User and Context Information in Context-Aware Recommender Systems: A Systematic Literature Review

Sergio Inzunza, Reyes Juárez-Ramírez, and Alan Ramírez-Noriega

School of Chemical Science and Engineering, Autonomous University of Baja California, Calzada Universidad 14418, Tijuana, B.C. 22390, México
`sinzunza@uabc.edu.mx, reyesjua@uabc.edu.mx,`
`alan.david.ramirez.noriega@uabc.edu.mx`

Abstract. Using contextual information inside recommendation systems is an effective approach to generate more accurate recommendations. This paper present a review conducted to identify what user's and context's information it's considered relevant by researchers to generate contextual recommendations from 2012 to 2015, based on Kitchenham systematic literature review methodology. The results indicated that there is a large set of possible user's and context's information that can be used to do recommendations. This review can be taken as basis for future context-aware recommender systems development, as well as development of contextual user models.

1 Introduction

During the last 20 years, the quantity of potentially interesting products (items) available to users through online services has been growing rapidly and now exceeds human processing capabilities [33]. As a result of this information explosion, users face situations where they would like to choose an item among a large set of alternatives but do not have sufficient knowledge, capabilities or time to make such decision [25], this created the need for intelligent systems that advice about what to buy, how to spend leisure time or what to watch in the TV, while taking into account their personal needs and interests. This type of systems is referred in the literature as personalization systems, which focus on provisioning of tailored products, services or information to individual users [34].

The type of personalization systems this works focus on are recommender systems, more specifically in the evolution of traditional recommender systems; Context-Aware Recommender Systems (CARS) [4]. While both types of systems provide users with recommendation about a product and services, CARS differ from traditional recommendation strategies because they predict how a given user will like an item, not only based on past user rating or item interactions, but also exploiting the context in which ratings/interactions were produced, and the user's aspects and context at request time [6] [14].

An essential input for every personalization technique is the data about the user [7], specially in systems like CARS which base its functionality in the knowledge of the user [30]. Such information about the user is known in the literature as User Model. A user model (UM) is the knowledge about the user, explicitly or implicitly encoded, which is used by the system to improve the interaction [39].

As Recommendation systems evolve into CARS, User Modeling evolve too, and adopt context-awareness capabilities. A UM is considered context-aware if it can express aspects of the user's contextual information and such information is used to help the system adapt its functionality to specific user characteristics and context [40]. Despite the technique used in a CARS to generate recommendations, it can provide high quality recommendations to users only after having modeled their preferences, behavior and context information [2] [8] [27].

In CARS most of the existing research studies focus on proposing new recommendation algorithms or improving existing ones [37], validating such algorithms using a small set of context's and user's aspects. However, no systematic literature review of CARS has been published previously to describe the wide spectrum of user's and context's information that has been used to generate context-based recommendations. Therefore the main objective of this paper is to present a holistic overview of what user's and context's information has been used to generate context-based recommendations, according to recent publications. The rest of this papers is organized as follows. The methodology used to carry out the review is presented on Section 2. Next in Section 3 we report the results found trough the review. And finally Section 4 we present a short discussion of the findings and the ongoing and future work.

2   Research Method

Rather than using a traditional literature review, we used a Systematic Literature Review (SLR), following the methodology proposed by Kitchenham [29] since it is a rigorous and well-defined method in the field od software engineering. The SLR is a formalized and repeatable process to document relevant knowledge on a specific subject for assessing all available literature related to specific research question(s) [10]. The steps presented in the Kitchenham methodology are documented below.

2.1   Planning the Review (Phase 1)

Need for a Review As we determined before, there was no systematic review in the field of user model for CARS; however the increasing number of papers on CARS is appearing in many disciplines (such as ubiquitous and mobile computing, e-commerce, marketing, ect.)[12] can be taken as evidence that the importance of contextual information has been recognized by researchers and practitioners [3]. We consider that identifying what user's and context's information had been used in CARS to do context-based recommendations can

be beneficial for future development and CARS research. Hence, we identified the need for a SLR that enlist the user and context information past studies has used to generate recommendations.

Research Questions. The main focus of this papers is to identify the user and context information that has been used inside CARS to generate recommendations, the research questions addressed by this study are:

RQ1. Which user aspects has been used in CARS?
RQ2. Which context information has been used in CARS?
RQ3. What items are the CARS recommending?

