown as a light gray footprint. Then let us suppose that at a certain time the building was torn down and the entire black parcel was abolished, with a new gray parcel being created in its place. In fact, this is an overly simplistic scenario. In the real world, single areal units get subdivided, or several units get merged into single areas, and these changes can occur at any time without necessarily affecting any adjacent areas.

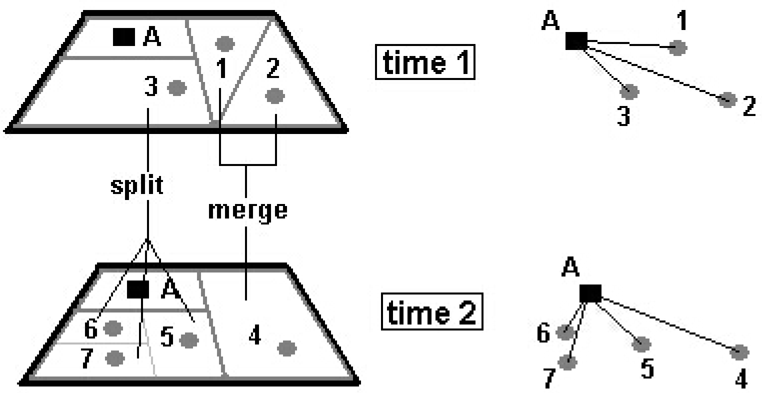

Figure 5: time slices showing transformation of objects and relationships

Visualizing such changes over time becomes somewhat problematic, forcing us to select “slices in time” to show the state of affairs at any particular moment. In Figure 5, we see a group of historical spatial objects as they existed at Time 1 and Time 2. At Time 1 a parent jurisdiction A had subordinate units 1, 2, and 3. Between Time 1 and Time 2 (though not necessarily at the same moment!), units 1 and 2 merged together to form a single unit 4; while unit 3 was itself split up into three new units 5, 6, and 7. Indeed, these are exactly the sort of events that occur frequently in administrative geography. In the left half of the illustration, the units are shown as areas with defined boundaries. On the right, the same units are shown simply as points, with their parent to subordinate relationships indicated by simple lines. In today’s world, we are accustomed to depicting administrative units as bounded areas. We dislike gaps of no-man’s land and fuzzy peripheries. But as we delve into pre-modern times we have no means of determining such cleanly defined adjacent areas, therefore I believe that a network model, which can be carried down through any number of levels of iteration, is more appropriate for modeling historical geographies.[8]

Regardless of whether we visualize historical places as nested areas or networks of points, the example shown in Figure 5 demonstrates the need for clarity in how we perceive of historical places as they change over time. Look at unit 3, which exists at Time 1 and then splits into units 5, 6, and 7 at Time 2. Is the “place” which was defined as unit 3 the same as any of the new units? Is it equal to the sum of the new units? Or are they all unique historical places unto themselves? Although the functional logic of spatio-temporal changes can be described[9], there is no basic proof of an identity that persists from one state to the next. For example, if unit 3 in the preceding Figure 5 has the same placename as unit 7, does that prove that unit 3 is still the same “place” as unit 7, while units 5 and 6 are new?

During the years I have spent working on the China Historical GIS, I have come to the conclusion that persistence of identity for historical places cannot be shown to exist. A case in point is the geographic space that now exists under the jurisdiction of China’s capital, Beijing. We have extensive historical documentation about the administrative units that were established, abolished, re-named, or re-established in roughly the same geographic space as today’s Beijing.[10] A brief (incomplete) sketch of this history is shown in Figure 6.

8 Berman, Merrick Lex, Boundaries or Networks in Historical GIS, in: Historical Geography 33 (2005), p. 118-33.

9 Hornsby, Kathleen; Egenhofer, Max J., Identity-based change: a foundation for spatio-temporal knowledge representation, in: International Journal of Geographical Information Science 14.3 (2000), p. 207-224.

