FOAF on Air

Context-aware User Profiles for the Social Web

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Abstract. In this work we report about the automatic creation of dynamic user profiles that combine personal data from diverse social networks with context information recorded by IYOUIT, a mobile community service in the field of context awareness. Data mining algorithms are applied to learn about users and their preferences over time. Rich, semantically annotated Friend of a Friend (FOAF) profiles are created on demand, and thus always reflect the latest level of information. Existing extensions and potential enhancements of FOAF are discussed.

1 Introduction

Are you on Facebook? How about Twitter? What's your Last.FM ID? Do you share photos on Flickr? Remembering all required account details and administrating all corresponding networks of friends, business acquaintances and personal profiles surely is a time-consuming task. However, in order to benefit from each individual community service, be it for fun or business purposes, effort in keeping personal information up-to-date is unavoidable.

With IYOUIT[1] [1], a mobile community service in the field of context-awareness, we recently introduced a prototype that mediates between diverse social networks and provides added value through the management and preparation of context information. Raw context data such as GPS coordinates or output from an accelerometer is recorded on the mobile handset and sent to networked server components to be further processed. In combining different types of information, including meteorological data, the proximity of other people or a user's call history (to name only a few), the user's actual surrounding can be characterized. Having knowledge about the user and his environment is useful for a multitude of services and applications. IYOUIT integrates some of the most popular Web 2.0 services including Flickr,[2] Twitter,[3] Facebook[4] and Last.FM,[5] thus enriching existing service offerings with meaningful annotations, automatic status updates and user profiles.

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[1] `http://www.iyouit.eu`
[2] `http://www.flickr.com`
[3] `http://www.twitter.com`
[4] `http://www.facebook.com`
[5] `http://www.last.fm`

In order to provide truly personalized services, having knowledge about the meaning and the correlation of personal information streams is inevitable. In the following, we present our attempts to interpret diverse types of information, either coming from sensing the user's vicinity via the mobile phone or retrieved from connected Web 2.0 services. As a result, rich user profiles can be deduced to explore social interaction in the virtual world. This paper summarizes first results of newly established research aspects in IYOUIT that focus on context-based user profiling and the adoption of common semantic representation formats.

2 Social Data Mining

With IYOUIT's mobile application personal information including digital location traces, status updates or communication patterns can be automatically recorded, processed and in turn made available to the user on the mobile handset or on the Web. From localized service offerings to real-time presence updates of registered buddies, IYOUIT offers a broad range of benefits to the mobile user. Most personalized service offerings require user profiles that hold information about basic demographics and application specific preferences. To facilitate and substantially improve the automatic creation of such profiles, data mining algorithms are applied. Here, the general aim is to learn about the user, his habits and liking to increase the personal profit in participating and contributing to the community.

IYOUIT builds upon a distributed component infrastructure to allow for flexible service deployments. Each distinct type of context information is therefore processed in a corresponding network component, in the following referred to as ContextProvider, and is made available to clients and other components through a rich API. Whenever possible, a ContextProvider is meant to abstract from raw data sources to qualitative information. In some cases, however, semantic references cannot be easily made, given the fact that some pieces of information, e.g. manual presence updates, may not be categorized subsequently.

Based on continuously recorded location traces, the LocationProvider applies clustering techniques [2] to deduce frequently visited places. Such places can be named and typified by the user to add meaning to automatically generated content. Places can be categorized in business related places, private as well as public areas of interest. Places that have been typified by the user are mapped to well-defined concepts in an underlying place ontology. These semantic references allow for several subsequent computations with regard to a user's personal profile. Based on a user's presence within a place typed as office, average working hours can be derived. Over time, not only the total hours of work are known but also a more detailed schedule of the time spent at home, at the office or on the train to work. Commuting time, for instance, can be approximated as the time between leaving and entering a home as well as office place. When comparing user specific values to those recorded by the entire community, a certain variance may further lead to interesting characteristics such as being a workaholic or frequent traveler. The latter can be assumed whenever the total number of automatically recognized trips within a predefined time interval exceeds a certain threshold, determined by the average travel activity of the entire community.

Since each ContextProvider may also encapsulate external data sources as well as 3rd party services, data provided by popular Web 2.0 services is in turn utilized within IYOUIT. To give an example, Last.FM, a community service that lets people socialize around music, offers an API to access a registered user's profile as well as music favors. This profile information can be enriched with automatically recorded usage patterns on the mobile handset. This way, not only the most popular artists or genres of a user are known, but also the context in which a certain type of music is preferred. Having information about the time of the day when a user is usually playing music in addition to associated activities such as commuting or being at home allows for significantly enriched music profiles.