Bibliographic Databases. We chose the following bibliographic databases as source of information for our reviews: ACM, IEEExplore (IEEE), Science Direct (SD) and Springer Link (SL). The search were limited to journal and conference proceedings papers that were published within January 2012 through July 2015.

2.2   Conducting the Review (Phase 2)

As we identified from previous studies, in literature, different terms has been used to refer to recommendation systems, user model and context-awareness, in order to retrieve the maximum number of relevant publication, we consider such synonyms in our research process. We chose tree synonyms for context-awareness (context-aware, context aware and contextual), two for recommendation (recommendation and recommender system) and tree terms referring to user models (user model, user profile and user aspect) as depicted in the Fig. 1. We carried out the research process manually, using the 12 possible combinations of the terms, and making an union operation of the 12 the results. We use this terms to search inside publication keywords, title, abstract and full text.

Topic 1		Topic 2		Topic 3	Search Results
context-aware		recommender system		user model	
OR	AND		AND	OR	
context aware		OR		user profile	175
OR		recommendation		OR	
contextual				user aspects	

Fig. 1. Search strategies

Selection of Primary Studies. We use the following strategy to identify the relevant publications out of the paper list retrieved from the search.

- Title-based exclusion: First we review the title of the publication to eliminate the publications that are clearly out of the scope of the review. After this stage we end up with 140 papers out of 175.
- Screening-based exclusion: Using abstract, keywords, sections titles, figures, tables, and conclusion (if present) we eliminate the publication out of this review interest. We shrink the list to 49 papers.
- Full text-base exclusion: Reading carefully the full paper, analyzing what it proposes and using the inclusion and exclusion criteria described below, we eliminate the papers that are out of the interest of this review. The results are 24 related papers.

Among the retrieved papers we select the written in English, published between January 1, 2012 and that met one of the following inclusion criteria:

- The papers discussed what user or context-information can be used to generate better recommendation results.
- The paper discussed a user and/or context model, and such model was used to CARS.
- The papers test or proposed data processing techniques or algorithms for CARS and mention what user or context information used to test their proposal.

We also considered a few additional exclusion criteria:

- We exclude books and posters.
- Personal expert opinions about what information can be used to generate recommendation but don't present experimental results.
- Publication related to CARS that don't describe what information about the user or context was used inside the CARS.

Data Extraction. Applying the aforementioned criteria and review strategies, 24 papers where selected as related literature that will be used to answer the proposed research questions. In our papers review, we consider context as any information that describe a person, or a situation of a person that can be used to generate recommendation.

3   Results

In this section we show the results, which correspond to Phase 3 (reporting the review) of the systematic review performed, in this section we also respond to the research questions. First Table 1 present the 24 papers selected as relevant publications as described by the later section. Also in Table 1, the last column (*Recommending*) refers to what type of item(s) the publication's CARS are recommending, such information responds to **RQ3**. The most common recommended items are *Movies* (10) and *Music* (6), although CARS are used to recommend an broad set of things.

Table 1. Resulting publications from data extraction

ID	Ref	Year	Database	Recommending
SL22	[1]	2015	SL	
SL25	[17]	2015	SL	News
SL27	[19]	2014	SD	Photos
SL33	[38]	2013	ACM	Music
SL43	[13]	2015	SL	Hotel, Restaurant
SL53	[35]	2014	IEEE	Movies
SL54	[36]	2014	SL	Movies
SL56	[26]	2012	SD	Music
SL69	[18]	2015	ACM	Music
SL64	[15]	2015	SL	Movies, Music, Places. Books
SL67	[43]	2015	ACM	Movies
SL83	[9]	2012	IEEE	Documents
SL89	[24]	2014	SL	Movies, Food, Shoes
SL91	[28]	2014	SL	Food
SL95	[31]	2014	SD	Smartphone Actions
SL98	[32]	2014	ACM	News
SL132	[16]	2015	SD	Movies
SL152	[11]	2014	SL	Movies, Music
SL155	[5]	2014	SL	Movies, Music
SL168	[21]	2014	SD	Movies
SL169	[21]	2014	SD	Movies
SL173	[20]	2013	ACM	Food
SL174	[41]	2012	SL	Places
SL175	[42]	2012	IEEE	Learning Material

3.1 Uses's Aspects Inside CARS

To organize the information about the user found in each of the papers reviewed, we started from the 'Basic user dimensions' proposed in GUMO [23] [22], we use 9 out of the 12 dimension proposed (*Mental state, Physiological state, Demographics, Contact information, Role, Emotional state, Personality, Ability and Proficiency and Nutrition*), living out *Characteristics and Facial expressions* as none of the reviewed papers use such dimensions to generate recommendations, we also leave out *Motion* as we consider this information as part of the Context information. Through the identification of the users aspects in the review, we realize that some papers consider information that lay out of the dimension list, therefore another 2 dimensions were added to the list (*Interest & preferences and Experience*). Table 2 responds to **RQ1** enlisting which user's aspects has been used in CARS.

