Maps as Research Tools Within a Virtual Research Environment.

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Abstract. The Tambora.org Virtual Research Environment (VRE) provides scientists with an IT infrastructure that supports research processes at the junction of historical sciences and climatology. This paper describes the work flow of historical climatology research and elaborates on the more complex scientific tasks that are in need of cartographic visualizations that consider space as well as time.

Keywords: historical climatology, space-time visualizations, virtual research environments

1. Introduction

Simply said, Virtual Research Environments (VREs) are "net-based platforms that enable scientists to work in collaboration." (Hüttner 2010) For this reason a Virtual Research Environment models large parts of the research life cycle in a digital environment and "facilitates the sharing and reuse of tools, data and results." (Fraser 2005) Besides research administration and project management, according to Fraser the areas of interest are discovery, collection and analysis of data, research relevant communication and scholarly publishing of texts as well as research data.

Fraser points out, that it is desirable to enable a linkage between Virtual Research Environments and Virtual Learning Environments (VLEs). This may be especially true for the visualization tools such a research environment offers. People of cartography involved in the development of a VRE – a "profoundly multidisciplinary" (Fraser 2005) enterprise – should keep this in mind, as visualizations created during the research process may be reused for communication purposes outside the research environment.

VREs are a relatively young form of scientific cooperation and still pose a number of challenges. Those challenges are not of technical nature: "Organisational issues – for instance, about access and access authorisation – represent a major challenge. Another difficult question is how virtual research environments can be funded on a permanent basis, so that they don't die when the project funding ends" (Hüttner 2010) says Sigrun Eickelmann, director of "Scientific Library Services and Information Systems" at the DFG. For this reason the German "Allianzinitiative" made the institutionalization of Virtual Research Environments a top priority, as "there is currently no virtual research environment intended for long-term use." (Allianzinitiative 2013)

The creators of the Tambora.org Virtual Research Environment were well aware of this problem. Thus, they choose to divide the environment into a collaborative "Data Collection Tool" and a "Repository" for publication and permanent storage of data collections (Borel and Steller, 2012). Both components will be transparently integrated parts of the project website, yet the repository is maintained independently by the Library of the University of Freiburg as part of their long-term institutionalized preservation strategy.

2. A Virtual Research Environment for Historical Climatology

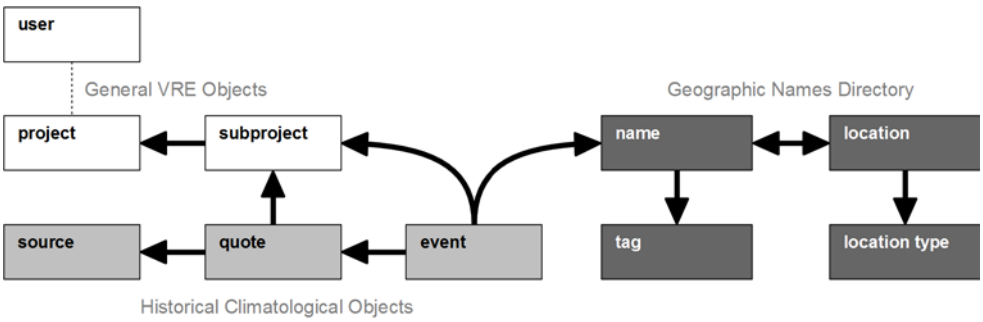
Historical Climatology analyzes the impact of weather, climate and climate change as it is reflected through historical sources like texts, documents, inscriptions etc. The objective of the Tambora.org project is to provide the science of Historical Climatology with a collaborative Virtual Research Environment.

The typical research process (Borel and Steller, 2012) begins with the finding and indexing of relevant "sources" and the recording of "quotes", a work that sometimes involves the translation of texts. At the heart of the process is the interpretation of the quotes through the creation of "events". This event coding is the assignment of codes to prescient the relevant information contained in a text passage. The "event code" values are provided by system wide catalogs and are facilitated through coding tools for the domains of *space*, *time* as well as weather event and impact *parameters*. The joint re-use of code catalogs across projects constitutes a great value of the Tambora.org Virtual Research Environment and is one major aspect of collaboration.

The coding of the spatial dimension of the text quotes, which is of particular interest to this paper, is accomplished through the use of a "name" that references a specific metric, spatial "location" of a certain "location type". These elements are facilitated and managed through a subsystem called the "Geographic Names Directory".

