Tag Clouds and Old Maps: Annotations as Linked Spatiotemporal Data in the Cultural Heritage Domain

Rainer Simon[1], Christian Sadilek[1], Joachim Korb[1], Matthias Baldauf[2], Bernhard Haslhofer[3]

[1] Austrian Institute of Technology, Digital Memory Engineering
{rainer.simon, christian.sadilek, joachim.korb}@ait.ac.at

[2] Telecommunications Research Center Vienna
baldauf@ftw.at

[3] University of Vienna, Department of Distributed and Multimedia Systems
bernhard.haslhofer@univie.ac.at

Abstract. In this paper we present a Web-based system for annotating digitised old maps. Using bibliographic metadata and geographical reference information associated with the map, annotations are represented as spatially and temporally defined RDF resources. At the same time, named entity recognition and semantic link discovery are applied to each annotation's text content to further facilitate its interlinking within the Web of Data. To ensure quality and correctness, the system relies on human feedback. This feedback is introduced through a novel interaction metaphor: contextual link suggestions are continuously generated in the background, and superimposed on the annotated map region in the form of a tag cloud. The user can create semantic links by simply clicking on the corresponding tags. The system thus acts both as a visualisation aid for contextually relevant linked data and as a tool for authoring new linked spatiotemporal data entities.

Keywords: Linked Data, Tag Cloud, Cultural Heritage, Semantic Tagging, Public Participation.

1 Introduction

The practice of annotation has traditionally been playing a crucial role in the cultural heritage domain. On the one hand, annotations enable scholars to share and exchange knowledge, and work collaboratively in the interpretation and analysis of cultural heritage artefacts. On the other hand, annotations are a valuable addition to traditional metadata, which is essential for organising and cataloguing, as well as for searching and retrieving of objects in cultural heritage collections.

As institutions are making increasing efforts to digitise their holdings and start making them available to the public over the World Wide Web [23], the role of annotations is also evolving: institutions are discovering the added value of user-contributed knowledge. The *Living Memory Annotation Tool* [10]; the National Library of Australia's Newspapers Digitisation Program [8]; the *LEMO Annotation Framework* [7]; a variety of initiatives and online community projects such as *Weaving History*[1] or *The Great War Archive Flickr Group*[2]; and, last but not least, the authors' own contribution to the Europeana[3] cultural heritage Web portal [21], [22] are examples which indicate that the idea of harnessing the collective volunteer effort of the public to accumulate, enrich and preserve valuable cultural heritage content is gaining momentum.

As a consequence, the need for data and metadata interoperability in the cultural heritage domain is growing. Yet despite some efforts to develop collection-spanning metadata vocabularies [20], interoperability of annotations is still an area of ongoing and active research. Most institutions employ their own proprietary in-house annotation solutions and models [7], and global digital cultural heritage is still distributed among isolated islands [9].

In this paper we present ongoing work on a Web-based annotation system for digitised old maps. The system is being developed over the course of the EU-funded Europeana*Connect* project, and leverages the principles of *linked data* to achieve interoperability of annotations. Spatial and temporal information plays a crucial role in this context: old maps are, on the one hand, an inherently spatial medium, because they are explicitly concerned with the representation of geography; on the other hand, they are catalogued with provenance and temporal metadata, because they are part of cultural heritage collections.

The remainder of this paper is structured as follows: in Section 2, we present an overview of our current prototype, which allows users to create annotations on old maps, and interactively enrich them with semantic links. Interactive feedback is thereby supported through a novel interaction mechanism based on the tag cloud metaphor, which we introduce in Section 3. We conclude the paper with a discussion of related work in Section 4, and an outlook on future work in Section 5.

2 System Overview

One of the objectives of the Europeana*Connect* project is the creation of portal technologies that enable community involvement on the Europeana digital cultural heritage Web portal. Our specific interest in the project is the design of services and user interfaces that enable public participation by means of media annotation. The goal is to extend Europeana with multiple dedicated annotation frontends for each of the various types of media hosted on the portal – images, maps, hypertext, audio and video – while storing all annotations according to a unified media-independent model.