Table 2: User's information considered in CARS

Dimension	Authors	Aspects

Mental	[42], [5], [38] [26], [15], [24], [28], [31], [16]	cognitive style, mental stress (elevated, neutral, relax), mood, objective, goals, habits, behavior
Physiological	[41], [38], [18], [24]	physiological aspects, needs, hear rate, blood pressure, respiration rate, skin conductivity, brain wave, EMA and ECG signals, physical information, disabilities
Demographics	[41], [42], [38], [36], [26], [15], [24], [28], [16]	age, personal information, gender, profession, socio-economic, culture, sex, hometown, show size, lives in, address(number, street, city, state, country), relationship status
Contact	[41], [42], [36], [24],	name. personal information
Role	[21]	role
Emotions	[42], [5], [1], [17], [26], [18], [24] [41]	emotions, affects, emotional situation, sentiments, emotional state
Personality	[26]	personality
Interest and Preferences	[41], [43], [13], [21], [1], [17], [38], [18], [9], [32], [21], [20]	interest, desire, opinions, preferences
Experience	[18]	experience
Abilities and Proficiency	[41]	capabilities
Nutrition	[41], [28], [20]	nutrition, food, taste

3.2   Context's Aspects Used in CARS

For organizing the context information found in the review we use Verbert [42] proposal, where the context is form by 7 contextual dimensions (*Computing, Location, Time, Physical conditions, Activity, Resource and Social relations*). Table 3 responds to **RQ2** showing what context's information has been used inside CARS.

Table 3: Context's information considered in CARS

Dimension	Authors	Aspects

Computing	[42], [21], [17], [19], [38], [35], [31], [41], [16]	network (GPS, Wi-Fi, Bluetooth, RFID, RF, 3G, 4G), hardware, software, device, incoming calls, system service, notification, battery charge, PC, mobile phone, network bandwidth, display resolution, display resolution, storage capacity, RAM memory, OS,
Location	[41], [42], [21], [38], [35], [36], [26], [26], [18], [9], [24], [28], [31], [16], [21]	location (in-door, out-door), place (home, shops, coffee shops, bus station, train station, office, school, sport center, store, movie theater, restaurant), surroundings, services
Time	[41], [42], [43], [13], [11], [1], [17], [19], [35], [36], [26], [15], [18], [9], [24], [28], [32], [41], [16], [21], [20]	time (morning, lunchtime, afternoon, evening, night), time of day, time of week, time of year, season, hour, minute, period
Physical Conditions	[41], [42], [21], [1], [17], [19], [38], [36], [26], [15], [24], [28], [16], [21]	environment, physical conditions, temperature, weather, traffic, noise level, light level, humidity, crowd
Activity	[41], [1], [17], [38], [35], [36], [26], [9], [31], [41], [16]	activity, event, walking, jogging, lying, running, standing, driving, sitting, ascending stairs, descending stairs, ascending in elevator, descending in elevator, charging cell, meeting, shopping, writing, cooking, swimming, reading, computing, exercise, travel, working, transit, walking, guided tours, movie show times
Resources	[42]	resource
Social Relations	[42], [21], [17], [38], [35], [26], [15], [18], [9], [24], [41], [16], [21], [20]	social relation, companion, relationship with, friends, family

4 Discussion and Future Work

Context-aware recommender systems take advantage of the information available about the user and the context, as well as previous user-system interactions, there is an almost infinite number of possible user's and context's aspects that can be used to generate contextual recommendations. In this paper we conducted a systematic literature review based on Kitchenham methodology in

order to identify what user's and context's information has been used in CARS publications between 2012 and 2015. We end up analyzing 24 papers and enlist what user's aspects (Table 2) and context's aspects (Table 3) such papers considered as relevant information to generate contextual recommendations. It's interesting to note that when recommending music the most commonly user's aspects considered (SL33, SL56, SL64 and SL69) are *Emotional states* and *Mood*, in case of context's aspects, *Time* is the most common information considered in recommendations followed by *Location* and *Social Relations*.

