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Augmented context-based recommendation service framework using knowledge over the Linked Open Data cloud



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ABSTRACT

This research proposes ACARDS (**A**ugmented-**C**ontext **b**Ased **R**ecommen**D**ation **S**ervice) framework that is able to utilize knowledge over the Linked Open Data (LOD) cloud to recommend context-based services to users. To improve the level of user satisfaction with the result of the recommendation, the ACARDS framework implements a novel recommendation algorithm that can utilize the knowledge over the LOD cloud. In addition, the noble algorithm is able to use new concepts like the enriched tags and the augmented tags that originate from the hashtags on the SNSs materials. These tags are utilized to recommend the most appropriate services in the user's context, which can change dynamically. Last but not least, the ACARDS framework implements the context-based reshaping algorithm on the augmented tag cloud. In the reshaping process, the ACARDS framework can recommend the highly receptive services in the users' context and their preferences. To evaluate the performance of the ACARDS framework, we conduct four kinds of experiments using the Instagram materials and the LOD cloud. As a result, we proved that the ACARDS framework contributes to increasing the query efficiency by reducing the search space and improving the user satisfaction on the recommended services.

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1. Introduction

Due to the rapid development of ubiquitous computing technologies and the exponential use of smart handheld devices, there have been increasing demands for context-aware recommendation services. To meet the demands of the times, a great deal of research has been carried out to provide high-quality services depending on the context of the individual users. Consequently, various context-aware recommendation systems employing unique methodologies have been proposed and implemented [1–8]. In addition, with the rapid progress of the information and communication technologies, the spectrum of the context to be utilized for the recommendation services has been widened to include the user's goals, tasks, work context, business processes, and the user's emotional states from the simple context like the location, light, and sound [9]. These are good news for the users as they will have an abundance of opportunities to receive high-quality services.

Recently, as a new attempt, a context-aware recommendation service using knowledge on the Linked Open Data (LOD) cloud is being carried out to increase user satisfaction [10,11]. The Linked Open Data (LOD) as a successful realization of

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Semantic Web, appears to interlink and integrate the heterogeneous data on the web using the open standards like URI (Uniform Resource Identifier), HTTP (Hypertext Transfer Protocol), and RDF (Resource Description Framework). Since its advent in 2007 through W3 LOD project, the number of the data sets on the LOD cloud has been increased from 12 to 295, and the number of the RDF triples was explosively increased to 325 billion. In addition, to support the knowledge acquisition from the LOD cloud, such structured query languages as SPARQL and RDQL have been proposed [12,13]. However, it still has a long way to go to acquire the knowledge from the LOD cloud because of the immense size of the LOD cloud. The data sets on the LOD cloud are represented in RDF triples with a subject, predicate, and object. All elements of the RDF triples should be identified by the unique namespace. It means that the users who want to get precise knowledge from the LOD cloud must acquaint the URI, DB title, namespace, and names of the things in the data sets on the LOD cloud. Unfortunately, it is almost impossible to require the capabilities and/or knowledge to the users because the LOD cloud contains 300 data sets with different qualities, different purposes, unique URIs, and the unique names of the things [14].

In this light, the first and most important thing in the context-aware recommendation using knowledge on the LOD cloud is to facilitate the knowledge acquisition from the LOD cloud. To support the knowledge acquisition, research about the queries on the LOD cloud without the structured query languages has been carried out. The research can be classified roughly into an information retrieval approach, natural language processing approach, query rewriting approach, and pre-defined template-based approach. However, none of them has succeeded in satisfying the criteria of usability, query expressivity, vocabulary-level semantic matching, entity reconciliation, and the improvement of semantic tractability [15]. Even though semantic tractability – defined as the ability to answer queries with vague statements – is one of the vital factors in acquiring the appropriate knowledge from the LOD cloud, the research has rarely paid any attention to improving. Therefore, we propose a fully automated keyword-based SPARQL query generation algorithm to contribute to the improvement of semantic tractability of the queries on the LOD cloud. The algorithm is embedded into our context-aware recommendation system named **Augmented-Context bAsed ReCommEndation Service** framework (hereafter, ACARDS framework). One of the biggest advantages of the ACARDS framework is that it can almost eliminate the burden of the knowledge acquisition from the LOD cloud through the automation of the SPARQL query generation process. In addition, it can contribute to the improvement of the quality of the context-aware recommendation service. In this paper, we researched as follows.

- A conceptual expansion of the user-typed hashtags: We proposed expanded concepts of the user-typed hashtags on the SNSs materials to recommend highly satisfactory services to the users in the ubiquitous computing environments (UCEs). There are two types of expanded hashtags, named enriched tags and augmented tags. The expansion is sequentially performed from the enriched tags to the augmented tags. Finally, the augmented tags form an augmented tag cloud as a search space for the recommendation.
- A dynamic reshaping method of the augmented tag cloud: The reshaping of the augmented tag cloud is a very novel feature of the research. The reshaping process is triggered as soon as the user's context is changed. Based on the reshaped tag cloud, we can derive the user's preferences or behavioral patterns in the changed context. Furthermore, the most appropriate service for the user is determined and recommended.
- A hybrid approach to the generation of SPARQL statements: To reduce the generation burden of SPARQL statements, the ACARDS framework implements an algorithm to generate fully automated SPARQL statements which is classified as a hybrid approach combining the template- and the keyword-based approaches.
- A dynamic service composition depending on the changed context: Based on an automatically generated SPARQL statement, the ACARDS framework will get query results that are highly relevant to the user's current context. The ACARDS framework uses the query results to compose the services instead of recommending an appropriate service. The service composition is reformed whenever the user's context is changed.

The preliminary version of this study has been presented as a conference paper [16]. As compared with the preliminary version, this paper features the following differences and major contributions:

- We expand our research scope from the automated keyword-based SPARQL query generation algorithm to the context-aware service recommendation in the UCEs.
- We expand the hashtags on the SNSs materials to the enriched tags and the augmented tags in order to reduce the burden of finding the appropriate services and to improve user satisfaction with the results of the recommendation. Consequently, new tags are the base ingredients for building an augmented tag cloud that should be utilized as a search space to find the appropriate services in the users' context. In this light, the concept of the augmented tag cloud is a new feature of this paper.
- We design the novel algorithm to reshape the augmented tag cloud depending on the user's current context (e.g., the time zone or the location). By applying the reshaping algorithm, the shape and the size of the augmented tag clouds may dynamically vary according to the frequency of the occurrences of similar events in the past and/or interesting changes in the context. As a result, the ACARDS framework can accurately identify the user's needs in UCEs.
- We enhance the ability of the SPARQL statement generation algorithm to render the context-aware service recommendation efficiently and effectively.

This paper is organized as follows. In Section 2, we describe works related to the context-aware recommendation and LOD query methods. Section 3 describes the ACARDS framework. In addition, Section 3 offers detailed descriptions of the Context Manipulation and Layer and Service Finding Layer of the ACARDS framework. Discussed in Section 4 are the functions of the

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