Maphub - Final Report

1. Introduction

Historic maps record historical geographical information often retained by no other written source (Rumsey and Williams, 2002) and give insight into socio-economic and environmental phenomena such as land use, river channel changes or flood (e.g., Pearson, 2006; Braga, G., & Gervasoni, 1989; Witschas, 2003). They allow the reconstruction of past urban environments (e.g.; Isoda et al., 2010) and draw a picture of the cultural, political and religious context in which they were created (Rumsey and Williams, 2002). Their geographical accuracy tells us much about the state of technology at the time of their creation. Consequently, historic maps are cultural heritage artifacts in their own right, part of the artistic heritage as much as of the history of science and technology as a whole (Boutoura and Livieratos, 2006).

Scholars who study these maps often want to take notes on certain maps or map regions, view certain areas in the context of today's maps, associate map regions with historical events, places, or even persons. Annotations are a fundamental scholarly practice common across disciplines (Unsworth, 2000) and a scholarly primitive that enables scholars to organize, share and exchange knowledge, and work collaboratively in the interpretation and analysis of source material. At the same time, annotations offer additional context: they supplement the item under investigation with information that may better reflect a user's setting (Frisse, 1987). However, many historic maps, which have been digitized so far, still reside in closed system environments within libraries, museums, or private collections (e.g., Rumsey Historical Map Collection[1]). Those that are already published on the Web don't allow scholars or end-users to annotate them in a way that is interoperable across systems.

Therefore we built a demonstrator entitled *Maphub*, which is a Web portal allowing annotation of digitized, high-resolution maps. It implement five major use cases:

1. **Annotating regions on high-resolution map images**: the high-resolution zoomable maps presented to Maphub users are, in fact, compound Web resources comprising a set of image tiles and a metadata descriptor file. Users have the possibility to zoom into maps and annotate map regions or complete maps.
2. **Georeferencing maps**: users can mark places on maps (control points) and link those places to geographical Web resources (e.g., Geonames[2]). Using this information, it is possible to establish a correspondence between a map's image coordinates and real-world geographic coordinates. This, in turn, enables creation of visual overlays on-top of modern mapping applications (e.g., Google Earth).

[1] http://www.davidrumsey.com/
[2] http://www.geonames.org/

3. **Semantic Tagging**: while a user is creating textual annotations on a map or map region, Maphub automatically proposes resources from the Linked Data Web (e.g., DBPedia), which may be semantically related to the annotation and therefore also to the underlying annotated map. Users can accept or reject link proposals and thereby create positively or negatively weighted associations between maps and URI-identified Web resources.
4. **Sharing Map Annotations**: all annotations created in Maphub follow the Open Annotation Data Model specification and and are published on the Web as first-class, URI-identified resources. Clients can easily consume map annotations by dereferencing HTTP URIs.

For demonstration purposes, we bootstrapped the portal with 6000 digitized historical maps taken from the Library of Congress Historic Map division. Those maps are not covered by copyright protection and can easily be reused without technical, financial, or legal restrictions. In the following, we will elaborate the conceptual and technical details of each use case. We will conclude this report with lessons learned from building the Maphub demonstrator and briefly discuss how selected system components are being further developed and how they can be reused in other applications.

2. Annotating Maps

Maphub is available in any modern Web browser and organized as an open source project[3]. It allows users to retrieve maps either by browsing or searching over available metadata and user-contributed annotations and tags. Users can zoom into maps, highlight a region on the map, and add their knowledge about that region by adding textual annotations. Figure 1 shows the central Maphub map annotation view.

Figure 1. Maphub Map Annotation View.

[3] http://maphub.github.io

To create an annotation, users markup regions on the map with geometric shapes such as polygons or rectangles. Once the area to be annotated is defined, they are asked to tell their stories and contribute their knowledge in the form of textual comments. While users are composing their comments, Maphub periodically suggests tags based on either the text contents or the geographic location of the annotated map region. Suggested tags appear below the annotation text. The user may accept tags and deem them as relevant to their annotation or reject non-relevant tags. Unselected tags remain neutral.

