GEOREFERENCING HISTORIC MAPS

What is Georeferencing?

Georeferencing is a process that converts a digital image from an arbitrary coordinate system to a real-world coordinate system. This process allows for the image to be viewed and queried with other geographic data. When the images are historical maps, there are several factors that need to considered before the new coordinates are assigned. These include projection issues, scale of the reference data, transformation and any applicable historical information about the map. A successfully referenced historic map can then be "lined-up" with other georeferenced maps or geographic data and utilized in a GIS.

The Geospatial Data Access Project

...is a Harvard Library Digital Initiative grant that aims to generate awareness of the possibilities for geospatial related research across Harvard University and provide increased access and use of geospatial data by:

- making digitized maps and digital spatial data accessible to the community via the Harvard Geospatial Library. To date, several hundred layers and images have been made available as part of the grant.
- establishing GIS training and support services in the library
- creating map tools for the iCommons/ICG tool set

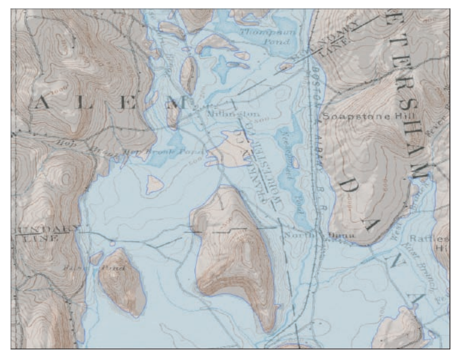
Why Bring Historic Maps into a GIS?

Context

What exists in one's study area at a given point in time?

An early 20th century USGS topographic map of central Massachusetts

Modern Quabbin Reservoir data overlayed in semi-transparent blue



A close-up of the northern Quabbin overlaying the early USGS topographic map reveals flooded towns, roads, railroads, etc.

Resource/Research Management Tool

GIS can be thought of as a spatial database or spreadsheet, whose information can be joined to spatial representations.

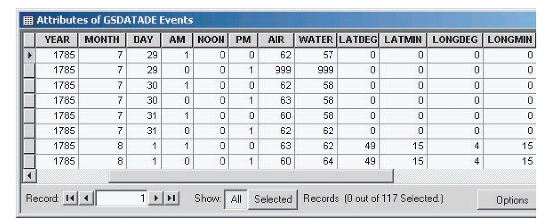
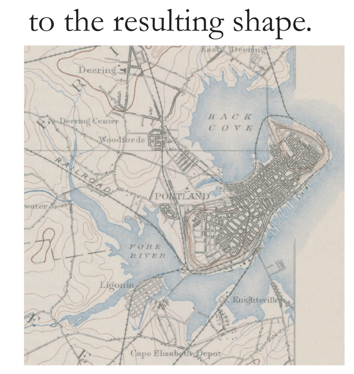


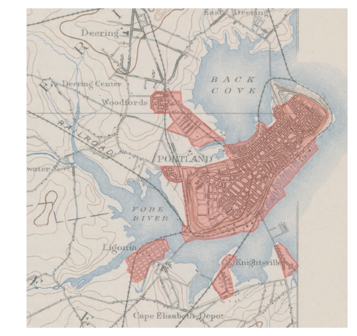
Table of Benjamin Franklin's Gulf Stream readings with latitude/longitude coordinates

Feature Extraction

Vectorizing and encoding is accomplished by tracing features from the historic map and assigning attributes to the resulting shape.



An 1898 USGS topographic map of Portland, Maine



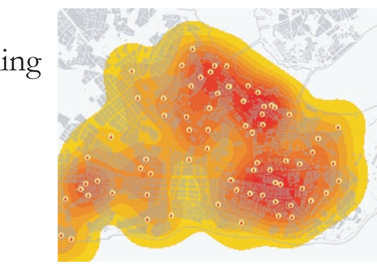
Built-up area is extracted (vectorized) in red.

Analysis

Analysis can be simple or complex in regards to interpreting and using historical maps. For example...

Simple: Locating inns within 5 miles of towns with a population greater than 10,000 in France around 1910.