The ongoing research, that lay out of the scope of this publication, is focused on building a generic user and context model specifically designed for context-aware recommender systems, so that the resulting model can serve as basis for future CARS developments.

References

1. Abbas, A., Zhang, L., Khan, S.U.: A survey on context-aware recommender systems based on computational intelligence techniques. Computing (2015)
2. Adomavicius, G., Tuzhilin, A.: Context-aware recommender systems. Recommender systems handbook pp. 67–80 (2011)
3. Adomavicius, G., Jannach, D.: Preface to the special issue on context-aware recommender systems. User Modeling and User-Adapted Interaction 24(1-2), 1–5 (2014)
4. Adomavicius, G., Tuzhilin, A.: Context-aware recommender systems. Recommender systems handbook pp. 67–80 (2011)
5. Alhamid, M.F., Rawashdeh, M., Al Osman, H., Hossain, M.S., El Saddik, A.: Towards context-sensitive collaborative media recommender system. Multimedia Tools and Applications (2014)
6. Baltrunas, L., Ludwig, B., Peer, S., Ricci, F.: Context relevance assessment and exploitation in mobile recommender systems. Personal and Ubiquitous Computing 16(5), 507–526 (2012)
7. Berkovsky, S.: Ubiquitous User Modeling in Recommender Systems. Um 2005 pp. 496–498 (2005)
8. Berkovsky, S., Kuflik, T., Ricci, F.: Mediation of user models for enhanced personalization in recommender systems. User Modelling and User-Adapted Interaction 18(3), 245–286 (2008)
9. Bouneffouf, D., Bouzeghoub, A., Gançarski, A.L.: Following the user's interests in mobile context-aware recommender systems: The hybrid-e-greedy algorithm. Proceedings - 26th IEEE International Conference on Advanced Information Networking and Applications Workshops, WAINA 2012 pp. 657–662 (2012)
10. Breivold, H.P., Crnkovic, I., Larsson, M.: A systematic review of software architecture evolution research. Inf. Softw. Technol. 54(1), 16–40 (2012)
11. Campos, P.G., Díez, F., Cantador, I.: Time-aware recommender systems: a comprehensive survey and analysis of existing evaluation protocols. User Modeling and User-Adapted Interaction 24(1-2), 67–119 (Feb 2013)
12. Champiri, Z.D., Shahamiri, S.R., Salim, S.S.B.: A systematic review of scholar context-aware recommender systems. Expert Systems with Applications 42(3), 1743–1758 (Sep 2014)
13. Chen, G., Chen, L.: Augmenting service recommender systems by incorporating contextual opinions from user reviews. User Modeling and User-Adapted Interaction (2015)

14. Codina, V., Mena, J., Oliva, L.: Context-Aware User Modeling Strategies for Journey Plan Recommendation. In: User Modeling, Adaptation and Personalization, pp. 68–79. Springer (2015)

15. Codina, V., Ricci, F., Ceccaroni, L.: Distributional semantic pre-filtering in context-aware recommender systems. User Modeling and User-Adapted Interaction (2015)

16. Colombo-Mendoza, L.O., Valencia-García, R., Rodríguez-González, A., Alor-Hernández, G., Samper-Zapater, J.J.: RecomMetz: A context-aware knowledge-based mobile recommender system for movie showtimes. Expert Systems with Applications 42(3), 1202–1222 (Feb 2015)

17. De Pessemier, T., Courtois, C., Vanhecke, K., Van Damme, K., Martens, L., De Marez, L.: A user-centric evaluation of context-aware recommendations for a mobile news service. Multimedia Tools and Applications (2015)

18. Deng, J.J., Leung, C.H.C., Milani, A., Chen, L.I.: Emotional States Associated with Music : Classification , Prediction of Changes , and Consideration in Recommendation 5(1) (2015)

19. Han, J., Schmidtke, H.R., Xie, X., Woo, W.: Adaptive content recommendation for mobile users: Ordering recommendations using a hierarchical context model with granularity. Pervasive and Mobile Computing 13, 85–98 (2014)