[1] http://weavinghistory.org/
[2] http://www.flickr.com/groups/greatwararchive/
[3] http://europeana.eu/

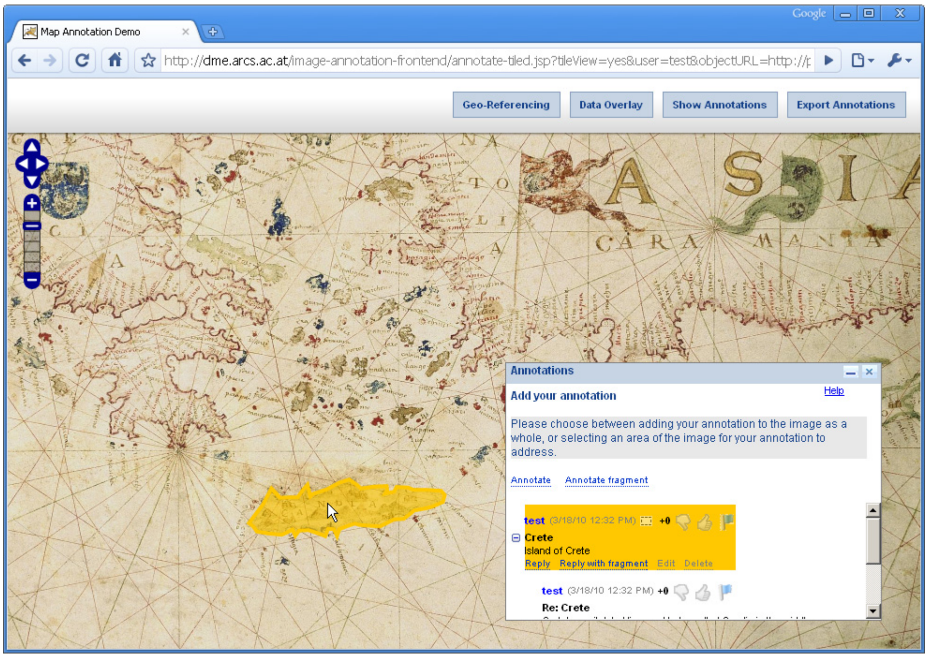

Fig. 1. User interface screenshot: Map viewer (in the background) and annotation management component (floating window in the foreground), with a single annotation selected.

Our map annotation prototype is a browser-based rich Web application, realised with the Google Web Toolkit[4]. The prototype integrates three basic functionalities: (1) A map browsing interface that provides a drag- and zoom-able representation of the digitised map. (2) Geo-referencing functionality that allows users to establish an (approximate) correspondence between the map's image-coordinates and geographical coordinates. (3) An annotation toolset including client-side GUI features that allow the user to draw points, lines and polygon shapes on the map and add free annotation text, combined with server-side functionality needed to store annotations, create links to external linked data sources, and expose the annotations as Linked Data. A screenshot of the prototype is shown in Fig. 1.

2.1 Map Browsing

The prototype's main user interface component is the map viewer. It is based on the open source OpenLayers[5] JavaScript Web mapping library, and provides a full-screen drag- and zoom-able representation of the digitised map. Similar to popular Web map services like Google Maps[6] or Yahoo! Maps[7], OpenLayers supports map tiling to

[4] http://code.google.com/webtoolkit/
[5] http://openlayers.org/
[6] http://maps.google.com/
[7] http://maps.yahoo.com/

minimise download latency when browsing high-resolution digitised maps. Instead of publishing each map as a single image file, collection holders can publish their maps as sets of (pre- or dynamically generated) image tiles, which the OpenLayers viewer will download progressively as needed, as the user pans and zooms the map.

Since, however, many collection holders (including Europeana member institutions) still publish their maps on the Web as single images rather than tile sets, the prototype integrates functionality to generate tiles from any online image on the fly, based on the open source GDAL2tiles utility [15].

2.2 Geo-Referencing

In order to establish a correspondence between the digitised map's image coordinates and a well-defined geographical coordinate system, the map must be geo-referenced. Geo-referencing of old maps, however, can be a major challenge. In the vast majority of cases, the metrical properties of the map will be uncertain: the system of reference may be undefined; accuracy and scale of representation are likely to vary across the map; the projection system may be approximate or even non-existent [3]. Nonetheless, if one accepts a certain level of inaccuracy, literature suggests that an approximate geo-reference can be established, at least as long as the map preserves basic topological properties.