The administrative infrastructure of the research environment is organized into "projects", "sub projects" and "users". Institutions or research projects can request the creation of a project. It is up to the maintainer of the project to organize their research phases or research groups into sub projects. An individual user can be assigned as manager or reader of a project and take the role of research staff on sub projects. Figure 1 summarizes the relationship of the objects of the VRE.

Figure 1: *The object model of the Tambora.org Virtual Research Environment (simplified).*



As the private, unpublished research data of a project is growing, as sources are being recorded and quotes are being analyzed and coded into events, there is a need to prepare a "collection" of events for presentation, for peer-review or for publication. These collections can be created in a simple manner through the use of the existing search tools of the research environment.

Once a collection is considered ready for publication, the project maintainers can publish the research data on the Virtual Research Environment website. At the same time, the published events and all of the connected quotes, sources, names and locations become public as well. These elements can be re-used by all other projects within the research environment now.

In addition, a permanent Document Object Identifier (DOI) for the published collection can be obtained from the Library of the University of Freiburg. The data collection is then moved to the libraries permanent storage repository *FreiDok*, is registered at the *datacite.org* service and is guaranteed to remain available to the public and in sound condition.

3. Spatial Aspects of the Coding Process

Within the VRE the object types “names” and “locations” are the key concepts in the understanding of space (see figure 1). The distinction between those accounts for the context of historical climatology, in which historical sources may use a number of different historic names to identify the same spatial location. While the “location” object can hold a collection of points, lines and polygons as geometry, multiple “name” objects can reference this location. On the contrary, a “location” object has one primary name only, usually a contemporary name. Meta-information is added to locations through the indication of a “Location Type” (e.g. place, river, lake, territory...). Meta-information to names is assigned through a flexible tagging system (e.g. tags for “arabic script”, “latin script”...).

The “Geographic Names Directory” enforces the connection between a name and a location, as a name without a location would introduce ambiguities into a collaborative use of the geographic names codes.

The spatial coding process has to accommodate to the uncertainties involved in the work with historical documents. For most cases the use of a simple flag communicating an “uncertain” state was considered as appropriate. Consequently, the assignment of a geographic name to an event contained in a text passage can be “uncertain”. Also, the assignment of a specific historic name to a certain location can be “uncertain”. In a future version of the VRE locations themselves may be extended with a geometric notion of uncertainty in one of the ways discussed by Humayun and Schwering (2012).

4. Space, Time and Space-Time Visualizations for Researchers

Analogous to the spatial coding the Tambora.org VRE models time as a property of an event too. Time is defined with a granularity ranging from hours over days, months or seasons to years. Events can either stand for a point in time or for a duration. As for space, the temporal coding of an event can carry a state of uncertainty.

Many use cases of the Virtual Research Environment require the concurrent visualization of the space and the time dimension of events. Researchers can generate theories and discover spatial and temporal patterns. Temporal clusters of weather events, for example, may validate a single ambiguous event or point a to larger relationship with inter-connected social or economic impact events. Additionally, scientists may as well identify areas

with sparse data and inform their decisions and priorities regarding the progression of data collection efforts.