Figure 2 shows an example user annotation created for a region covering the Strait of Gibraltar. While the user entered a free-text comment related to the naming of the area, Maphub queried an instance of Wikipedia Miner[4] to perform named entity recognition on the entered text and received a ranked list of Wikipedia resource URIs (e.g., http://en.wikipedia.org/wiki/Mediterranean_sea) in return. URIs should not be exposed to the user, so Maphub displays the corresponding Wikipedia page titles instead (e.g., Mediterranean Sea). Since page titles alone might not carry enough information for the user to disambiguate concepts, Maphub offers additional context information: the short abstract of the corresponding Wikipedia article is shown when the user hovers over a tag.

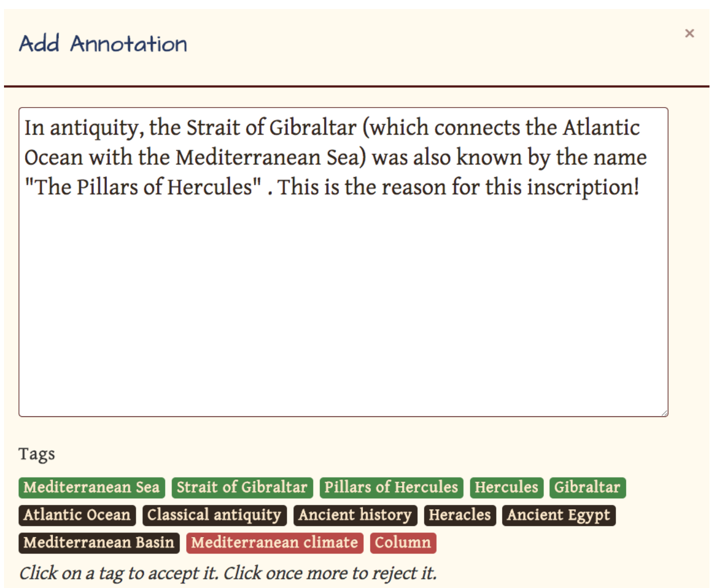

Figure 2. Maphub Annotation Input Dialogue.

Once tags are displayed, users may mark them as relevant for their annotation by clicking on them once, which turns the labels green. Clicking once more rejects the tags, and clicking again sets them back to their (initial) neutral state. In the previous screenshot, the user accepts five tags and actively prunes two tags that are not relevant in the context of this annotation.

[4] http://wikipedia-miner.cms.waikato.ac.nz/

3. Georeferencing Maps

Besides commentarial annotations, which have been described in the previous section, Maphub also support so-called Georeference Annotations, which allows users to create an annotation with the intention to express a correspondence between a point/region on the map and either a point/region in a defined geographic coordinate system or an authoritative Gazetteer. The goal of this type of annotation is to establish *control points* for raster image maps. The current Maphub application uses Geonames as Gazetteer and links control points to URI-identified locations, which provide further information such as latitude and longitude coordinates. Figure 3 shows examples of control points added to historic maps.

Figure 3. Control Point Annotation Examples.

After at least three of these control points are added to a map, a geographical model can be computed for the map. This allows Maphub to prompt the user with more locations and suggest those locations as semantic tags in the annotation input dialogue.

Furthermore, after adding at least three control points to a map, it is possible to calculate real-world locations for any point on the map and create overlay views on modern mapping applications such as Google Maps or Google Earth. These views will overlay a historic map onto its current day location. Figure 4 shows example map overlays.