Complex:
- Archaeological predictive modeling
- Spatial modeling techniques to model fires or disease patterns



Interpolated density of the Great Fire of Constantinople, 1660

Techniques

The process of georeferencing maps begins with image capture. At the Harvard Map Collection, maps are digitally photographed by Widener Library Imaging Services at a resolution sufficient to view the details of the map and then stored as 24-bit TIFFs.

At the Harvard Map Collection, we typically utilize ESRI ArcMap-ArcInfo to perform the georeferencing steps. There is other software available, such as Blue Marble's Geographic Transformer and Erdas Imagine.

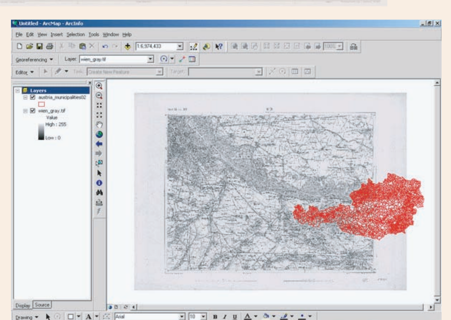
There are two methods we employ to perform georeferencing:

(A) Absolute coordinates or tics
-OR-
(B)Feature linking

Absolute Coordinates

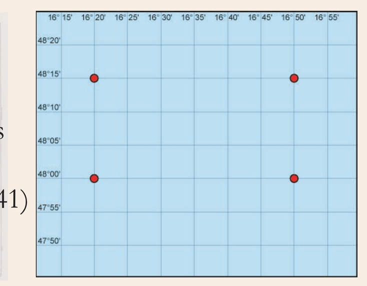
Absolute coordinates were chosen as the best way to georeference the Austro-Hungarian Monarchy Topographic Series. Each map in the series has corner tic marks labelled with precise latitude-longitude coordinates. These tics were used to assign real-world locations to the corners of the map.

Step 1: *Map research*
Research:
-Map Projection (polyhedric projection (antiquated))
-Coordinate System (Bessel 1841 Spheroid)
-Prime Meridian (Ferro)
-any other applicable metadata like scale, dates, etc.

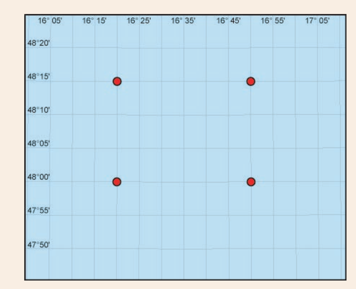


Austro-Hungarian Monarchy Topo Series, Scale 1:75,000, Date:1874-1912. This map is unprojected/misaligned against modern GIS municipal boundaries (in red).

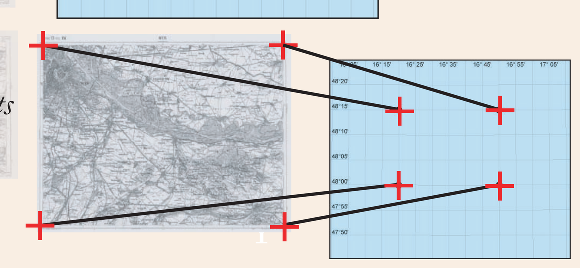
Step 2: *Create a point layer*
-from the geographic coordinates of the corner tics
-based on the historic coordinate system (Bessel 1841) and Ferro prime meridian



Step 3: *Project points into the historic map projection*
-in this example we used a polyhedric antiquated projection (polyconic)



Step 4: *Link tic marks on the map to the projected points*



Step 5: *Transform the map*

Georeferenced topo map with with modern GIS municipal boundaries (in red) and rivers overlaid

Feature Linking

Feature linking was chosen as the best way to georeference 1797 Carleton Map of Boston. No real-world coordinates are shown on the map but there are many recognizable features that can be easily identified from modern information. These features are used to assign coordinates to the historic image.

Step 1: *Map research*
Research:
-Map Projection
-Coordinate System/Datum
-any other applicable metadata like map sources, scale, dates, etc.

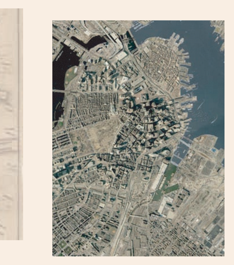
A 1797 street map of Boston

Step 2: *Acquire reference GIS dataset(s) which will be used to create links with the historic map*

2001 MassGIS digital orthophoto

1996 Boston Water and Sewer GIS road data

Step 3: *Project modern GIS data to match that in which the map was originally drawn*



Step 4: *Establish points in common on the map AND on the reference data for linking*

Step 5: *Transform the map*

Factors to Consider when Georeferencing...