A common practice to geo-reference a map with unknown properties is through the use of *control points*: control points are identifiable points (e.g. landmarks, cities, natural formations, etc.) on the map to which the geographical coordinates are known. These control points can then be used as a basis for analytical translations between both coordinate spaces [6]. Alternatively, "trial and error" can be used to test the old map against a known map projection model [5]. In this case, the control points can be used to quantify the amount of agreement with the tested projection. Experimental results using the above approaches are reported e.g. in [3], [5] or [24].

In the current implementation, our prototype allows users to collaboratively add control points to the map. Translation between map-image coordinates and geographical coordinates is performed by computing a local affine transformation from the closest neighbour control points. This way, approximate geo-referencing is established, which improves successively as users add more control points to the map. First results obtained with this implementation using sample maps from the 16^{th} century are reported in [22].

2.3 Annotation

For the implementation of annotation functionality, the prototype relies in part on existing functionality developed for Europeana*Connect* and its predecessor TEL*plus*. In particular, the prototype makes use of the same annotation management component as the existing Europeana*Connect* image annotation frontend, and of a common server-side annotation 'middleware'.

The annotation management component provides GUI elements for viewing, creating and editing annotation text, for creating replies (and reply threads), for annotation ‘scoping’ (setting an annotation’s visibility to public or private), and a basic moderation feature that allows users to report inappropriate annotations to the system administrator via E-Mail (see Fig.1).

The component exchanges annotations with the middleware through a REST interface, using an RDF/XML representation based on the W3C Annotea [11] model [7]. The middleware can be configured to work with different storage back ends such as an RDF triple store or a relational database, and exposes annotations on the Web as RDF resources so that external data sets can link to them from outside.

In order to achieve deeper integration of the annotations with the Web of Data, we have extended the existing annotation management component to allow for the creation of outbound links. This way, users can create semantic references that point from the annotation to related resources in other data sets. The details of the semi-automatic approach we devised for this purpose is described in detail in the following section.

3 Annotations as Linked Spatiotemporal Data

Our design approach was guided by two key requirements. First, we aimed for a process that is human-controlled. While the system should suggest potential links automatically, the user should have an immediate and intuitive way of verifying, accepting or rejecting them interactively. Second, we aimed for a system architecture that makes it easy to use, chain together and exchange different tools, APIs, and data sources to derive the link suggestions. With regard to the kinds of links that are suggested to the user, our prototype distinguishes between three different types of resources to which an annotation can link:

1. Geographical features that lie inside the annotated map region.
2. Geographical features that are mentioned in the annotation text (irrespective of whether they are located inside or outside the annotated map region).
3. Any recognisable non-spatial named entity (e.g. person, date, organisation, etc.) which can be identified in the annotation text and where an appropriate link to an encyclopaedic data set such as e.g. DBpedia [1] can be established.

3.1 Semantic Linking Procedure

When creating a new annotation in the prototype, the first step is to draw a point, a line or a polygon on the map to indicate the location or area to be annotated. In cases in which the map is already geo-referenced with control points, the system will compute geographical coordinates for the annotated region. Using this information, the system will obtain link suggestions for the first resource type mentioned above (geographical features inside the annotated region). In the current implementation, Geonames[8] is used as linked data source for this purpose, since it provides a

[8] http://www.geonames.org/ontology/

convenient query API for retrieving references to places within a specified bounding box.

While the user starts editing the annotation text, the system begins to successively suggest contextual semantic links. In general, the procedure for generating those suggestions is comprised of two steps: (1) The unstructured annotation text is parsed for named entities. (2) Recognized entities are linked to semantic resources in the namespace of a linked data set, if possible. A number of free as well as commercial tools which implement above functionalities have recently become available. As mentioned above, our idea was to test different combinations in our prototype. For the named entity recognition step, we experimented with Yahoo! Shortcuts[9] (as part of a Yahoo! Pipes[10] workflow), the Yahoo! Placemaker[11] API and the DIGMAP Geoparser[12]. For the semantic linking step, we relied on Geonames (which only resolves place names, but no other named entities) and DBpedia Lookup[13] to obtain dereferenceable URIs for the identified entities. As an alternative, we experimented with the OpenCalais REST API[14] which provides named entity recognition and semantic linking in a single, combined step.