10 Hou, Renzhi (ed.), Beijing lishi dituji (Historical Atlas of Beijing), Beijing 1988.

name	nation-state	begin-year	end-year
Nanjing	Liao	938	1152
Zhongdu	Jin	1153	1215
Dadu	Yuan	1267	1402
Beijing	Ming	1403	1420
Jingshi	Ming	1421	1643
Shuntianfu	Ming	1421	1643
Beijing	Qing	1644	1911
Beijing	Republic	1912	1928
Beiping	Republic	1929	1949
Beijing	PRC	1949	present

Figure 6: historical instances of Beijing

When presented with the facts, we must admit that when the state of Liao established an outpost at the southern part of their territory and named it Nanjing [Southern Capital], that there is no logical connection between that administrative unit and the subsequent administrative units that were established in roughly the same area later on by other peoples. For the Jin people, the place was roughly in the middle of their territory, so the name Zhongdu [Middle Capital] is appropriate in the context of the state of Jin at that point in time. Then the city was sacked and destroyed by the Mongols in 1215. Only fifty years later did the Mongols themselves establish a capital city there, called Dadu [Great Capital] in Chinese, which was called Khanbalik in their own tongue. Does Khanbalik = Nanjing = Zhongdu = Beijing? Frankly, the answer is no. They are not temporal aspects of a single identity differentiated by their temporal extents.

If we are to take the sum of the information about what transpired at a particular geographic location over the course of time, we must realize that what we are not observing a single persistent identity, but a series of historical instances. Each instance of an historical place, although it may indeed be seen as occupying a certain temporal extent and geographic extent, actually makes more sense in a political and cultural context which expands and contracts. This set of circumstances resembles series of waves lapping back and forth over the same space, each wave arising from a set of circumstances unique to itself. In my view it does not make much sense to model one aspect of a wave of human activity in terms of a single point on the ground. Instead I believe that the wave itself should be mapped as a network of nodes that spreads and articulates across the landscape over time.

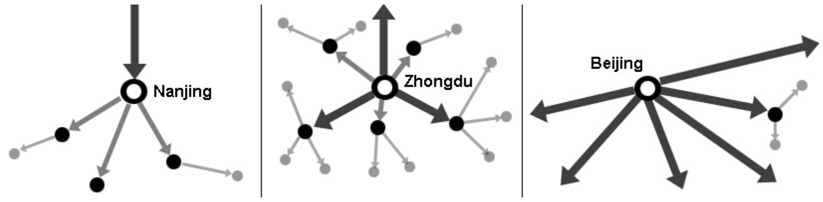

Figure 7: one location has different roles depending on its historical context

In Figure 7 several snapshots, or slices in time, are shown as hypothetical scenarios for the geographic location now known as Beijing (depicted here as a black circle with a white center). On the left side is the Liao city Nanjing [Southern Capital], shown as a southern node from a larger political system radiating from the north. In the center is the Jin city Zhongdu [Middle Capital], here shown as the central capital of a much smaller political system, surrounded by its subordinate units. Note that bolder or lighter lines can be used to depict various types of relationships among the nodes. On the right hand side, we see the Qing city Beijing [Northern Capital] which was the seat of the central government for a much larger political system, shown radiating beyond the extent of the map.

These three slices in time demonstrate the very different roles that administrative units played at the same geographic location. In this case, the administrative units were not even part of the same political system, therefore it is not reasonable to presume that they maintained a single persistent historical identity over the long course of time. Rather, I would argue that geographic location exists as a stage upon which a series of transient events occur. Following this line of reasoning, a more realistic way to model historical geographies would be as a series of networks, within which each historical place gains its identity more from its relationship to the historical context of each specific network, rather than its location in space and time. Nor is there any reason that networks cannot overlap and either compete or co-exist while sharing some of the same nodes.

Allowing for overlapping roles in historical GIS is particularly useful in the case of Chinese history, which presents us with the problem of administrative jurisdictions that were simultaneously occupying the same space as military commands, or circuits of surveillance. The way in which data is collected and modeled in historical GIS must be flexible enough to handle the intermingling and overlapping of political spheres of influence and the movements of peoples across time. It is not correct to look backwards from the present state of affairs and to say that the place we now call Berlin, or Beijing, or Bogota, had such and such earlier incarnations. Those earlier states can be easily discovered with a spatial query. What we must do is to avoid the mistake of building out historical GIS from the present going backwards in time, as if each place has some sort of persistence of identity that lasts for eternity. Yes, history itself is continuous, and yes, locations have histories that aggregate into what we think of as “places.” The problem we face is that we are trying to capture the waves of historical influences lapping to and fro over space and time, and the residual influence of these waves is made up of a hodge-podge of artifacts: historical documents, dialects, cuisines…characteristics that are difficult to measure and map. To reconstruct the authentic history of places, we need to think of each place as transient not persistent. By thinking of historical places as a sequence of events, by defining them as points of interconnection, and by modeling the relationships each place has to the larger geopolitical context for specific periods of history, we can begin to establish an extensible and global historical GIS.

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