There are several factors to take into consideration when georeferencing, including:

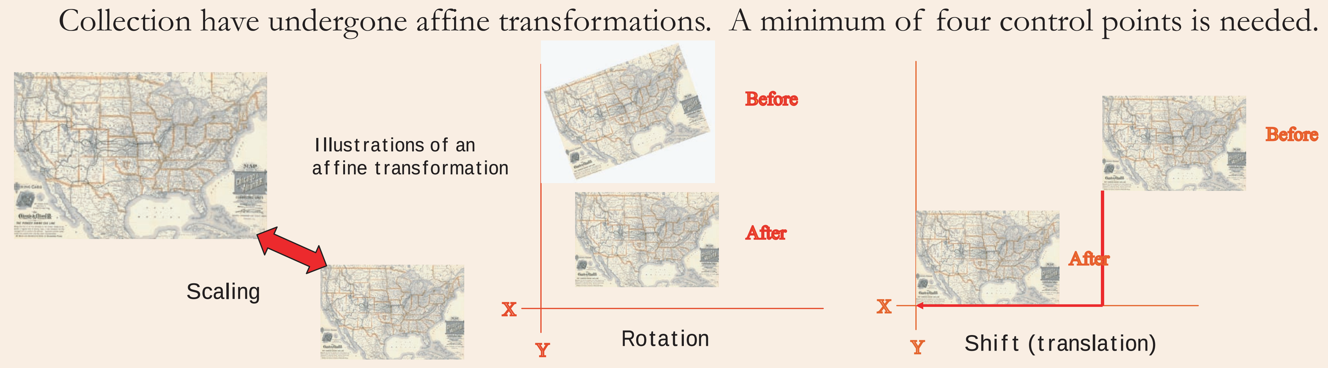
Transformation technique
and
RMS (Root Mean Square) error

Keep in mind that the results of georeferencing are only as good as the sources you use. If the modern data are inaccurate or not of a proper scale, the results won't be reliable. Additionally, if the historic map is inaccurate, georeferencing won't make it more accurate. The paper map can have a good deal of additional error which, in turn, is carried over to the digital image. Paper stretch or creases due to improper storage or folding or material type are an often overlooked source of trouble when trying to reduce RMS error.

Transformation

Transformation permanently adjusts the image being georeferenced. This is the process that makes the map fit in a real-world coordinate system. With most GIS software there are a few options:

Affine transformation is commonly used for large-scale maps (1:100,000 or less) that are in a nearly rectilinear projection such as Transverse Mercator. Use this transformation when your dataset needs to be scaled, rotated or shifted. All images to date in the Harvard Map Collection have undergone affine transformations. A minimum of four control points is needed.



2nd-order and 3rd order polynomial transformations are performed when the image needs to be bent, curved or warped. These transformations are commonly applied to aerial photographs and satellite images that contain distortion as a result of terrain relief. A polynomial transformation also works well for small-scale maps that are in a non-rectilinear projection such as Lambert Conformal Conic.

RMS (Root Mean Square) Error

The degree to which the transformation can accurately map all control points can be measured mathematically by comparing the actual location of the map coordinate to the transformed position in the raster. The distance between these two points is known as the residual error.

The RMS error is a measure of the accuracy of the control points. It describes the deviation between the control points in the output image and the values calculated by the transformation. At least three control points are needed to calculate an RMS error.

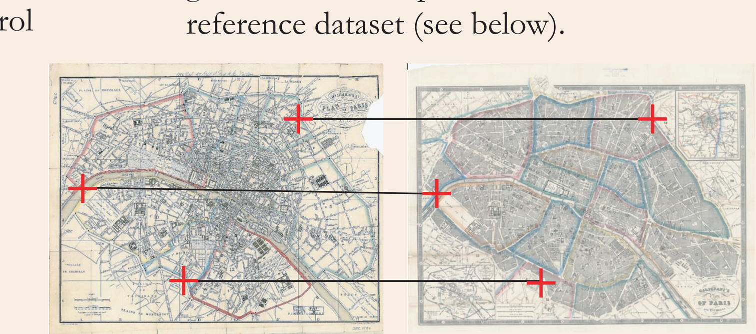
[*Source: Environmental Systems Research Institute*]

Other factors to consider...