20. Harvey, M., Ludwig, B., Elsweiler, D.: You are what you eat : learning user tastes for rating prediction pp. 1–12

21. Hawalah, A., Fasli, M.: Utilizing contextual ontological user profiles for personalized recommendations. Expert Systems with Applications 41(10), 4777–4797 (2014)

22. Heckmann, D., Schwartz, T., Brandherm, B.: GUMO the General User Model Ontology. User modeling . . . (2005)

23. Heckmann, D.: Ubiquitous User Modeling, vol. 297 (2005)

24. Hussein, T., Linder, T., Gaulke, W., Ziegler, J.: Hybreed: A software framework for developing context-aware hybrid recommender systems. User Modeling and User-Adapted Interaction 24, 121–174 (2014)

25. Jawaheer, G., Weller, P., Kostkova, P.: Modeling User Preferences in Recommender Systems. ACM Transactions on Interactive Intelligent Systems 4(2), 1–26 (2014)

26. Kaminskas, M., Ricci, F.: Contextual music information retrieval and recommendation: State of the art and challenges. Computer Science Review 6(2-3), 89–119 (2012)

27. Kim, H.N., Ha, I., Lee, K.S., Jo, G.S., El-Saddik, A.: Collaborative user modeling for enhanced content filtering in recommender systems. Decision Support Systems 51(4), 772–781 (2011)

28. Kim, J., Lee, D., Chung, K.Y.: Item recommendation based on context-aware model for personalized u-healthcare service. Multimedia Tools and Applications 71(2), 855–872 (2014)

29. Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, M., Bailey, J., Linkman, S.: Systematic literature reviews in software engineering - A systematic literature review. Information and Software Technology 51(1), 7–15 (2009)

30. Lakiotaki, K., Matsatsinis, N.F., Tsoukiàs, A.: Multicriteria user modeling in recommender systems. IEEE Intelligent Systems 26, 64–76 (2011)

31. Lee, W.P., Lee, K.H.: Making smartphone service recommendations by predicting users' intentions: A context-aware approach. Information Sciences 277, 21–35 (2014)

32. Li, L., Zheng, L., Yang, F., Li, T.: Modeling and broadening temporal user interest in personalized news recommendation. Expert Systems with Applications 41(7), 3168–3177 (2014)
33. Maes, P., Others: Agents that reduce work and information overload. Communications of the ACM 37(7), 30–40 (1994)
34. Mulvenna, M.D., Anand, S.S., Büchner, A.G.: Personalization on the Net using Web mining: introduction. Communications of the ACM 43(8), 122–125 (2000)
35. Otebolaku, A.M., Andrade, M.T.: Context-aware media recommendations. Proceedings - 2014 IEEE 28th International Conference on Advanced Information Networking and Applications Workshops, IEEE WAINA 2014 1, 191–196 (2014)
36. Otebolaku, A.M., Andrade, M.T.: Context-aware media recommendations for smart devices. Journal of Ambient Intelligence and Humanized Computing 6(1), 13–36 (2014)
37. Ricci, F., Rokach, L., Shapira, B., Kantor, P.B.: Recommender Systems Handbook. Springer US, Boston, MA (2011)
38. Schedl, M.: Ameliorating Music Recommendation: Integrating Music Content, Music Context, and User Context for Improved Music Retrieval and Recommendation. Proceedings of International Conference on Advances in Mobile Computing & Multimedia pp. 3:3—-3:9 (2013)
39. Schreck, J.: Security and Privacy in User Modeling. No. September (2003)
40. Siolas, G., Caridakis, G., Mylonas, P., Kollias, S., Stafylopatis, A.: Context-Aware User Modeling and Semantic Interoperability in Smart Home Environments. 2013 8th International Workshop on Semantic and Social Media Adaptation and Personalization pp. 27–32 (Dec 2013)
41. Skillen, K.L., Chen, L., Nugent, C.D., Donnelly, M.P., Burns, W., Solheim, I.: Ontological user profile modeling for context-aware application personalization. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). vol. 7656 LNCS, pp. 261–268 (2012)
42. Verbert, K., Manouselis, N.: Context-aware recommender systems for learning: a survey and future challenges. Learning . . . 5(4), 318–335 (2012)
43. Yin, H., Cui, B.I.N., Chen, L., Hu, Z., Zhou, X.: Dynamic User Modeling in Social Media Systems 33(3) (2015)