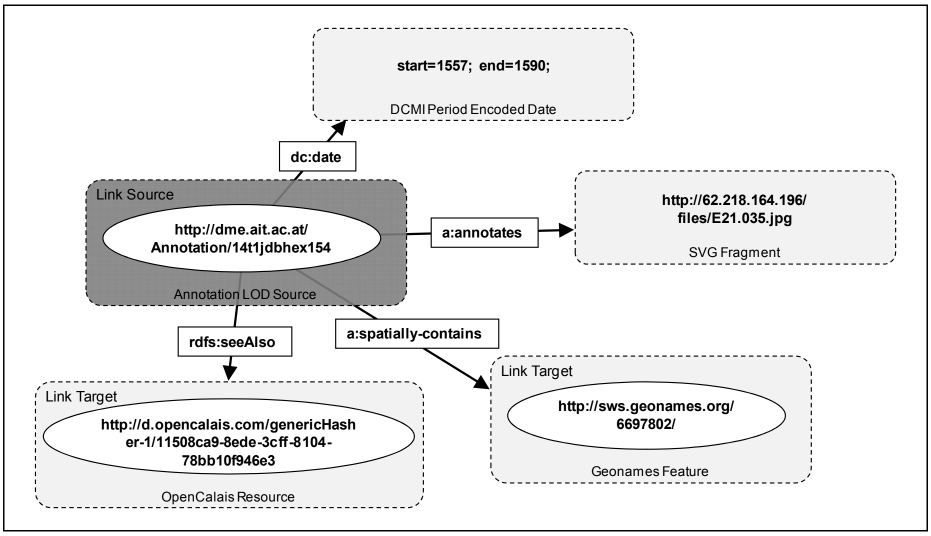

Fig. 2. Annotation model (example with Geonames and OpenCalais)

An example of the annotation model resulting out of this process is shown in Fig. 2. The annotation links to the annotated map area using the `annotates` predicate, which is derived from the W3C Annotea annotation schema. The object in this case is

[9] http://shortcuts.yahoo.com/
[10] http://pipes.yahoo.com/
[11] http://developer.yahoo.com/geo/placemaker/ (Note: resolves place names only.)
[12] http://geoparser.digmap.eu/
[13] http://lookup.dbpedia.org/
[14] http://www.opencalais.com/documentation/calais-web-service-api/

a representation of the spatial fragment (point, line or polygon) expressed in SVG[15] (using the map image's pixel coordinate space). Links to resources of the first type (geographical features inside the annotated map region) are expressed through a custom extension we introduced for this purpose: the *spatially-contains* predicate. Links to resources of the second and the third type (i.e. geographical features and other named entities in the annotation text, respectively) are expressed using the *rdfs:seeAlso* core property. Date information obtained from the map's metadata is included in the annotation by means of a Dublin Core[16] date element, formatted according to the DCMI Period Encoding Scheme[17].

3.2 The Tag Cloud Metaphor for Semi-Automatic Semantic Linking

On the Web, tag clouds have been gaining popularity as a way to compactly and efficiently visualise dominant topics and emerging key themes in structured or unstructured datasets. They are built from keywords ("tags") which users have freely assigned to digital resources and show the most frequently assigned tags in different font sizes according to their popularity. Tag clouds are especially prevalent on user-driven Web sites such as photo sharing or social bookmarking sites, where hundreds of thousands of tagged items may be hosted and organised. The resulting representation not only eases the browsing and searching of the dataset; it also helps to get the "gist" of the underlying items by providing a content-centric compact overview [17].

In previous work [22] we have discussed the tag cloud metaphor as a means to convey a "sense of context" to users while they are exploring old maps: as users hover over a region of the map with their mouse, a tag cloud can be superimposed directly around the mouse cursor. The tag cloud can summarize dominant terms appearing in other users' annotations, or in external sources of geo-referenced information such as Wikipedia. Users can thus get an overview of relevant topics related to the map region they are focusing on, without needing to divide their attention between multiple areas of the screen.

