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Collaborative Creation of Semantic Points of Interest as Linked Data on the Mobile Phone

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Collaborative Creation of Semantic Points of Interest as Linked Data on the Mobile Phone

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Abstract. The novel mobile application csxPOI (short for: *collaborative, semantic, and context-aware points-of-interest*) enables its users to collaboratively create, share, and modify semantic points of interest (POI). Semantic POIs describe geographic places with explicit semantic properties of a collaboratively created ontology. As the ontology includes multiple subclassifications and instantiations and as it links to DBpedia, the richness of annotation goes far beyond mere textual annotations such as tags. With the intuitive interface of csxPOI, users can easily create, delete, and modify their POIs and those shared by others. Thereby, the users adapt the structure of the ontology underlying the semantic annotations of the POIs. Data mining techniques are employed to cluster and thus improve the quality of the collaboratively created POIs. The semantic POIs and collaborative POI ontology are published as Linked Open Data.

1 Introduction

The widespread adoption of powerful mobile devices with permanent Internet connectivity and context-aware applications running on such devices is turning the vision of ubiquitous computing to into reality [1]. Such applications are among others aware of the user's geographic location and can adapt their behavior and content accordingly. For location-based applications, points of interest (POIs) are the most basic form of adapted content. POIs provide useful information about specific geographic places. Whether users are able to quickly find the POIs they are interested in, depends among others on the quality of the POIs' annotations. Unstructured textual descriptions of POIs and folksonomic tags are a good starting point. However, with mere textual descriptions and tagging of POIs, the relation between the POIs remains hidden in the data and is hard to extract and understand for the machine. Other (mobile) systems such as [2, 3] provide a semantic representation of POIs but do not provide for a collaborative creation and modification of semantic POIs and an underlying ontology of POI categories.

In order to understand semantic POIs and their relations, we have developed the mobile application csxPOI, which is short for *collaborative, semantic, and context-aware points of interests.* The csxPOI application allows its users to collaboratively create, share, and modify *semantic POIs.* While working with the POIs, the users implicitly collaboratively modify and improve an ontology of POI categories underlying to the application. The csxPOI application integrates both the developments of ubiquitous computing and extensive volunteer collaboration to create a geographic dataset with explicit semantics. All permanently stored data is expressed in RDF (`http://www.w3.org/TR/rdf-concepts/`) and made publicly available according to Linked Open Data principles (`http://www.w3.org/DesignIssues/LinkedData.html`).

Such user-contributed POIs gathered from a large group of people will likely include duplicate POIs with similar but unequal annotations and slightly varying locations for the same physical places. In order to improve the quality of the collaboratively created POIs, we provide a POI revision engine that applies data mining techniques for POI clustering.

2 Collaborative Ontology for Points of Interests

For representing collaboratively created semantic POIs, we have created a set of ontologies for modeling the structure of POIs, content of POIs, user accounts, and most notably the history of all collaborative user activities. The *base ontology* defines the fundamental concepts such as POI, contribution, and user and their relationships. The *vocabulary ontology* defines POI categories such as monument, park, and others. It also provides the properties, relationships, and interlinks of the POIs. The vocabulary ontology is open to direct collaborative modification by users of the csxPOI application. The *POI ontology* comprises all instances of POIs and their associated metadata. As such, the ontology directly depends on the categories defined in the vocabulary ontology. Users of the csxPOI application primarily interact with this ontology during POI creation and POI retrieval. The *collaboration ontology* represents any kind of collective activity in the csxPOI application and are called *contributions*. A contribution is either the creation, modification, or deletion of a POI as well as the creation, modification, and deletion of a POI category in the vocabulary ontology. The collaboration ontology directly depends on the previous three ontologies. Finally, the *user ontology* contains all instances of users of the csxPOI system and their respective account information.

As the first users of our csxPOI application have not yet created their own POI categories, there is an initial vocabulary ontology extracted automatically from LinkedGeoData (`http://linkedgeodata.org/vocabulary`). The relevant resources from the LinkedGeoData vocabulary are transformed into and related to the `voc:` namespace of the vocabulary ontology.

Each resource from our ontologies is dereferenceable over HTTP URIs. For example, an HTTP request to the URI `http://csxpoi.isweb.uni-koblenz.de/users#max` returns information about users and `http://csxpoi.isweb.uni-koblenz.de/vocabulary#monument` refers to a single category in the returned comprehensive collection. The responses of HTTP requests to the URIs `http://csxpoi.isweb.uni-koblenz.de/poi/100` and `http://csxpoi.isweb.uni-koblenz.de/contribution/200` contain information about instances of a POI and some user contribution to the system.