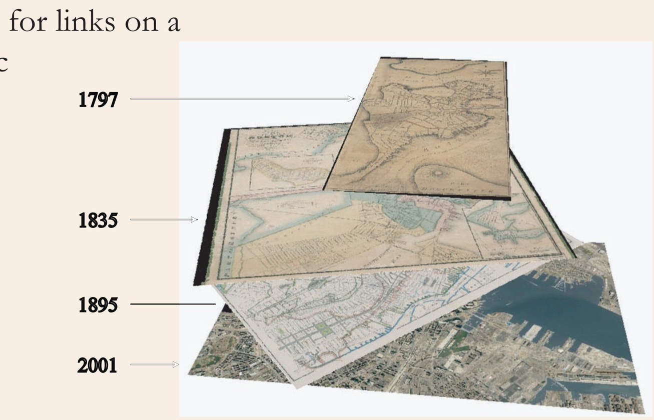
Be aware that features such as shorelines and rivers can change, sometimes dramatically, over time. Use caution when using these types of features as control points. Cultural features such as bridges, landmarks and roads are oftentimes a better choice.

A general rule of thumb is to use a reference dataset that is a larger scale than the map scale. For instance, a 1:5,000 road dataset would be a better reference than a 1:100,000 road dataset for a 1:10,000 historic street map.

If it is difficult to find enough good features for links on a historic map, keep in mind that other historic georeferenced maps can be used for the reference dataset (see below).



Map of Paris, 1832 — Map of Paris, 1865



When georeferencing multiple maps of the same area, keep in mind to start with the most current map and work backward in time.

Gallery of Georeferenced Images

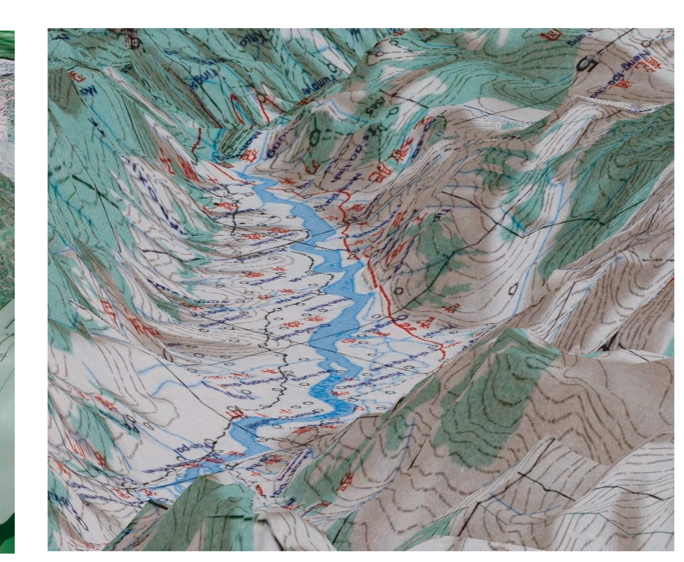
1797 (brown) - 2001 (photo) shoreline change in downtown Boston

Georeferenced 1865 street map of the City of Cambridge. Modern GIS road centerline data from the City of Cambridge shown in red.

The same georeferenced 1865 street map of Cambridge, overlaid with 3D buildings and the modern shoreline of the Charles River.

Georeferenced 1867 Boston Sanborn Fire Insurance Company Atlas with modern buildings overlaid in red.

Note the inset (below) that has been mosaiced to the larger image.



Army Map Service L500 Series of China topographic maps, georeferenced and draped over GTOPO30 elevation data. The 3D effect was done with ESRI ArcGlobe software, with the terrain model exagerated by a factor of 2.

Credits:
Poster layout by Whitley Frost, Harvard Map Collection with text and image input by Patrick Florance, Harvard Map Collection, Bonnie Burns, Harvard Map Collection, and David Siegel, Harvard University Library Office of Information Systems
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