The work described in this paper builds on this idea, but extends it with regard to how the tags are being employed in the user interface. In the previous scenario, the tag cloud served primarily as a visualisation aid. In the case of our semantic linking prototype, the tag cloud becomes a dynamic user interface element which facilitates direct manipulation of the annotation's underlying data model. Each tag represents a semantic link suggestion generated by the system. New tags are added to the tag cloud as additional suggestions become available, e.g. after the user has finished drawing or editing the annotation shape, or while the user is typing annotation text. The three different types of link suggestions (as defined above) are distinguished in different colours. In cases where the services used to generate link suggestions provide an implicit or explicit relevancy or recognition certainty metric, this value can be used to define the size of the tag. Suggestions with a higher relevance are drawn in a larger

[15] http://www.w3.org/Graphics/SVG/
[16] http://dublincore.org/documents/dces/
[17] http://dublincore.org/documents/dcmi-period/

font than less relevant suggestions. (For example, Geonames sorts results by population and filters out smaller places that are in the vicinity of larger places; Yahoo! Shortcuts and OpenCalais both provide an explicit “prediction probability” or “relevance score”, respectively.)

Fig. 3. Adding semantic links to annotations (example uses Geonames and OpenCalais). Source material: Martin Waldseemüller, 1507, *Universalis Cosmographia*[18] (map); *Pillars of Hercules* Wikipedia article[19] (text).

Fig. 3 shows the user interface during the annotation process. At any time, the user can choose to accept a semantic link suggestion by clicking on the corresponding tag. The link is added to the annotation model; and a small check mark icon is placed on the tag to indicate that the annotation now links to the external resource. Clicking on the tag a second time will remove the link from the model (and the check mark icon from the tag).

4 Related Work

There are two areas of related research we consider particularly relevant to our work: (1) automatic and semi-automatic approaches to interlinking of open data and (2) the application of tag clouds in the context of linked data and the Semantic Web.

---

[18] http://memory.loc.gov/cgi-bin/query/h?ammem/gmd:@field(NUMBER+@band(g3200+ct000725C))

[19] http://en.wikipedia.org/wiki/Pillars_of_Hercules

A system which combines named entity recognition with human feedback to generate semantic links between documents (e.g. editorial Web sites or news articles) and DBpedia resources is described by Kobilarov et al. [12]. In their work, the authors also remark on their experience that the user interface of any semantic annotation tool is critical to the creation of high quality metadata; and that high quality automated link suggestions are needed to make the annotation process as painless as possible. A framework which allows users to find semantic relations between entities in different data sets is presented by Bizer et al. [4]. Their system features a declarative language which allows users to define a set of linking criteria a priori, and then identifies links which fulfil the specified criteria in an unattended process. An automatic approach for interlinking is presented by Raimond et al. [16], who discuss the interlinking of music-related datasets. They point out the challenges involved with naïve automatic interlinking approaches (based on matching of string literals), and present an algorithm for disambiguation based on graph matching. Furthermore, Auer et al. [2] discuss a solution for finding `owl:sameAs` mappings between geospatial linked data entities based on supervised machine learning.

With regard to the application of tag clouds in a Semantic Web context, there is related research on "augmented tagging" systems, i.e. systems which allow users to assign tags to digital content which are semantically meaningful in a machine-readable way, rather than free-form. For example, Passant and Laublet [13] discuss a framework where users can define tags, relationships between them, and their meanings. The framework relies on a central server through which the tags and relationships can be shared within a community, and has later resulted in an implementation called LODr [14]. Another stream of work concerns the visual design and layout of tag clouds to better reflect semantic relations between tags. Schrammel et al. [19] survey some recent research in this field. Furthermore, they present a user study which provides evidence that "semantic clustering" (i.e. arranging tags so that related tags are kept close to each other) can increase a tag cloud's usability with regard to visual searching tasks. However, they also acknowledge that the topic of semantic presentation is yet to be fully understood.

5 Discussion and Future Work

In this paper we have discussed a use case from the cultural heritage domain in which the principles of *linked spatiotemporal data* can be applied: the collaborative annotation of digitised old maps. We have presented a prototype annotation system which records annotations along with both a spatial and a temporal footprint, and exposes them to the Web of Data. To derive the spatial footprint, the system relies on geographical reference information, provided collaboratively by users through control points. The temporal footprint is taken from metadata associated with the map.

In addition, our system supports the user in the process of creating links to related RDF resources in other datasets. Link suggestions are created automatically, based (1) on the geographical footprint of the annotation, and (2) on an analysis of the annotation text, which is performed with external named entity recognition and semantic link discovery tools. A key design goal of our prototype was to enable an immediate and direct way of including human feedback into the semantic linking process to ensure the quality and correctness of the generated links. In order to achieve this, we have introduced a novel interaction approach, based on the tag cloud metaphor. This approach allows users to quickly survey link suggestions which may be relevant to an annotation they are creating, and to confirm valid suggestions with a single click.