2.1 Profile Management

Even though distinct, context-type specific user profiles are available in distributed components, the management and enrichment of profiles across multiple context types is accomplished by one central component - the ProfileProvider. In regular time intervals, all published profiles are harvested from registered components to provide a single endpoint for the retrieval of profiles for services building on top of the framework. The ProfileProvider's main task, however, is concerned with the cross-context analysis of personal data, as summarized in Figure 1. So-called context summaries, an aggregated variant of the actual data record, are retrieved periodically from all available components. The subsequent procedure identifies a uniform weighting of the context summaries retrieved, to compare different types of information with regard to their importance in the given time interval. References to the original information residing in the respective network component as well as its measured significance values are stored for further assessment. This context retrieval process is executed in periodical time intervals, eventually resulting in multiple snapshots of a concept's significance distribution over time. A concept stands for any atomic piece of information being considered, for instance information about staying in a personal place or updating ones presence information. Semantic associations that may have been computed within the respective ContextProvider, e.g. references to the place ontology, are maintained for subsequent reasoning tasks. The significance distribution of a concept results in trends of increasing, decreasing or steady importance.

Even though a certain trend of a given concept may indicate its relevance over time, the overall importance of a concept in a user's digital trace cannot solely be characterized by its presence in only one context stream. In addition, the degree of correlation with other concepts of different types and their respective co-occurrence considerably adds valuable meta-information about a concept's significance in general. As soon as a concept is being considered relevant, its

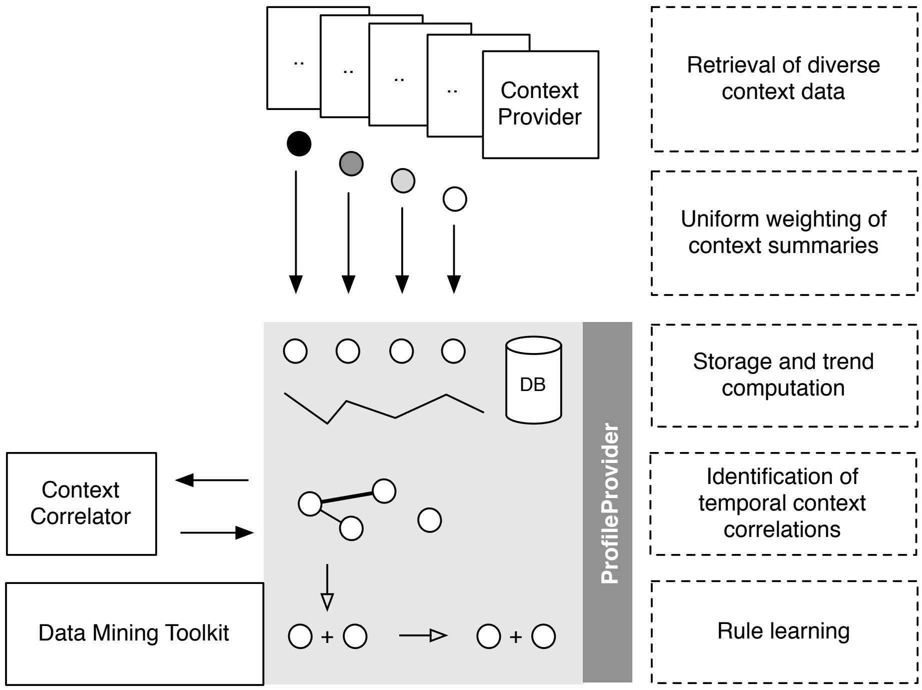

Fig. 1. Context correlation and rule learning procedure

temporal correlation with other context categories is computed. The computation of such context correlations is accomplished within the ContextCorrelator. Here, the temporal co-occurrence is the deciding factor whether or not two or more concepts are marked as correlated. To improve this co-occurrence measurement, each distinct type of context has been annotated with a validity attribute. The validity attribute has been assigned by the respective ContextProvider and is meant to quantify a concept's temporal duration. To give an example, an actual weather reading may have a validity of one hour, whereas a single location measurement may only be considered valid for 10 minutes.