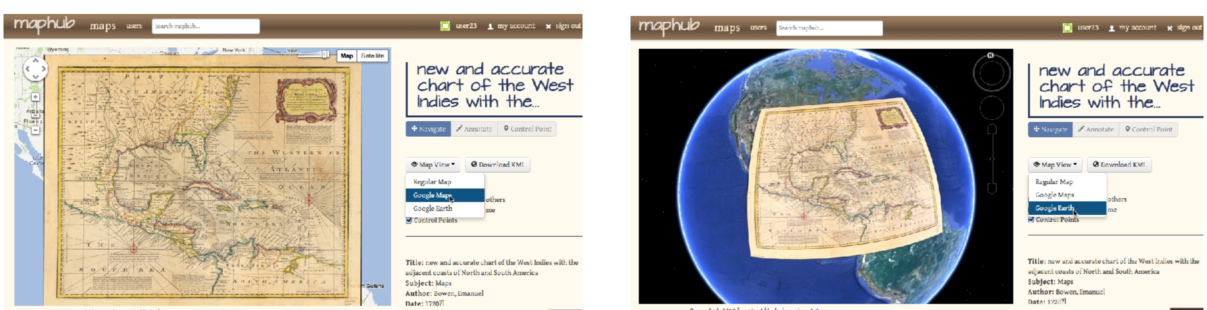

Figure 4. Google Maps and Earth Overlays created from georeferenced historic map images.

4. Semantic Tagging

Maphub's semantic tagging feature has been motivated by the problem that despite their wide-spread adoption, tagging systems still face a number of problems: a tag can be ambiguous and have many related meanings (*polysemy*), multiple tags can have the same meaning (*synonymy*), or the semantics of a tag might range from very specific to very general because people describe resources along a continuum of specificity (Golder and Huberman, 2006). These issues are rooted in label-based nature of tags and important for system providers who want to exploit the semantics and contextual information associated with tags for resource discovery. If, for instance, a user tags a resource with *Paris* it is not entirely clear whether this tag means *Paris*, the capital of France or *Paris*, the city in the United States. Contextual information, such as the translations of the term *Paris* in other world-languages or its geographical location can only be determined after reconciling label-based tags with data entries in other data sources.

Mapping label-based tags to concepts defined in knowledge contexts, such as Wikipedia is a possible solution. Sigurbjörnsson and Van Zwol (2006) use string matching to map Flickr tags to WordNet semantic categories and found that 51.8% of the tags in Flickr can be mapped. Overell et al. (2009) use concept definitions from Wikipedia and Open Directory to classify tags automatically and show that nearly 70% of Flickr tags can be classified correctly. However, in all these approaches tag semantics is determined heuristically and a-posteriori, without taking into account the user who created and assigned the tag and knows about its precise semantics.

To solve this problem, we propose that users associate URI-identified Web resources from a knowledge context, such as Wikipedia, as part of their tagging activity. A tagging system could suggest the label *Paris* as a possible tag in the user-interface, but create a link to a Web resource (e.g., http://en.wikipedia.org/wiki/Paris) in the back-end. We call this technique *semantic tagging*. Different from label-based tagging, the semantics of a tag is determined by its creator at creation time. Each tag also leads to further contextual information that can be exploited for resource discovery purposes. Explicit user feedback on suggested tags results in a graph of positive and negative tagging relationships that can be used to improve tag recommendation strategies.

To demonstrate the user acceptance of this approach, we implemented semantic tagging in Maphub. We wanted to illustrate how to design semantic tagging systems so that users can easily select from suggested semantic tags, accept or reject proposed tags, without ever having to interact with URIs directly. We also ran an empirical evaluation to compare semantic tagging with other tagging techniques. In the following we discuss the conceptual and design-related aspects of the semantic tagging technique and compare it with existing, label-based tagging design characteristics. We also briefly summarize the main findings of our experiments, which are described in more detail in Haslhofer et al. (2013).

4.1. Conceptual Model

In the conceptual model for label-based tagging systems introduced by Marlow et al. (2006), which is shown in Figure 5, a user *u* assigns a tag *t* to a resource *r*. Tags are represented as labeled edges that connect users and resources but do not carry or refer to any additional contextual information. Both resources and users may be connected to other nodes, since there may be links between Web pages and users may belong to social networks. Label based tagging systems can allow for multiplicity of tags around resources (*bag-model*) or deny tag repetitions (*set-model*).