As future work, we plan to focus on several issues. First, we intend to investigate how the use of named entity recognition and link discovery tools can be made more customisable. In the current prototype, a wrapper component must be implemented for each new tool, so that the prototype can access it in a uniform way. Tool chaining is done programmatically. A future version should provide a more declarative approach and make it easier to use and combine different tools and data sources for generating link suggestions. Experiments with the BPEL workflow execution language yielded some promising first results [18]. However, they also made a number of significant shortcomings apparent, which make BPEL a challenging and cumbersome option in this context: e.g. high runtime performance demands of the execution engine, as well as high complexity and a steep learning curve, due to lack of good (open source) authoring tool support, in particular with regard to the orchestration of RESTful Web services.

A second key item for future work is the explicit modelling of the geographical footprint in the annotation. As explained in Section 3.1, the present annotation model expresses the spatial footprint only in terms of pixel coordinates (in SVG format), not in terms of geographical coordinates (e.g. through a GeoRDF[20] representation). It would therefore not be possible to (easily) perform geographical queries on the annotations. For our current prototype, we intentionally decided to follow this approach. The reason for this is that, since the geo-reference of the map is based on user-contributed control points, it will improve as users add or modify points. Consequently, an explicit geographical footprint would potentially become outdated and require re-computation after every change to the control points. The current prototype therefore computes the footprints on the fly when needed, e.g. when they are exported from the system to the OGC KML[21] format for viewing in a virtual globe browser. As future work, we intend to investigate strategies for addressing this issue in a more scalable way (e.g. by providing an infrastructure that records whether changes have been made to a map's control point set, and performs re-computation of all affected annotations in a nightly batch job.)

Last but not least, we aim to further explore the use of the tag cloud metaphor in the context of linked data, and experiment with different presentation, layout and interaction concepts.

6 Acknowledgements

This paper presents work done for the best practice network Europeana*Connect*. Europeana*Connect* is a project funded by the European Commission within the area

[20] http://esw.w3.org/GeoRDF

[21] http://www.opengeospatial.org/standards/kml

of Digital Libraries of the eContentplus Programme and lead by the Austrian National Library.