The ContextCorrelator does not only identify correlations in multiple context streams but also assigns a weighting factor to each correlation pair. Based on these correlations and their corresponding weighting factors, association rule learning algorithms are applied subsequently. The ProfileProvider incorporates the WEKA toolkit [3], a collection of open-source data mining algorithms, to infer descriptive rules from temporal context correlations. More specifically, a Tertius algorithm is applied to compute arbitrary attribute combinations. Premise and consequence item-sets, each consisting of one or more attribute/value pairs define such a rule, further characterized by its coverage (the number of instances for which it applies correctly) and confidence (the fraction of examples satisfying the rule). An exemplary rule that has been automatically inferred from a user's combined context streams is shown below. It states that the respective user typically listens to Jazz music while being at home on Saturday.

```
place="space.owl#home" and weekday="time.owl#saturday" =>
    activity="activity.owl#listening_to_music" and genre="music.owl#jazz"
```

2.2 Profile Matchmaking and Visualization

The prime advantage of having rich user profiles in place are better, personalized service offerings. Usually, a community service commits itself to connecting users across explicitly given social relationships to leverage interaction and information exchange. To do so, the computed profiles and deduced patterns are further utilized in IYOUIT by applying a matchmaking mechanism, meant to identify and weight similarities in user profiles within the community. Users with similar hobbies, interests or preferences can thus profit from being implicitly connected. Input parameters for the actual matchmaking algorithm include a concept's current significance, its temporal distribution (trend) as well as its correlation degree. The latter can be seen as another indicator for a concept's overall importance among a given set of concepts. The weighting factors for each input parameter may vary depending on the actual application. In case the latest state of a concept's importance is the key factor, its significance value can be seen as the deciding factor. On the other hand, long-term considerations can be stressed by weighting a concept's temporal distribution accordingly.

So, in order to provide such a matchmaking algorithm for finding other users with similar interests, for instance as part of an online community portal, several other aspects with respect to the actual visualization of profile information in general and a corresponding query interface in particular need to be considered. Since the resulting user profiles are meant to be edited and reviewed by the user, the actual requirements on the data visualization are manifold. For one, the user should not be overwhelmed by the amount of information being displayed while, at the same time, the dynamic aspects of the profile data should be considered, too. On the other hand, the user should also be able to browse through profile information of other users in case a certain match has been found.

The most common way to visualize (mainly unstructured) data on the Web is by utilizing tag clouds. With tag clouds, the importance of concepts can be visualized by a tag's overall font size. However, only a very limited amount of meta-data is encoded within the cloud, preventing important information from being visualized. On the other hand, the advantages of a tag cloud based visualization are its wide adoption, ease of use and applicability to diverse domains. To overcome the limiting factors while still maintaining some beneficial aspects, we came up with a more advanced visualization paradigm, still borrowing the basic concept of representing data in a way similar to tag clouds. In short, the significance distribution of a tag over time is visualized by changing its font characteristics (e.g. by using different font sizes) within the representation of one tag. So in case the significance of a tag has decreased significantly, the font size of the distinct tag decreases, too, and vice versa. As a result, the tendency of the observed significance of multiple tags can be visualized in one (static) cloud, and thus enables a better identification and selection of tags not only based on their current significance, but their significance distribution over time. In addition, being able to visually identify trends of single data items or groups of items, it becomes possible to not only better understand the provided information but also to browse to historic samples of the data as recorded in the past. Once a certain tag has been selected, distinct parts of this tag that represent historic samples of the data set can be picked. As a result, the tag cloud is recomputed given the chosen temporal constraints. Likewise, through visualizing a tag's significance distribution over time, a trend-based browsing through the given dataset becomes possible.

The actual font sizes used for a given tag and its significance distribution can be computed by assuming that the number of distinct sections (or letters) of a given tag also restricts the number of significance measurements considered. This trend visualization can be described by

$$\forall_{i=0}^{k} f_i = F_{min} + \frac{s_i}{S_{max}}(F_{max} - F_{min})$$

with f_i being a distinct fonts size, F_{min} and F_{max} representing minimum and maximum font sizes, s_i being a distinct significance measurement and S_{max} representing the maximum significance measurement. Apart from those temporal aspects, existing tag cloud representations do often not allow for visualizing the degree of correlation and therefore lack another suitable differentiating factor between tags in one cloud. As a result, navigating through the dataset and restricting a given query along the lines of correlated tags is not possible. Our proposed visualization and interaction techniques tackle this constraint in visualizing the correlation factor between tags with either a distinct grouping, color-coding or distance indication. Figure 2 depicts a screenshot of our Web-based profile browser that implements the aforementioned visualization characteristics. By visualizing the correlation of tags by, for instance, more than one color, it becomes possible to differentiate between concepts representing a premise item set from the ones representing consequence attribute/value pairs.