Figure 5. Label-based Tagging Model.

Semantic tagging, which is shown in Figure 6, extends this model by representing a tag *t* as a qualified relationship between two resources: r_x is the resource identifying and defining the semantics of a tag (e.g.,http://en.wikipedia.org/wiki/Paris), and r_y is the resource being tagged (e.g., a photo taken in Paris). The former is defined within a knowledge context *K* and can carry textual labels (e.g., *Paris*) and additional context information (e.g., Paris is a city in France). Possible knowledge contexts are online encyclopedias such as Wikipedia, place name registries such as GeoNames, structured Web data sources such as Freebase[5], domain-specific Web vocabularies or gazetteers, or any other Linked Data source providing suitable concept definitions. An explicit, qualified semantic tagging relationship also implies an *about* relationship between the involved resources, meaning that r_x is about r_y if they are connected by a user via a semantic tagging relationship.

Figure 6. Semantic Tagging Model.

Since semantic tags can also be represented as first-class URI-identified Web resources, the resulting model is not label- or set-based but *graph-based*, with different types of nodes (users, resources) being connected to each other. This enables multiplicity and aggregation of tags not

[5] http://www.freebase.com/

only around resources but also around users and user groups, which can be exploited for graph-based tag recommendation and user-based collaborative tag filtering.

We believe that an information system implementing semantic tagging should allow users to easily select from suggested tags, accept or reject proposed tags, without ever having to interact with URIs. Therefore we will now continue discussing the following design aspects in more detail: *tag recommendation*, *user feedback*, and *user transparency*.

4.2. Tag recommendation

Marlow et al. (2006) distinguish between three main categories existing systems fall into: *blind tagging*, where a user cannot view tags assigned to the same resource by other users, *viewable tagging*, where users sees tags associated with a resource, and *suggestive tagging*, where the system suggests possible tags to the user. Suggestive tagging systems can derive tags from existing tags by the same or other users or gather them from a resource's context.

Following this classification, we perceive semantic tagging as a special form of suggestive tagging, where tag resources are recommended from a given knowledge context, based on the context of any resource that is part of the semantic tagging graph. As in other suggestive tagging systems (see Gupta et al., 2010), tag recommendation strategies can consider the content (e.g., image file) or context (e.g., metadata, other tag resources) of a resource. If the applied knowledge context follows a graph structure, it is also possible to apply graph-based recommendation strategies for tag resource proposals. When, for instance, a system proposes the semantic tag *Paris*, it could also propose related resources such as *France*, and *Eiffel Tower* if these concepts are semantically connected in the underlying knowledge context - as it is the case in Wikipedia. In Maphub, for example, we recommend semantic tags based on the text users are entering while they are authoring annotations on historical maps.

Semantic tag suggestion can be implemented by calling named entity recognition services that link things mentioned in plain text to Web resources, such as Wikipedia Miner[6] or DBPedia Spotlight[7].

4.3. User feedback

Adding a label-based or semantic tag to a given resource usually means that the tag is somehow about or describes the resource, at least within the context of the tag creator. If a user applies the tag *Paris* to an image it is assumed that Paris is somehow about that image. Thus, an intrinsic assumption of existing tagging models is that relationships between tags and resources have positive connotations.

However, with tags becoming first-class resources describing a qualified relationship between resources, one can also capture negative relationships: when the system recommends a set of possibly relevant (semantic) tags and the user accepts one of them, it can infer a positive tagging relationships. However, the system could also capture the non-accepted or explicitly

[6] http://wikipedia-miner.cms.waikato.ac.nz/
[7] https://github.com/dbpedia-spotlight

rejected tags and interpret them as negative tagging relationships, as illustrated in Figure 7. An explicitly rejected tag *Berlin* on an image showing Paris is an example for such a negative relationship.