3 The csxPOI Architecture

The csxPOI application is organized in a three-tier client-server architecture. Figure 1 shows a schematic overview of this architecture consisting of mobile clients, a server, and a triplestore. The mobile client provides features such retrieval, creation, modification, and deletion of POIs. It is implemented using the Android software stack (`http://developer.android.com/`) and is described in detail in Section 4. The server consists of an abstraction layer for the collaborative ontology of POIs introduced in Section 2 and provides the user management. It also provides a POI revision engine to improve the quality of the collaboratively created POIs, which is described in Section 5. The server is implemented as Apache Tomcat servlet handling the communication with the mobile clients and the triplestore over HTTP. The csxPOI data such as the semantic POIs, categories, and users are stored and retrieved by the triplestore. It is realized as Sesame web application on top of the same Apache Tomcat web server.

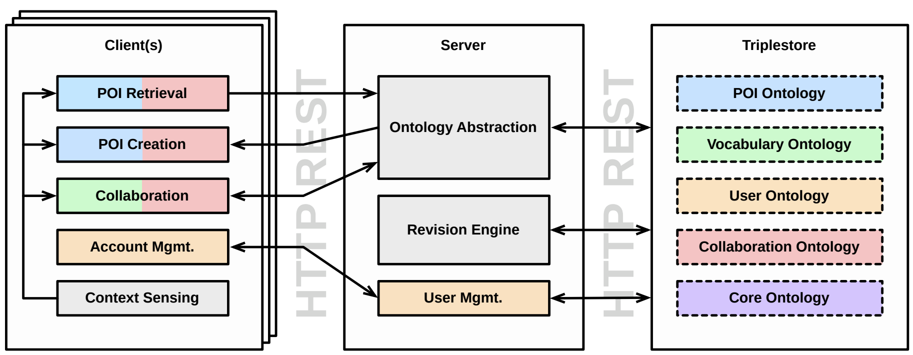


Fig. 1. Overview of the csxPOI architecture

4 The csxPOI Application

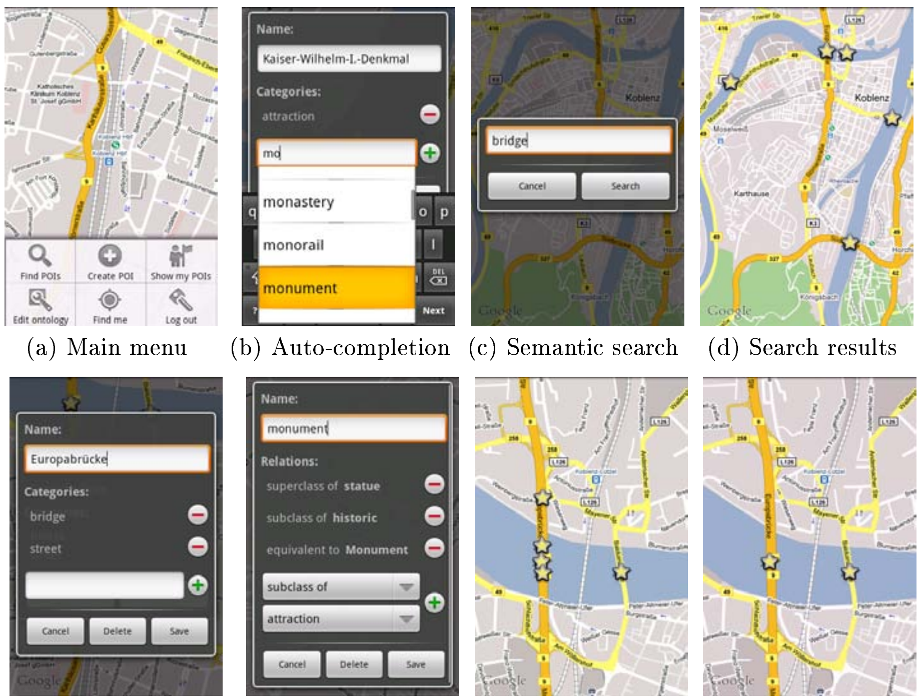
The csxPOI application allows its users to collaboratively create, share, and modify semantic points of interest (POI). While working with the POIs, the users implicitly collaboratively modify and improve an ontology of POI categories underlying to the application.

4.1 Creation of POIs

The default screen of the csxPOI application is shown in Figure 2(a). Once registered, users can *Create POIs* at the position centered on the map. The POI's altitude is supplemented by GeoNames SRTM3 elevation web service (`http://www.geonames.org/export/web-services.html`). Subsequently, a dialog containing a text field for the POI's name is shown. In addition, semantic categories of the POI can be entered. Figure 2(b) shows a sample POI created for the *Monument to Kaiser Wilhelm I*[1] in Koblenz, Germany. The screenshot

[1] `http://www.travelsignposts.com/Germany/sightseeing/kaisermonument`

shows the POI with its German name *Kaiser-Wilhelm-I.-Denkmal* and a list of the two categories named *attraction* and *monument*. Categories are added by entering their name in the corresponding text field which features a semantic auto-completion function. A sample usage of the semantic auto-completion can be seen in Figure 2(b), where the categories beginning with *mo* are shown. Each entry corresponds to a category from the collaborative POI ontology introduced in Section 2 with all its relations and interlinks. The user can either select one of the suggested categories and annotate the POI by pressing the plus button or enter a new name, i.e., a category that is not included in the ontology. Entering a new category opens the ontology editor for further specification of it.