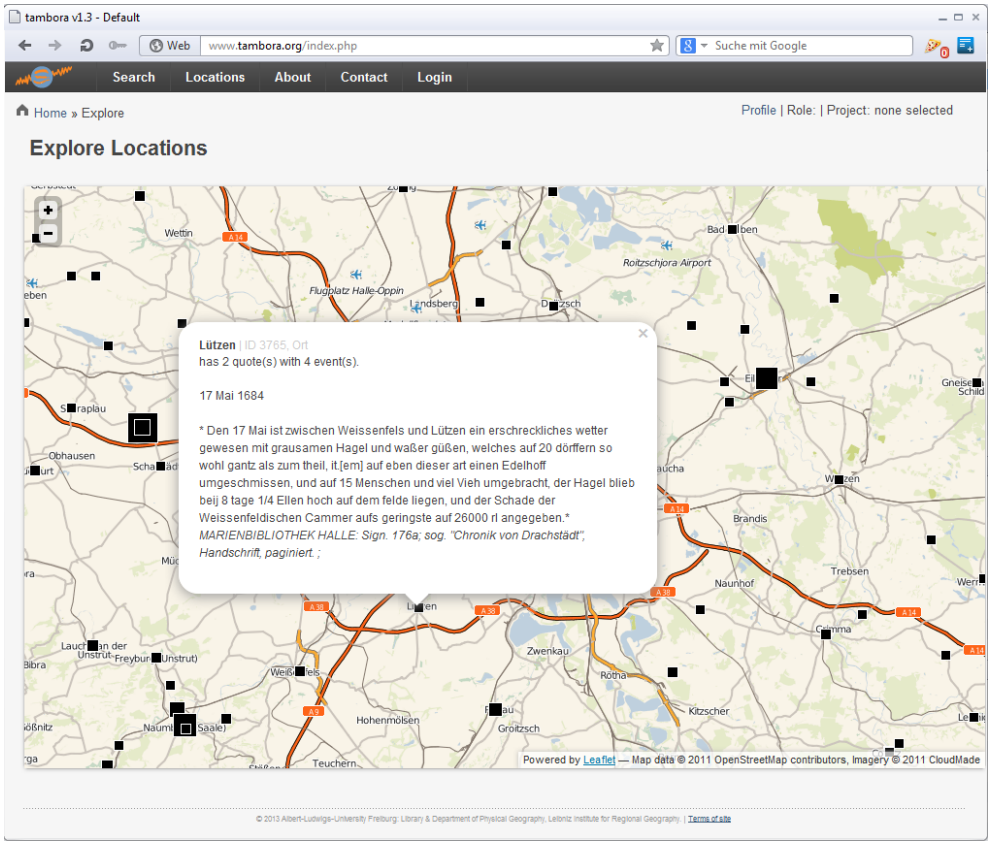


Figure 2: *A screenshot of the Tambora.org website depicting the prototype of a map display. The map shows location and number of events. The user clicked a map symbol to read the connected text passages.*

Only two general use cases will be elaborated here. Both use cases occur during the recording and coding phases of the research process, where quotes from historical sources are entered into the system and are being augmented with event codes. In the use case "browse locations" the user defines a time range to see the location of the existing events (time view defines map view). Figure 2 shows the prototype of a resulting map view. The use case "browse time" requires the user to define a space, either by zooming/panning a map or by selecting a region on a map, to see a diagram of temporal sequence of events or event frequency (map view defines time view). Both use cases will need to allow for comparison of two time ranges or two spatial regions.

As a result, any heuristic visualization of events must incorporate space as well as time. But contrary to the integration of space and time into synthetic indicators, as it is often done in cartography to depict a “change”, the dimensions of space and time should remain largely unprocessed for the purpose of heuristics.

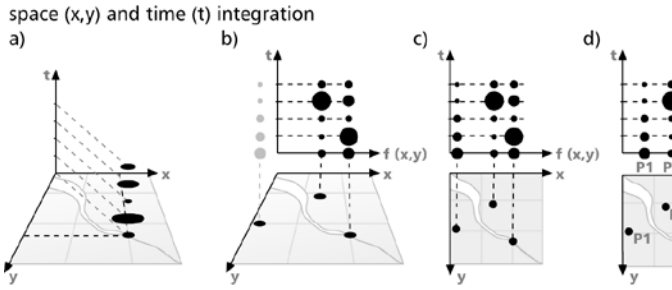


Figure 3: *Space and time integration alternatives.*

Figure 3 depicts several conceptual alternatives for the integration of space and time, where figures 3a to 3d depict methods for use cases where the map defines the temporal view. Figure 3a is a visualization method known as space-time-cube. This method understands time as the third dimension of map space. Although visually exciting, the perspective distortions inherent in a 3D visualization would hardly allow a comparison of events with equal temporal codes, as synchronous incidents would not be “in line” with each other. Figure 3b is a variation that removes the perspective distortion from the visualization of the temporal dimension but keeps the relation to the 3D visualization below. Figure 3c is a variation based upon a 2D map. Figure 3d is quite similar, although is shows another degree of abstraction and separation between space and time. The space dimension of the temporal view is no longer understood as as a function of the map space but instead as categories: The user defines a set of “areas of interest” to be visualized within the temporal view. Finally, figure 3e depicts a variation of the small multiples technique which serves the use case, where the temporal view defines the map view.

5. Conclusion

Although some aspects of Virtual Research Environments present organizational challenges, they enable researchers to work collaboratively.

The Tambora.org VRE has reached a state of maturity where it is already used by a number of projects. The project was funded by the DFG (Deutsche Forschungsgemeinschaft) and enabled the Library and the Department of Physical Geography at the University of Freiburg, the

Departement of Physical Geography at the University of Augsburg as well as the Institute for Regional Geography (Leipzig) to create this virtual research environment.

Since Historical Climatology is interwoven with the dimensions of space and time, it offers application areas for cartographic competency regarding space-time visualizations.

The Institute for Regional Geography (Leipzig) will support the future development of the Tambora.org VRE in aspects of cartographic visualization as well as in the development of the “Geographic Names Directory”.

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