Figure 7. Semantic Tags forming a Graph of Positive and Negative Relationships.

Qualified semantic tagging relationships carrying positive and negative weights can easily be transformed into a bipartite graph of positive (accept) and negative (reject) *about* relationships between semantic tags and tagged resources. From this graph, one can directly derive relevance judgments for given pairs of Web resources and build gold standards, which are required for subsequent information retrieval tasks.

4.4. User transparency

The World Wide Web uses HTTP URIs to unambiguously identify Web resources, such as the Wikipedia article about Paris. However, URIs are opaque strings that do not necessarily carry any semantics. While the design choice in Wikipedia was to use-human readable URIs (e.g.,http://en.wikipedia.org/wiki/Paris), other sources do not follow this approach. In the GeoNames knowledge context, for instance, Paris is identified by a URI with a numeric path element http://www.geonames.org/2988507. Such a URI syntax is hard to remember for human end-users and might lead to errors when being transcribed manually.

Therefore, semantic tagging systems should hide the technical aspects of this approach underneath the user-interface and follow the design of existing suggestive tagging interfaces: they should neither display nor prompt users to input HTTP URIs, but suggest labels and maintain internal, user-transparent mappings between labels and their corresponding resources. For example, instead of displaying a semantic tag URI for Paris the system should present labels such as *Paris*.

This of course requires that the knowledge context also provide human-readable labels for resource definitions, which is common practice in real-world data sources. In the case of Wikipedia one can, for instance, extract the article's title (*Paris*) directly from the Web page or rely on DBpedia, which provides structured data extracted from Wikipedia.

4.5. Empirical Evaluation Summary

While working on Maphub, its semantic tagging functionality has become our core research interest. We conducted an in-lab user study with 26 participants to find out how semantic tagging differs from label-based tagging and other suggestive techniques. Our central findings can be summarized as follows:

- Our semantic tagging implementation does not affect tag production, the types and categories of obtained tags, and user task load, while providing tagging relationships to well-defined concept definitions.
- When compared to label-based tagging, our technique also gathers positive and negative tagging relationships, which can be useful for improving tag recommendation and resource retrieval.

Hence, semantic tagging as implemented in Maphub could produce the same result as a label-based tagging, with the main difference that semantic tagging gives references to unambiguous Web resources instead of semantically ambiguous labels. More details on the methodology and results of that experiment are described in our report available at (http://arxiv.org/abs/1304.1636).

5. Sharing Map Annotations

Sharing collected annotation data in an interoperable way was another major development goal. Maphub is an early adopter of the Open Annotation model[8] and demonstrates how to apply that model in the context of digitized historic maps and how to expose comments as well as semantic tags. As described in the Maphub API[9] documentation, each annotation becomes a first class Web resource that is dereferenceable by its URI and therefore easily accessible by any Web client. In that way, while users are annotating maps, Maphub not only consumes data from global data networks - it also contributes data back. In the following we briefly introduce the central aspects of the Open Annotation model and describe how we implemented it in Maphub.

5.1. Open Annotation Data Model

Annotations on the Web have many facets: a simple example could be a textual note or a tag annotating an image or video. Things become more complex when a particular paragraph in an HTML document annotates a segment in an online video or when someone draws polygon shapes on tiled high-resolution image sets, such as the historical maps used in Maphub. Therefore in a generic, Web-centric conception, an annotation can be regarded as an association between a body and a target resource (Haslhofer et al., 2011) .

Annotea (Kahan, 2002) already defines a specification for publishing annotations on the Web but has several shortcomings: (i) it was designed for the annotation of Web pages and provides

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[8] http://www.openannotation.org/spec/core/
[9] http://maphub.github.io/api

only limited means to address segments in multimedia objects, (ii) if clients want to access annotations they need to be aware of the Annotea-specific protocol, and (iii) Annotea annotations do not take into account that Web resources are very likely to have different states over time.