Through the selection of one distinct tag, its significance and correlation with other concepts can be assessed. At the same time, the selected tag's meta-information is used to find matching descriptions in other user's profiles. The resulting weighted list of users is retrieved and displayed in a separate drawer on the left hand side of the profile browser. Here, the similarity degree of the profiles determines the ranking within the result set. Once another user's profile has been selected, the interactive tag cloud displays the selected user's profile. By browsing through different (anonymous) profiles, patterns found within the cloud can be explored to draw meaningful conclusions about the respective user. The profile browser as depicted in Figure 2 represents a prototypical implementation of the proposed visualization paradigm and will thus be further refined with respect to its adoption within the deployed service framework. The IYOUIT user community is invited to try out several aspects of the automatic user profiling and the profile matchmaking to provide valuable feedback on the practical use and general perception.

Fig. 2. Profile browser

3 Semantic Representation

Even though some semantic references are present, the underlying format of the profile data mainly builds upon a hierarchical XML representation shared among all IYOUIT components, including meta-information such as a concept's correlation or significance distribution. This allows for efficiently processing large amounts of data with common technologies while, at the same time, higher-level reasoning can still be accomplished by references to underlying ontology-concepts. However, a complete semantic foundation of the profile data would be beneficial in some respects. For one, a standard vocabulary for describing user profiles makes data exchange across service providers far easier. At the same time, a growing number of tools in the field of the Semantic Web provide support for enhanced query mechanisms across distributed knowledge sources [4]. The interconnected nature of IYOUIT and the Web 2.0 has always been predestined to create added value through the exchange of information across community barriers. Therefore, Friend-of-a-Friend (FOAF) [5], one de-facto standard vocabulary for the representation of social data on the Web, has been chosen as the external representation format. FOAF allows for the meaningful interpretation of personal profile information in a broad variety of services. It has been designed as a lightweight and extensible vocabulary. Incomplete by design, a number of extensions emerged since its introduction in 2001, covering a broad range of application specific requirements.

The core of each FOAF profile is comprised of the social network of the respective person. With the `foaf:knows` property, other people and their FOAF profiles can be interlinked. As stated in the vocabulary specification, `foaf:knows` is rather vague by design. Some applications, however, require a more fine-grained representation of social relationships between people. IYOUIT is an application of the latter, and provides means to express a social network by well-defined properties in a social ontology [6]. With it, ontology based reasoning mechanisms allow for maintaining the consistency of the network and its completion by making implicit relationships explicitly available. To preserve at least parts of this valuable information within the FOAF representation, we chose the RELATIONSHIP[6] ontology to express social relationships in addition to the unrefined `foaf:knows` constructs. Even though, the RELATIONSHIP ontology provides additional vocabulary to describe a number of relationships, some roles that could meaningfully describe the social connections between two or more people are missing. The trade-off between the possibility to model all facets of a social network and the reusability of the resulting representation needs to be carefully considered. The restrictions inherent in the limited expressivity of the resulting representation format also do not allow for distinguishing asserted from inferred knowledge. For instance, given the currently available vocabulary definitions, it is not possible to distinguish whether or not a social relationship has been inferred or has been given explicitly. However, the widespread use of FOAF and some of its most popular extensions allow for a rich tool support on the Web and therefore outplays the somehow limited expressivity in our case.

Another rather small vocabulary that is being used to express information about a user's visited countries is VISIT.[7] Through IYOUIT's worldwide adoption of people who tend to travel frequently, this addition is most welcome to represent at least one aspect of their travel activity. By constantly observing a user's location traces, trips can be automatically detected by computing the distance between subsequent measurements and the resulting speed approximation. Being able to automatically recognize trips, a user's profile can be updated instantly and without any user interaction.

In fact, most context data available within the IYOUIT framework is primarily concerned with real-time presence information about a user's current activity. Even though the principle use of FOAF is focused on rather static profile and contact information, the idea to also represent highly dynamic and frequently changing data seems to be reasonable as well. However, to actually state the timeliness of information, a timestamp must be present along with the data attribute and its value. One existing approach that utilizes `dc:date` attributes is the so-called MeNow vocabulary.[8] Basically, MeNow aims at describing the

[6] `http://vocab.org/relationship/`
[7] `http://purl.org/net/vocab/2004/07/visit`
[8] `http://crschmidt.net/foaf/menow/`

current status of a person. Its properties allow for expressing that a user is currently reading a book, the type of music he is listening or the websites he is browsing, amongst others. Also worth noting is the possibility to express the physical proximity of other users and their online activities. Therefore, MeNow addresses the growing demand for vocabularies that express the timeliness of information, as required for applications dealing with frequently changing information. An excerpt of an automatically created IYOUIT user profile is shown in the Appendix, including applicable real-time presence information encoded with the MeNow vocabulary.