(a) Main menu (b) Auto-completion (c) Semantic search (d) Search results

(e) Editing a POI (f) Category editing (g) Duplicate POIs (h) Revised POIs

Fig. 2. Screenshots of our csxPOI application showing its different feature

4.2 Retrieval of POIs

Users can *Find POIs*, i.e., search for POIs in the vicinity and display them on the map. Here, two options are possible: semantic search and presenting all POIs associated with the current user. A sample result for the semantic search *bridge* can be seen in Figure 2(d), where the POIs are marked with star symbols. The feature *Show my POIs* (see button in Figure 2(a)) provides a list of all POIs the specified user created or modified. The details of a POI displayed on the map can be shown by tapping on it. It shows the name at the top and below a list of all categories the POI belongs to. For example, a POI named *Europabrücke* (in english: Europe bridge) with the two categories *bridge* and *street* is shown in Figure 2(e).

4.3 Modification of POIs and Shared Ontology

The user can *Edit* the POI, when he is logged in. Figure 2(e) shows the POI editor for the previous example. The POI name can be edited in a text field at the top. Categories are added by entering their name in the text field at the bottom with support of semantic auto-completion and pressing the plus button. This may open the ontology editor if a category name is unknown. Removing categories is conducted via the minus button.

Besides creating and editing semantic POIs, the collaborative POI ontology can also be edited directly through the *ontology editor*. There are two ways of starting the ontology editor: automatically during POI creation when the user adds an unknown category or manually via the *Edit ontology* option from the main menu of the application (Figure 2(a)). In the latter case, the user first selects a category of a POI to edit. An example for the appearance of the ontology editor dialog for the category *monument* is shown in Figure 2(f). Users can edit the category's name in the text field. Below is a list of relations, each representing one RDF triple with the edited category as the subject of the triple. The predicate is defined by the relation type. It can be one of *subclass of*, *superclass of*, and *equivalent to*. The former two correspond to the property `rdfs:subClassOf` and its inverse, the latter to `owl:sameAs`. The object of the triple is the target category. It is shown on the right hand side and can be any category from the vocabulary ontology. In addition, it can be a concept from an external resource such as DBpedia (`http://dbpedia.org/`). New relations are added by choosing the relation type and category from the lower drop-down menus as shown in Figure 2(h) and pressing the plus button. Existing relations can be removed by pressing the minus button to the right of them.

4.4 Individualization and Rollback

As with all modifications in the csxPOI applications, no type of information is entirely removed from the collaborative POI ontology by the end user. Rather, user activities such as POI creation, modification, and deletion are added and stored as contributions by individual users. Thus, the individual user or administrator may reject spam users and roll back to previous versions of either the ontology or POI definitions.

5 Revision of Collaboratively Created POIs

Collaboratively created semantic POIs inevitably introduce a significant amount of inaccuracy, inconsistency, and redundancy. To improve the POI quality, the csxPOI application provides a revision engine that clusters POIs with combinations of spatial, linguistic, and semantic similarity measures in order to identify duplicate POIs. The revision engine follows a two-step approach: In a first step, the similarity of POIs is computed based on spatial, linguistic, and semantic characteristics. In a second step, clusters of duplicate POIs are identified and the database of POIs is updated.

Computing Spatial, Linguistic, and Semantic Similarity The spatial similarity is measured by calculating the distance between two POIs and mapping it to inverse values in $[0, 1]$ with 1 indicating the identical location and 0 indicating maximal distance. The distance is based on the WGS 84 reference ellipsoid modeling the earth's surface [4]. Linguistic similarity is modeled by the Jaro-Winkler [5] string metric between the labels of two POIs. In the csxPOI ontology, POIs are instances of categories which themselves have subclass relations among each other. This taxonomic structure is utilized to assess a semantic similarity between POIs by comparing their relative position in the hierarchy. This is computed with the asymmetric similarity measure MDSM [6]. The different metrics are integrated with a weighted linear combination of their individual normalized values.