Throughout the years several Annotea extensions have been developed to deal with these and other shortcomings: Koivunnen (2006) introduced additional types of annotations, such as *bookmark* and *topic*. Schroeter et al. (2007) proposed to express segments in media-objects by using \emph{context} resources in combination with formalized or standardized descriptions to represent the context, such as SVG or complex datatypes taken from the MPEG-7 standard. Based on that work, Haslhofer et al. (2009) introduce the notion of *annotation profiles* as containers for content- and annotation-type specific Annotea extensions and suggested that annotations should be dereferenceable resources on the Web, which follow the Linked Data guidelines. However, these extensions were developed separately from each other and inherit some of the above-mentioned Annotea shortcomings.

In 2011 the Open Annotation Collaboration (OAC)[10] formed as an international group with the aim of providing a Web-centric, interoperable annotation environment that facilitates cross-boundary annotations, allowing multiple servers, clients and overlay services to create, discover and make use of the valuable information contained in annotations. A Linked Data based approach has been adopted and resulted in the formation of the W3C Open Annotation Working Group, which recently published a first Open Annotation Community Draft[11]. Figure 8 shows the core conceptual model of the current model specification.

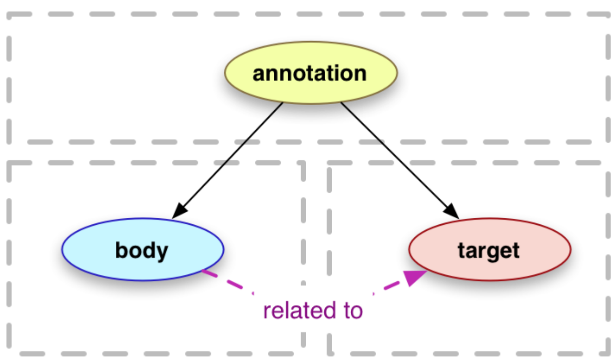

Figure 8. Open Annotations Data Model - Core Model.

Maphub is an early adopter of the Open Annotation model and demonstrates how to apply the model in the context of annotations on historic maps and how to expose georeference and commentarial annotations as well as semantic tags as first class Web-resources that are dereferenceable by their URIs. In that way, while users are annotating maps, Maphub not only consumes data from open data sources - it also contributes open data back. In the following we describe how Maphub implements the Open Annotation Data model for the types of annotations it currently supports.

[10] http://www.openannotation.org/
[11] http://www.openannotation.org/spec/core/

5.2. Sharing Georeference Annotations

A Georeference Annotation associates a place URI, which can be interpreted as a semantic tag, with a place on the map (the annotation Target). Place URIs are provided by the Geonames online gazetteer (e.g., London, UK: http://sws.geonames.org/2643743/). Georeference Annotations in Maphub are dereferenceable Web resources. When a client issues an HTTP GET request against the Georeference Annotation HTTP URI, Maphub determines the response format based on the value of the HTTP Accept header submitted by the client.

Figure 9 shows an example Georeference Annotation represented in the Open Annotation model. Each annotation receives its own URI (yellow) and follows one more annotation types (e.g., oa:Annotation). Common types can be defined as part of the (extended) Open Annotation specification or introduced on a per-application basis (e.g, maphub:GeoReference). Descriptive metadata can be attached to each annotation (e.g.: annotation author information). In this case, the annotation's body is a semantic tag, i.e., the place identified by a GeoNames URI, whereas the target is a specific resource, which represents the highlighted region on the map, identified by x,y, width, and height parameters.