4 Related Work

The FOAF vocabulary is the semantic representation format of choice for expressing social data in online networks. It has been explored in a broad variety of research areas with recent interest stimulated by the Linked Data approach [7]. A profound study of FOAF profiles found in online networks has been conducted by Golbeck and Rothstein [8]. By crawling available FOAF profiles and the subsequent application of reasoning mechanisms, overlapping profiles and links between separated networks are revealed. The authors show that users tend to make connections between separate networks, leveraging once again the need for a common representation format. Furthermore, implications on the use of social networking data and the development of intelligent user interfaces are given. In [9], the authors extract social graphs from online networks to investigate overlapping network fragments to link person instances from different information sources. Three alternative methods to compute graph similarity are discussed, including a low-level reasoning approach to investigate the implicit semantic similarity. Identified matches in separated graphs are resolved and the resulting links are in turn provided as a social graph.

Likewise to the semantic representation of data, the visualization of information on the web is a well-established research topic, too. In [10], the authors describe algorithms for improving existing tag cloud visualization techniques by optimizing the amount and placement of white spaces within the cloud. The authors propose to utilize the font spacing attribute to describe the visual weight and importance of single tags, however, the inner-tag space remains constant and does not encode a temporal significance or correlation distribution. An attempt to visualize tags over time is described by Dubinko et al. [11]. In contrast to our proposed methodology, the authors follow an animation-based approach. The principle idea is to present only a selection of tags in a pre-defined time interval. This approach is concerned with characterizing a certain time period rather than describing tags over time. No query restriction through the interaction with the tags can be achieved, whereas the selection of tags is only based on their frequency within the given time interval.

5 Summary & Outlook

The steady increase in the availability of semantically annotated knowledge sources across the Web and the development of tools making use of that information drives the ongoing trend towards a widespread, practical use of semantic data. Even though FOAF has been around for almost a decade, it has seen recent uptake through Google's attempt to crawl publicly available FOAF profiles and Yahoo's SearchMonkey[9] and its support for structured data, including RDF.

Typically, the information represented with FOAF can be seen as rather static, involving less frequent updates. However, the way people tend to use tools and services on the Web and in turn their personal reflection in social communities has changed considerably over the years. Frequently updating ones presence in Twitter and the provision of personal information is common practice for a lot of people. With IYOUIT we aim at simplifying this process through the combination of context information with personal profile data. Rich user profiles are automatically created and published, always reflecting the latest level of information. The timeliness of the information and the rich descriptions of a user's preferences are meant to provide the basis for novel, user-centric services.

In utilizing FOAF as the external representation format in combination with the use of cool URIs [12], IYOUIT user profiles enter the Linked Data Web [7]. However, FOAF has not been designed to represent frequently changing information. Existing extensions like MeNow vocabulary provide at least a minimal vocabulary to express a user's current activity. Nevertheless, in order to express all available presence data in IYOUIT, a more fine-grained vocabulary is required. Here, the possibility to not only express the actual level of information but also outdated data and future trends might be worth considering. A broad range of applications like personal recommendation engines [13] would considerably profit from multiple data snapshots in one distinct user profile to better reproduce the user's preferences over time. Having knowledge about the temporal distribution of personal information allows applications to dynamically adjust their service offerings and would therefore provide added value through the use of social data on the Web.

A future aspect of our work is to evaluate the use of flexible semantic representations, like (extended) FOAF, also as basic data structures internally within IYOUIT components. Preliminary results on realizing an IYOUIT social network visualization on a FOAF/RDF substrate via corresponding SPARQL queries demonstrated greater flexibility and improved robustness. The common representation format allows to interlink distributed social graphs through the interpretation of `foaf:holdsAccount`, `owl:sameAs` and `rdfs:seeAlso` triples in a generic way and thus allows for browsing friendships across social networks (almost) for free. Web 2.0 accounts that do not provide FOAF descriptions like Flickr, Twitter, Last.FM or DBLP [14] are linked to wrappers that generate the user profiles on the fly using the corresponding Web 2.0 APIs or SPARQL endpoints [15]. We hope to extend this FOAF substrate with the dynamic aspects discussed above, to realize the IYOUIT profile browser completely based on RDF and to fully integrate the current social network visualization.

[9] `http://developer.yahoo.com/searchmonkey/`

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Appendix

```xml
<foaf:PersonalProfileDocument rdf:about='http://.../user/1086/foaf'>
    <foaf:maker rdf:resource='http://.../1086/foaf#me'/>
    <foaf:primaryTopic rdf:resource='http://.../user/1086/foaf#me'/>
</foaf:PersonalProfileDocument>
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    <rel:friendOf rdf:resource='http://.../1231/foaf#me'/>
    <rel:acquaintanceOf rdf:resource='http://.../user/1239/foaf#me'/>
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