Determining Clusters of POIs For clustering POIs, we employ the DBSCAN algorithm [7] as it supports noise such as duplicate POIs. DBSCAN is based on the notion of density-reachability, where clusters are expanded by adding similar points.[2] If the clustering algorithm classifies a POI as noise, it is considered to be the only representative of the described physical place and no duplicates have to be merged. However, if a cluster is found its members are interpreted as a group of neighboring points of interest with properties similar enough to be considered as referring to the same physical place. If the clustering of POIs is based on a multi-dimensional similarity like the previously described combination of spatial, linguistic, and semantic measures, the number of false classifications can be minimized. On the one hand, the proximity of POIs alone is not sufficient to merge them. For example, the physical distance between two different shops may be below the resolution delivered by the GPS system. On the other hand, one point of interest may actually be spread over a larger area, e.g., over the length of a bridge or the area of a zoo. Hence, it should be merged into a single attraction with a larger spatial coverage. For the latter purpose, we consider the high similarity of linguistic features and semantic features of created POIs. We choose the medoid as representative of the cluster. The medoid is the member in the group of POIs with the maximum average similarity to rest of the cluster. An `owl:sameAs` relation pointing to the medoid is then added to the remaining members of the cluster.

Figure 2(g) shows a screenshot where five semantic POIs have been created where some of them refer to a single physical place, in this case a bridge. The four POIs on the left are all variations of the actual bridge and vary in location and the name given, which is *Europabrücke* (two times), *Europa-Brücke*, and *Europabrucke*. These four POIs are categorized as bridges as they instantiate the category `voc:bridge`. But some additionally belong to the `voc:street` category and others to `voc:pedestrian`. The bridge can be used by both vehicles and

[2] Please find a detailed description of the algorithm in [8].

pedestrians, which lead to this ambivalent categorization. The POI on the right has the name *Balduinbrücke* and also represents a bridge.

After clustering, the four POIs on the left have been merged into one POI as shown in Figure 2(h). They were identified as a cluster because their mutual similarity was high enough when combining the similarity of their name strings, their spatial proximity, and their similarity within the taxonomy. Although the POI on the right is semantically very similar and linguistically somewhat similar, the geographic distance to the cluster on the left caused its classification as noise. Thus, the POI remains unchanged.

6 Related Work

Context-awareness and location-based information is a central aspect of the csxPOI application. One of today's most sophisticated mobile context-aware applications is IYOUIT [2]. It features social relationships, location records, and weather conditions, which are stored in formal ontologies. DBpedia [3] is an effort to extract structured information from Wikipedia and publish it in Linked Data. DBpedia Mobile [9] is a mobile client to explore that data. It uses the client's GPS sensor and semantic datasets to display nearby places on a map. DBpedia Mobile's Linked Data browser provides the user with background information about discovered places. Unlike our approach, IYOUIT and DBpedia mobile do not allow for the collaborative creation of a network of semantic POIs and their respective categories.

For collaborative ontology creation, Holsapple et al. [10] identify five approaches: inspiration, induction, deduction, synthesis, and collaboration as well as hybrid approaches combining them. The *collaborative approach* focuses on cooperation in the design process, thus creating a rich and dense ontology while fostering its acceptance by reflecting diverse experiences and viewpoints. The coordination of the collaboration should be supported by mediating mechanisms, such as the iterative improvement of an anchor ontology. The DILIGENT framework [11] is based on the observation that loosely-controlled continuous improvement through argumentation can help non-experts in ontology engineering to efficiently find a truly shared ontology. The framework foresees the collaboration of domain experts, ontology engineers, knowledge engineers, and users. The introduced approaches describe a collaborative ontology design process that is carefully organized and requires a certain level of expertise and explicit communication between the participants. These innate requirements usually do not hold in a volunteer collaboration context such as considered for the csxPOI application. Balance is needed between the limited commitment of volunteer non-expert user contributions [12] (resulting in quality deficiencies of the data) and the need to retain a necessary degree of organization of the collaboration.

As described in Section 5, we combine with the csxPOI application spatial, linguistic, and semantic similarity measures [5,6,13] and are using the DBSCAN algorithm [7] for clustering POIs in order to detect and remove duplicate POIs.

7 Conclusions

We presented a novel mobile application csxPOI for collaboratively creating, sharing, and modifying semantic points of interest. Additionally, the vocabulary ontology comprising the POI categories used for the semantic annotation of POIs is itself a product of a collaborative process. As user-contributed POIs inherently introduce duplicate POIs, we provide a POI revision engine based on data mining techniques to improve the quality of the collaborative POI data set. The collaboratively created POIs and categories are made available according to Linked Open Data principles.

With respect to context-awareness, we currently focus on the location of the user for POI retrieval. As there is more to context than location, we plan to extend context-awareness to leverage, e.g., user interests and preferences. Currently, users can modify and delete POIs created by other users. In a future extension of the system, one might want to add other policies such as setting POIs to private and thus invisible to others. Further information and updates can be found at: `http://isweb.uni-koblenz.de/Research/systeme/csxPOI`.

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