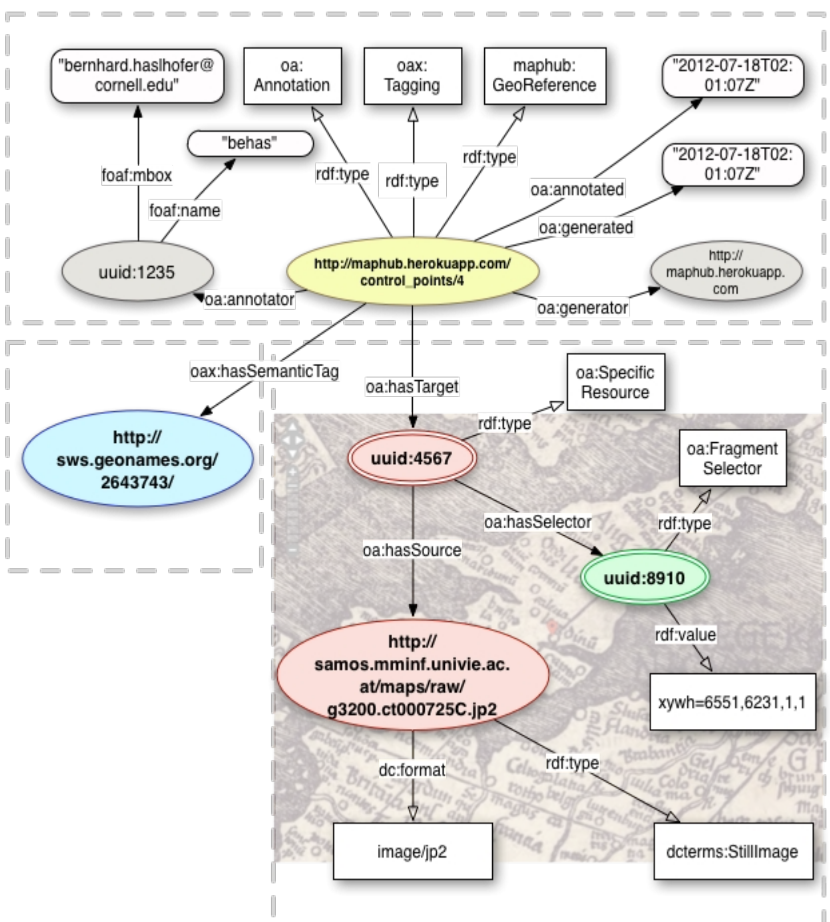

Figure 9. Example Georeference Annotation exposed as Open Annotation.

5.3. Sharing Commentarial Annotations and Semantic Tags

Figure 10 illustrates how this annotation is represented in the Open Collaboration Model. The annotation text is represented as an Inline Body, and the semantic tags as Semantic Tags. Since the annotation is about part of the map resource, the annotation target is a Specific Target, which is further described by two Selector representations: one SVGSelector and a custom Selector that expresses the same information in the Well-known text (WKT) markup language, which is commonly used in geographic information systems.

