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Context-aware Recommender Systems

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Recommender systems have been researched and deployed extensively over the last decade in various application areas, including e-commerce, technology enhanced learning, e-health, adaptive multimedia and knowledge management. The three approaches of recommender systems commonly implemented are collaborative filtering, content-based filtering and hybrid filtering which combines aspects of both approaches [Balabanović, 97]. Content-based recommender systems match content resources to user interests, typically specified in a user profile. Collaborative recommender systems recognize commonalities between users on the basis of their ratings, and generate new recommendations based on inter-user comparisons. Hybrid recommending approaches combine both content and user based similarity measures in recommendation algorithms.

Whereas the various approaches have been adopted and validated on a large scale, not much research has been done to incorporate contextual information of the user in the recommendation process [Anand, 07] [Adomavicius, 05]. The context of the user, such as the task she is working on, time of the day, location and device used, has a direct impact on the relevance of the recommended items. For example, if a student is being recommended material to study the theory of relativity while commuting from the workplace to school using a smartphone, short, audiovisual material that fits the screen of the smartphone will be more relevant than a long, text-only document. Accordingly, the recommender system should rank short videos higher than long documents. On the other hand, if the student is reviewing the same subject at night, at home, more in-depth material, including long texts and formulas, will be more useful and, consequently, this material should be recommended first. This re-ranking of the

recommended materials is not possible if the system does not have any information about the context of the user. In this perspective, new challenges emerge for capturing and understanding the context of the user and exploiting such contextual information for creating intelligent recommendations adapted to the current, contextual, needs of the user.

The articles contained in this special issue on context-aware recommender systems present innovative methods, techniques and systems that allow the measurement, analysis and exploration of context data and the exploitation of such data to drive personalized and contextual recommendations.

El Helou, Salzmann and Gillet present the 3A recommender system that targets context-aware recommendation in personal learning environments. The authors give interesting insights into technology that can be used to extract contextualized user profiles from emerging information systems. Context is measured and represented by actors, activity spaces and assets in learning environments as well as explicit interest parameters such as tags and queries of the user. The authors propose a contextual and multi-relational ranking mechanism that adapts a version of Google's PageRank algorithm to the particular modelling framework, recommending to users not only assets (content), but also relevant activities and actors to interact with. This approach is an interesting alternative to existing conceptualizations of the various actors and components in knowledge sharing environments, offering contextualized recommendations that consider all types of relations between actors and components.

Schirru, Baumann, Memmel and Dengel focus on the automatic identification of topics a user is interested in and the identification of thematic groups from which contextualized interest profiles are built. The approach uses non-negative matrix factorization (NMF) for resource clustering and has two goals: delivering recommendations with intra-topic diversity and delivering targeted context-sensitive recommendations. These context-sensitive recommendations are based on matching currently visited resources with available interest topic vectors to enable the generation of recommendations that can meet the current needs and preferences of the user.

Stern, Kaiser, Hofmair, Kraker and Lindstaedt also focus on the derivation of user context by exploiting the topics a knowledge worker is currently working on. In addition, the experience level with these topics is used to tailor recommended content according to the current needs of the user. A multi-layered associative network is presented that employs, among others, a domain model to automate the annotation of resources and fragments of resources. This approach enables to suggest automatically relevant fragments of resources to the user, based on her current work context. The article describes in detail the architecture of a learning material recommender that follows this approach in the extensive set of APOSDLE tools.

Choi, Lee and Moon present an alternative approach that is based on the classification of Web contexts and the application of such a classification for recommendation purposes. They conducted a thorough study to identify information quality factors and

to relate these factors to user tasks. In this study, based on user interviews and survey data analyses, two Web context groups, "careful" and "casual", were identified. Results indicate that in a careful Web context, users have clear target information to seek and want to find relevant and credible content. In a casual Web context, users want to view new and popular content even without clear target information. An evaluation of the proposed algorithm to recognize the current context has been conducted by gathering and analysing usage data collected by a browser monitoring module.

Butoianu, Vidal, Verbert, Duval and Broisin and *Niemann, Scheffel, Friedrich, Kirschenmann, Schmitz and Wolpers* also base their work on the monitoring of usage interactions with tools and resources as a basis to capture context information. A comparative analysis of approaches to capture such interactions is presented by *Butoianu et al.* The authors have compared several modelling approaches and architectures for managing such data against several criteria, such as flexibility, extensibility and scalability. Then, they present a framework that takes into account the advantages of the presented approaches and that tackles their limitations.

Finally, *Niemann, Scheffel, Friedrich, Kirschenmann, Schmitz and Wolpers* present a new approach for calculating item-based similarity in order to support collaborative recommendation. A context-based usage similarity measure is presented and contrasted with the results of classic content-based item similarity. The authors then discuss scenarios of how recommendations may be supported by exploiting the pre- and post-context in which an item was used.

This special issue is comprised of selected, extended and peer-reviewed papers presented at the 1st Workshop on Context-aware Recommendation for Learning at the Second Alpine Rendez-Vous (ARV), held in Garmisch-Partenkirchen, Germany, on November 30 and December 1, 2009. The Alpine Rendez-Vous is a series of workshops that is organized and supported by the STELLAR Network of Excellence (http://www.stellarnet.eu/) and aimed at building a Technology Enhanced Learning researcher capacity on a European level. The scientific work of STELLAR is organized around three themes: (1) Connecting learners (2) Orchestrating learning, and (3) Contextualizing virtual learning environments and instrumentalizing learning contexts. These themes are intended to be a starting point for advancing the future of technology enhanced learning. The contextualization theme addressed in this special issue is an emerging paradigm for building systems that can anticipate the needs of learners and act on their behavior. Context-aware recommender systems are therefore a promising approach for generating personalized recommendations adapted to the current needs of the learner and are used for generating suggestions of relevant learning resources and suitable peer learners who share similar interests. To that end, these context-ware recommender systems are also a key enabler towards the "Connecting Learners" theme. Key research questions include: (a) What characteristics of users can be exploited to find suitable peer learners or resources? (b) How to evaluate the efficiency and effectiveness of context-sensitive recommendations? (c) How to measure whether learning increased because of the

generated recommendations? and (d) How to deal with key issues of trust, privacy and security?

These research questions were shaped at the Alpine Rendez-Vous Workshop on Context-aware Recommendation for Learning. Thanks to the workshop contributions, links have been made through STELLAR with several projects on context-aware recommendation issues, including APOSDLE (http://www.aposdle.tugraz.at/), MACE (http://portal.mace-project.eu/) and ROLE (http://www.role-project.eu/).

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