References

1. Auer, S., Bizer, C., Kobilarov, G., Lehmann, J., Cyganiak, R., Ives, Z.: DBpedia: A Nucleus for a Web of Open Data. In: Proceedings of 6th International Semantic Web Conference, 2nd Asian Semantic Web Conference (ISWC+ASWC 2007), pp. 722–735, Springer-Verlag, Berlin, Heidelberg (2008)
2. Auer, S., Lehmann, J., Hellmann, S.: LinkedGeoData – Adding a Spatial Dimension to the Web of Data. In: Proceedings of the 7th International Semantic Web Conference (2009)
3. Balletti, C.: Georeference in the Analysis of the Geometric Content of Early Maps. In: e-Perimetron, vol. 1, no. 1 (2006)
4. Bizer, C., Volz, J., Kobilarov, G., Gaedke, M.: Silk – A Link Discovery Framework for the Web of Data. In: Proceedings of the 18th International World Wide Web Conference (2009)
5. Boutoura, C.: Assigning Map Projections to Portolan Maps. In: e-Perimetron, vol.1, no. 1, pp. 40-50 (2006)
6. Boutoura, C., Livieratos, E.: Some Fundamentals for the Study of the Geometry of Early Maps by Comparative Methods. In: e-Perimetron, vol. 1, no. 1, pp. 60-70 (2006)
7. Haslhofer, B., Jochum, W., King, R., Sadilek, C., Schellner, K.: The LEMO Annotation Framework: Weaving Multimedia Annotations with the Web. In: International Journal on Digital Libraries, vol. 10, no. 1, pp. 15-32 (2009)
8. Holley, R.: Many Hands Make Light Work: Public Collaborative OCR Text Correction in Australian Historic Newspapers. In: National Library of Australia Staff Papers, ISBN 978-0-642-27694-0 (2009)
9. Jankowski, J., Cobos, Y., Hausenblas, M., Decker, S.: Accessing Cultural Heritage using the Web of Data. In: Debattista, K., Perlingieri, C., Pitzalis, D., Spina, S. (eds.) 10th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST 2009 (2009)
10. Jochum, W., Kaiser, M., Schellner, K., Wirl, F.: Living Memory Annotation Tool – Image Annotations for Digital Libraries. In: L. Kovács, N. Fuhr, C. Meghini (eds.) ECDL, LNCS, vol. 4675, pp. 549-550. Springer (2007)
11. Kahan, J., Koivunen, M.-R., Prud'Hommeaux, E., Swick, R. R.: Annotea: An Open RDF Infrastructure for Shared Web Annotations. In: Proceedings of the 10th International Conference on World Wide Web, pp. 623-632 (2001)
12. Kobilarov, G., Scott, T., Raimond, Y., Oliver, S., Sizemore, C., Smethurst, M., Bizer, C., Lee, R.: Media Meets Semantic Web — How the BBC Uses DBpedia and Linked Data to Make Connections. In: ESWC 2009 Heraklion: Proceedings of the 6th European Conference on the Semantic Web, pp. 723–737, Springer-Verlag, Berlin, Heidelberg (2009)
13. Passant, A., Laublet, P.: Meaning of a Tag: A Collaborative Approach to Bridge the Gap Between Tagging and Linked Data. In: Proceedings of the WWW 2008 Workshop Linked Data on the Web (LDOW2008), Beijing, China (2008)
14. Passant, A.: LODr - A Linking Open Data Tagging System. In: Workshop on Social Data on the Web, SDoW 2008, (2008)
15. Přidal, P., Žabička, P.: Tiles as an Approach to On-Line Publishing of Scanned Old Maps, Vedute and Other Historical Documents. In: e-Perimetron, vol. 3, no. 1 (2008)
16. Raimond, Y., Sutton, C., Sandler, M.: Automatic Interlinking of Music Datasets on the Semantic Web. In: Proceedings of the WWW 2008 Workshop Linked Data on the Web (LDOW2008), Beijing, China (2008)

17. Rivadeneira, A. W., Gruen, D. M., Muller, M. J., Millen, D. R.: Getting Our Head in the Clouds: Toward Evaluation Studies of Tagclouds. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM (2007)
18. Sadilek, C., Simon, R., Haslhofer, B.: Service Orchestration for Linking Open Data: Applying a SOA Principle to the Web of Data. In: Proceedings of the 1st International Workshop on Recent Trends in SOA Based Information Systems (2010)
19. Schrammel, J., Leitner, M., Tscheligi, M.: Semantically Structured Tag Clouds: An Empirical Evaluation of Clustered Presentation Approaches. In: Proceedings of the 27th International Conference on Human Factors in Computing Systems (CHI '09), pp. 2037-2040. ACM (2009)
20. Schreiber, G., Amin, A., Aroyo, L., van Assem, M., de Boer, V., Hardman, L., Hildebrand, M., Omelayenko, B., van Osenbruggen, J., Tordai, A., Wielemaker, J., Wielinga, B.: Semantic Annotation and Search of Cultural-Heritage Collections: The MultimediaN E-Culture Demonstrator. In: Journal of Web Semantics, vol. 6, nr. 4, pp. 243-249 (2008)
21. Simon, R., Korb, J., Sadliek, C., Schmidt, R.: Collaborative Map Annotation in the Context of Historical GIS. In: Workshop on Geospatial Computing for the Arts, Humanities and Cultural Heritage, Oxford, UK (2009)
22. Simon, R., Korb, J., Sadilek, C., Baldauf, M.: Explorative User Interfaces for Browsing Historical Maps on the Web. In: 5th International Workshop on Digital Approaches in Cartographic Heritage, Vienna, Austria (2010)
23. van der Sluijs, K., Houben, G. H.: Metadata-Based Access to Cultural Heritage Collections: the RHCe Use Case. In: PATCH'2008, Proceedings of the 2nd International Workshop on Personalized Access to Cultural Heritage, workshop at the 5th International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH2008), Hannover, Germany, pp. 15-25 (2008)
24. Tobler, W. R.: Medieval Distortions: The Projections of Ancient Maps. In: Annals of the Association of American Geographers, vol. 56, no. 2, pp. 351-360 (1966)