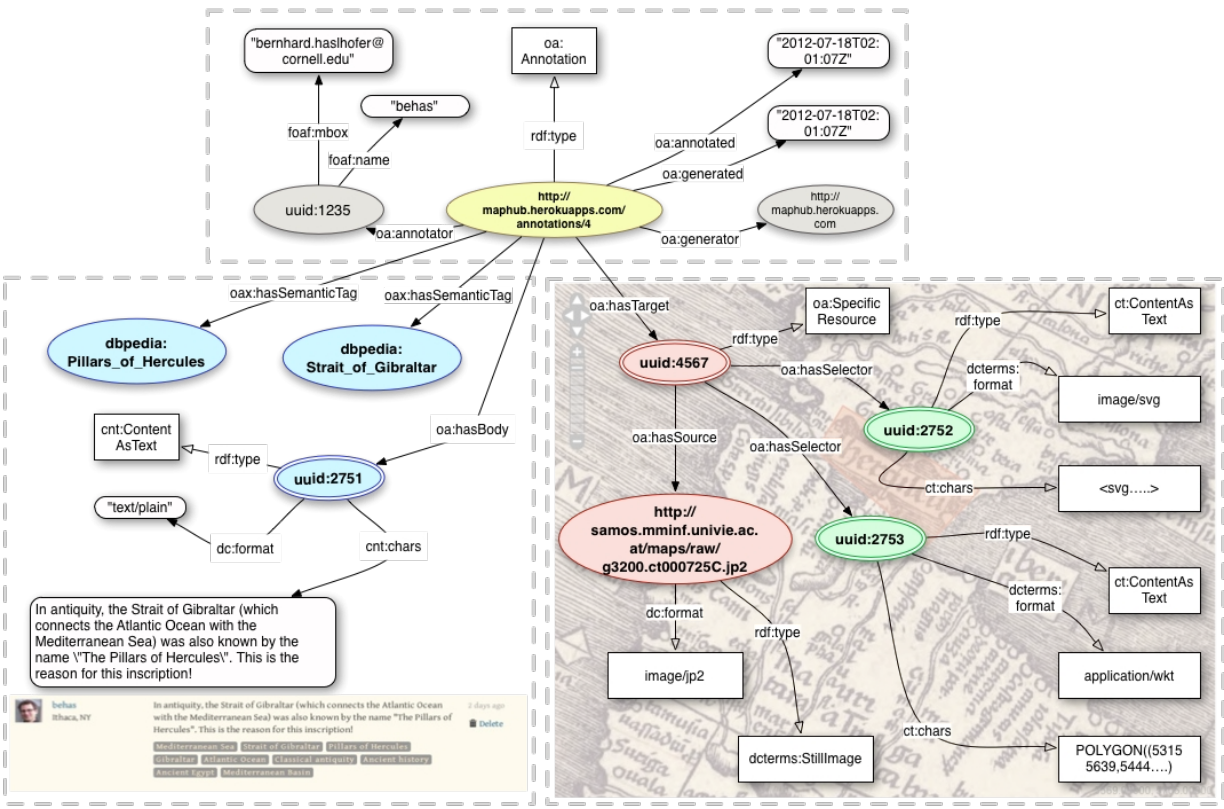

Figure 10. Example Commentarial Annotation exposed as Open Annotation.

Besides exposing individual georeference and commentarial annotations, Maphub also exposes annotation indices that enable discovery of those annotations.

6. Lessons Learned and Future Work

With Maphub we demonstrated how a Web-based approach could support scholars who study historical maps in taking notes on certain maps or map regions, viewing certain areas in the context of today's maps, and associating map regions with historical events, places, or even persons. We believe that semantic tagging is a key feature in such a process and findings from our empirical evaluation confirmed that this feature is worth to be further explored.

Overall, we believe that our findings carry implications for designers who want to adopt semantic tagging in other scenarios. A major incentive for system providers to implement tagging is to obtain metadata describing the content and context of online resources, which is important for efficient resource discovery but expensive in terms of time and effort when created manually. In traditional, label-based tagging systems providers can add possibly ambiguous label- based tags to their records. With semantic tagging, they obtain references to concepts defined in other Web-based knowledge context. Traditional information retrieval techniques can be enhanced to exploit these relationships and consider additional contextual information.

We believe that people might also want to annotate other things on the Web and that Web annotation tools should support semantic tagging as well. Therefore, we will make it available as a plugin for Annotorious[12], which is a JavaScript image annotation library that can be used in any Website, and is also compatible with the Annotator[13] Web annotation system. Figure 11 shows how semantic tagging can now be applied for any Web image using the Annotorious library.

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[12] http://annotorious.github.io
[13] http://okfnlabs.org/annotator

Figure 11. Semantic Tagging in Annotorious.

Finally, we would like to emphasize that availability of **open metadata and content** - in our case the historic map collection from the Library of Congress - has been key for designing and implementing Maphub and for experimenting with previously unavailable features. Availability of open APIs and absence of copyright restrictions allowed us to bootstrap Maphub with minimal technical and no financial or legal effort.

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